AFM® activated filter media

Instructions for use document: AFM Water treatment

IFU Title	AFM® activated filter media
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Applications	• Drinking water from all sources; surface water and ground water • Pre-treatment prior to membranes; freshwater and marine • Swimming pools, private & public • Aquaculture and public aquaria marine or freshwater • Industrial process high purity water • Water supply for Pharmaceuticals and Drinks companies • Tertiary treatment of waster water • Process wastewater

Contents

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Nicola Sturgeon, first minister for Scotland and Howard Dryden. In our AFM production facility in Edinburgh

Key Points about AFM® for reference

Product key points

- Verified to provide a much better performance in comparison with high quality silica sand
- Will remove all know parasites. Verified to achieve 99% filtration down to 3 microns with no coagulation or flocculation using grade 0, 1000mm bed depth 20m/hr velocity
- Verified to achieve 97% filtration down to 5 microns, with no coagulation and flocculation using grade 1, 1000mm bed depth 20m/hr velocity. When used with flocculants, AFM achieves nominal filtration of 0.1 microns
- Return of investment measured at under 2 years by UK Carbon Trust and Oakdene Hollins
- Potential solution to effectively remove parasites such as cryptosporidium oocysts
- High surface negative charge density, works well with coagulants and flocculants to remove dissolved components and provide nominal filtration down to sub micron level in certain applications
- Bio-resistant, will not become a biofilter, AFM is not subject to transient wormhole channelling, and unfiltered water will never pass the filter bed
- Stable and predictable performance in freshwater and marine systems, perfect for SWRO
- Product water will have at least 50% lower chlorine oxidation demand than an equivalent sand filter, so lower concentration of disinfection by products
- SDI will be lower with AFM in comparison to sand filtration
- Future proofing against tighter legislation and regulation
- AFM is expected to last for the life of the filtration systems.
- AFM is an engineered product manufactured to a precise specification under ISO9001-2008 conditions
- Certified under Reg31, NSF50 & NSF61, Environmental standards, Singapore Green Tick, HCAAP approval imminent

Production facility and videos

Dryden Aqua has invested € 8 million on a new AFM production facility in 2014. View a video of our facility https://youtu.be/0oeBXs-DoZk
Swimming pool water treatment video animation click here

IFTS report

The report is a Dryden Aqua condensed version of the IFTS report that has been endorsed by IFTS.
click here

Quote from Scottish Water

Scottish Water tested AFM, the results demonstrated significant performance advantage over sand in relation to suspended solids/iron removal and process efficiencies. I can also confirm that Scottish Water has been using AFM for targeted effluent treatment for some 14 years with considerable success in the removal of solids and BOD reduction. Mark Haffey , R&D Technical Leader, Technology & Innovation Scottish Water

1.Description of AFM®

AFM® is an amorphous alumino-silicate manufactured by up-cycling post-consumer green glass bottles in a dedicated factory designed and operated specifically to produce activated glass water filtration media.

AFM® is manufactured and offered as a direct replacement for filter sand and used in most types and designs of sand filter. The one exception is slow bed sand filters operating as biological filters at filtration velocities of less than 0.2m/hr. AFM® rejects the growth of biofilm and as such it is not suitable for use in slow bed sand filters.

Grades & Particle size distribution

The particle shape of AFM® is controlled to maximise surface area and to minimise pressure differential and bed lensing effects.

The particle size distribution is also controlled to within very tight tolerance. We can control the sphericity and uniformity coefficient of the grains to maximise particle filtration. While a high sphericity is beneficial for sand this is not necessarily the case for AFM®.

The higher the uniformity coefficient the better the filtration performance, but this increases the risk of bed compaction and lensing. AFM® is manufactured as opposed to quarried, the particle size distribution and shape can therefore be maximised to improve performance as a water filtration media.

AFM® has an optimised uniformity coefficient in order to maximise filtration performance without causing pressure drops or bed lensing effects.

AFM® product specifications

Specification	grade 0	grade 1	grade 2	grade 3
Particle size	250 - 500 microns	0.4 to 1.0mm	1.0 to 2.0mm	2.0 to 4.0mm
Undersized	<5%	<5%	<5%	<5%
Oversized	<5%	<5%	<5%	<5%
Effective size	320 microns	0.46mm	1.3mm	2.6mm
Hardness	>7 mohs	>7 mohs	>7 mohs	>7mhos
Sphericity	>0.7	>0.7	>0.7	>0.7
roundness	>0.6	>0.6	>0.6	>0.6
uniformity coefficient	1.5 to 1.7	1.5 to 1.7	1.5 to 1.7	1.5 to 1.7
aspect ratio	2 – 2.4	2 - 2.4	2 - 2.4	2 - 2.4
Purity	>99.95%	>99.95%	>99.95%	>99.95%
Colour	>95% green	>95% green	>95% green	>95% green
specific gravity (grain)	2.4kg/l	2.4 kg/l	2.4 kg/l	2.4 kg/l
Embodied energy	<72kw/tonne	<65kw/tonne	<50 kw/tonne	<50 kw/tonne
Bulk bed density	1.28 kg/l	1.25 kg/l	1.23 kg/l	1.22 kg/l
Attrition, 50% bed expansion 100 hours backwash in water	<3%	<3%	<3%	<3%

Chemical Composition by % (all grades)

Composition (oxides)	Percentage +/- 10%	Composition (oxides)	Percentage +/- 10%
Silica	72	Calcium	11
Magnesium	2	Lanthanum	1
Sodium	13	Cobalt	0.016
Aluminium	1.5	Lead	<0.005
Antinomy	<0.001	Mercury	<0.0005
Arsenic	<0.0001	Titanium	<0.1
Barium	0.02	Rubidium	<0.05
Cadmium	<0.0001	Iridium	<0.05
Chromium	0.15	Platinum	<0.0001
Inorganic undefined	<0.0005	Organic undefined	<0.0005

There will be no metal ion leaching between pH4 and pH10, indeed AFM® will adsorb heavy metals and release on back-wash, AFM® provides drinking water and food security.

2. Description of AFM® product use

Filter design

AFM® is a filtration media and direct replacement for filter grade sand in all types of filter used for the treatment of drinking water.

The scope includes:

- Pressure sand filters.
- RGF Rapid Gravity Filters.

Filtration performance varies inversely relative to filtration velocity; the filters should therefore be operated with the slowest possible hydraulic loading.

Type of Water

AFM® is used for the treatment of drinking water this includes water from the following sources;

- Reservoirs.
- Lakes.
- Rivers.
- Springs.
- Boreholes.
- Brackish water and seawater prior to desalination membranes.
- Wastewater to be recycled as potable water.

Pre-treatment of water prior to AFM® filtration

AFM® can be used to treat any type of drinking water source, however in the case of ground water or water with a low oxygen content, it is important that the water is strongly aerated for a period of up to 30 minutes prior to filtration.

Aeration blows off the volatile organic compounds (VOC's), raises the oxidation potential, drops the zeta potential and oxidises metals such as ferrous to ferric. If the water contains Manganese then longer aeration or the use of an oxidising agent such as ozone may be required to oxidise the manganese to the insoluble oxide form prior to filtration.

Back-pressure

With respect to pressure sand filters, the filters must be back-washed before the differential bed pressure exceeds 0.4bar.

Back-washing

The backwash frequency will depending upon the rate of change of back-pressure. However, if the water has a low solids content such as borehole or ground water the pressure may not reach 0.4 bar. With water temperatures under 28°C the AFM® bed should be back-washed once a week, with water temperatures over 28°C the filter should be back-washed twice a week.

Bed depth

There is no minimum or maximum bed depth, but filtration performance will improve with increasing bed depth. For pressure filters a typical bed depth ranges from 1m to 1.4m, for RGF filters 0.5 to 2.0m.

Grades

AFM® is provided in 4 different grades, just like a sand filter you start off with the largest grade on the base of the filter and build up the bed to the finest grade. The ratio of grain sizes in a filter is a function of the filter design. Generic examples are provided in this document.

Carbon

Anthracite may be used with AFM® but there will be fewer occasions where it will be required in comparison to sand. Activated carbon, granular and powdered can also be used with AFM® to aid in the removal of dissolved organics.

Flocculants and Coagulants

AFM® carries a permanent surface negative charge and works well with cationic coagulants and flocculants that have a positive charge. There are no restrictions on the use of AFM®, the product may be used with the following generic products;

- Ferric coagulants and flocculants.
- Aluminium coagulants and flocculants.
- Polyamide and other polyelectrolytes.

Dryden Aqua quality control and DNA crypto Laboratory. There are three laboratories in the factory, one for water and two for glass analaysis

3. Product packaging and delivery

AFM® is packaged in a fully automatic factory at Dryden Aqua. AFM® is packaged in sealed plastic sacks and printed with the appropriate product identification and tracking information.

Packaging

AFM® is supplied in bags of the following size:

a. 1000 kg bags with bottom discharge.
b. 25 kg plastic bags & 21.5 kg sacks.
c. 11.4 kg plastic bag.

Delivery

AFM® will usually be delivered in multiples of 1 tonne pallets.

Bags and Labelling

The example shown is for a 25 kg sack.

Each bag is printed during packaging with the following information:

1. Lot batch number.
2. Size Grade.
3. Uniformity coefficient.
4. Effective particle size.

Product codes

	Product order codes			
	Grade 0	Grade 1	Grade 2	Grade 3
	0.25 to 0.50mm	0.40 to 1.0mm	1.0 to 2.0mm	2.0 to 4.0mm
AFM® 11.4 kg sack	10020	10021	10022	10023
AFM® 21 kg sack	10030	10031	10032	10033
AFM® 25 kg sack	10000	10001	10002	10003
AFM® 1 tonne	10010	10011	10012	10013

When supplied in 1000kg tope bags, a label will be connected to each bag to provide the same information as the plastic bags.

4. Commissioning and preparing AFM® for use

Disinfection of AFM®

During the manufacturing process of AFM® it is exposed on two occasions to temperatures in excess of 1000°C. The product is clean and sterilised. All production takes place in a secure building and the product is protected at all times. If further disinfection is required, AFM® is compatible with most oxidising agents in a pH range pH 4 to pH10.

pH range	pH 4 to 10
Hypochlorous	500mg/l
Chlorine dioxide	1000mg/l
Ozone	10mg/l
Hydrogen peroxide	10g/l

Filter bed depth and type of filter

The depth of the filter bed is a function of the filter design, it is always best to use filters in compliance with the German DIN standards. However, this is not always the situation, especially with small filters.

Filter bed depth in compliance to DIN will have a bed depth from 1200mm to 1400mm, however AFM® may be used in any sand filter design including:

1. Vertical pressure filters.
2. Horizontal pressure filters.
3. RGF rapid gravity filters.
4. Moving bed sand filters with vertical up-flow or down-flow mode.

The deeper the bed depth of AFM®, the better the performance of the filter.

How to fill a pressure filter with AFM®

In all cases it is essential that the filters are on a level concrete pad or plinth, and that the valve manifold and pipework is supported to prevent any stress on the filter flanges.

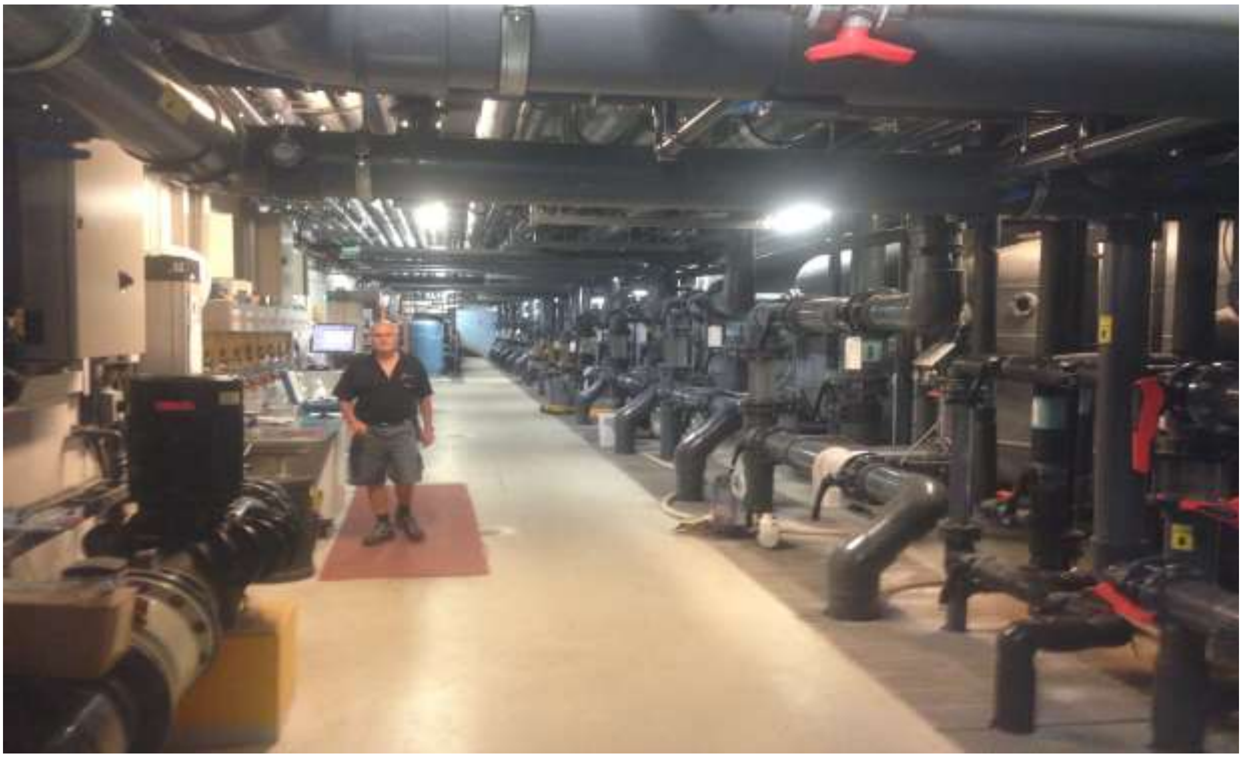
Before the first layers of filter media are introduced via the top access port, it is best to half fill the filter with water. This helps to prevent damage to the laterals or the nozzle distribution plate by the falling media.

For filters with a side manhole, open the bags and gently empty the first layer onto the base of the filter bed. The larger grades are added first, grade 3 for filters over 1m in diameter, and grade 2 for filters 1m and smaller in diameter. See Table 1. For horizontal filters we also recommend grade 3 on the base of the filter up to a point that is level with the laterals.

After the addition of each layer it is important to make sure the media is evenly distributed and the bed is flat. Once all the media is in place, perform a backwash in accordance to Table 3.

After the back-wash, inspect the bed, there may be fines on top of the bed. Carefully skim the top off the filter bed to remove the fines and any other debris that may be present that could interfere with filtration performance. With AFM this is never required, but with a new installation there may be debris such as plastic shavings from the pipework and filter installation.

Once the filter bed has been skimmed, refit the filter lid and backwash for a period of 5 minutes, or until the water runs clear. After the back-wash, place the filter on a rinse phase for 2 minutes. Once the rinse phase has completed and if there is sufficient water, repeat the backwash and rinse phase for a third time. The bed is now ready for service, however before going on-line with the network it is required to conduct an analysis of the water in compliance with Annexe 1 if the media is being used for drinking water.



The make-up of the pressure filter bed depends upon the size of the filter and configuration of the base, there are eight options.

1. Filters under 1m diameter with laterals.
2. Filters under 1m diameter with nozzle plate.
3. Filters over 1m diameter with laterals.
4. Filters over 1m diameter with nozzle distribution plate.

Table 1. AFM® filter bed depths as a percentage for each grade for Vertical Filters Bed depth may range from 300mm to 1400mm				
	Grade 3	**Grade 2**	**Grade 1**	**Grade 0**
With flocculation, Pressure & RGF filters				
Pressure filters, under 1m Ø with laterals	0%	20%	80%	0%
Pressure filters under 1m Ø with nozzle plate	0%	20%	80%	0%
Pressure filters over 1m Ø and RGF filters with laterals.	15%	15%	70%	0%
Pressure filters over 1m Ø with nozzle plate & RGF filters with nozzles or screened floor	0%	20%	80%	0%
Without flocculation, Pressure & RGF filters				
Pressure filters, under 1m Ø with laterals	0%	20%	60%	20%
Pressure filters under 1m Ø with nozzle plate	0%	20%	60%	20%
Pressure filters over 1m Ø and RGF filters with laterals.	15%	15%	50%	20%
Pressure filters over 1m Ø with nozzle plate & RGF filters with nozzles or screened floor	0%	20%	60%	20%
Grade 0 optimised filters, pressure filters under 1m Ø with laterals	0%	20%	10%	70%
Grade 0 optimised filters, pressure filters under 1m Ø with nozzle plate	0%	10%	10%	80%
Grade 0 optimised filters, pressure filters over 1m Ø with laterals	10%	10%	10%	70%
Grade 0 optimised filters, pressure filters over 1m Ø with nozzle plate and RGF filters	0%	10%	10%	80%

Notes.
Filters from different manufacturers will have different dimensions. With regards to filters that have a lateral arrangement. In general for filters under 1m in diameter, you want grade 2 to fill the space and cover the laterals to a depth of at least 50mm. If the filter is larger than 1m diameter, then grade 3 should be used to fill the space below the laterals. The remainder of the bed is then made up with grade 2, 1 & 0 in accordance to the percentages give above.

How to fill an RGF filter with AFM®

Prior to placement of the filter material(s) tests for water retention must have been completed satisfactorily. Air scour testing and backwash pump functional tests should if possible have been completed. (If this is not possible before one filter is operational then it is preferable that only one filter be charged with media. However circumstances may not always permit such an ideal sequence.

The filter and associated filtered water ducts and channels, pipes and clean wash water tank must be physically clean and free from loose dirt and other extraneous matter especially polystyrene from form work and plastic wrapping materials. Ideally, the filter should be vacuum cleaned especially if the discharge arrangement from the filter has fine slots or nozzles.

The filter bed is prepared in the same way as if sand was being used as the filter and / or support material. However, less AFM ® Grade 1 (by weight) is required compared to sand due to the lower bulk density of AFM ® Grade 1.

AFM ® Grade 1 (0.40 – 1.00mm) is used to replace 16/30 sand.

The walls of the filter should be marked with the levels of each layer and on larger filters suitable gauge sticks may be erected. The expected quantities of material for each layer should be calculated and included in the method statement. Table 1 provides the recommend percentages of the different grades of media. The various layers will be levelled off with levelling boards or raked level to levelling strings. The levels of the working material(s) should be marked in a waterproof medium to withstand submergence during washing.

Each support layer should be protected after placing and walking boards used for access. Footprints cause compaction of the support layers and can cause mal-distribution during backwashing. Local humps act as trigger sites for boiling and spouting.

Support layers should preferably be lowered on to a board within the filter and then spread. They should not be tipped over the side, particularly on exposed lateral floors where the laterals can be displaced. Tipping over the side can also displace previously installed layers. The support layers do not expand and should be laid to design depth.

The working layer (grade 1 or grade 0) should also be placed carefully to avoid displacement of the top support layer. If the working layer is to be delivered by hose (with air or water) the hose should be kept off the top of the previous layer. After this layer has been placed the situation is less critical. Walking on the working layer after 150mm has been placed is of less concern providing that the bed is dry. The working layers need not be levelled accurately. The backwash procedure will perform this task. The working layers should be left short by 10% of the design layer depth if fluidising washes are proposed, because the bed will usually expand by that amount as it stratifies. This is not the case with combined air and water unless a high rate rinse is included.

Do not charge second or third layers in multimedia filters until the lower layers have been washed and skimmed.

RGF Bed Conditioning Procedures.

Do not air scour a freshly installed bed.

The first step, unless the material was placed in to a flooded filter, is to gradually initiate a backwash. If the media shows signs of floating allow it to stand for a few hours or overnight with the water level below the wash out cill.

Raise the backwash rate to the maximum design value and continue until the water clears. Skim off any extraneous material. The wash can then be repeated with air scour according to the intended procedure. The same is true for combined air water washing.

In cases where there is no water available until the first filter has been commissioned then the first filter in the freshly charged condition may be allowed to filter slowly before the first wash but this is a last resort dispensation and may cause some penetration of fines in to the under drain. Temporary arrangements to fill the clean wash water tanks are recommended in this case.

After 3 back washes, skim the surface of the filter to remove fines. The process should be repeated until no further accumulation occurs. It is not necessary to skim AFM beds, but with new installations there may be other debris in the system that needs to be removed.

Only after this state has been reached should any additional layers be placed. The washing / skimming procedure will need to be repeated with the second (and third) layer. Such skimming is less important with combined air and water washing unless high rate re-grading washes are employed. The air tends to prevent stratification and also carries fines over in to the washout channel (launder).

After washing and skimming, the material level in the filter may require adjustment. It can be quicker to transfer washed material from another filter so that only one bed has to be rewashed and skimmed after further topping up. The designated level of the material is attained after washing, when the filter is ready for service. The support layers do not expand and settle.

The final bed should be sampled in depth to ensure that the size grading is as intended. Surface layers will tend to be finer than deeper layers and a composite sample is necessary unless a combined air/water wash is used.

A filter should not be placed on-line within the network until the product water has been tested for compliance with water quality parameters detailed in annexe 1.

5. **Operational Routines & criteria**

Turning off and starting up a media bed filter

AFM® media bed filters should be operated continuously; they must never be stopped or allowed to go anaerobic. If the filters have to be turned off for a protracted period of time the following procedure should be used prior to start up.

Decommissioning and commissioning a filter

Prior to turning off an AFM® filter it should be given a standard backwash with clean water. After the backwash the filter should be drained of as much water as possible.

Prior to going back-online, backwash the filter for a period of 5 minutes at a water flow rate that gives a 20% bed expansion followed by a rinse phase for 10 minutes. Repeat the backwash and rinse phase for a 2nd and 3rd time prior to going back on-line.

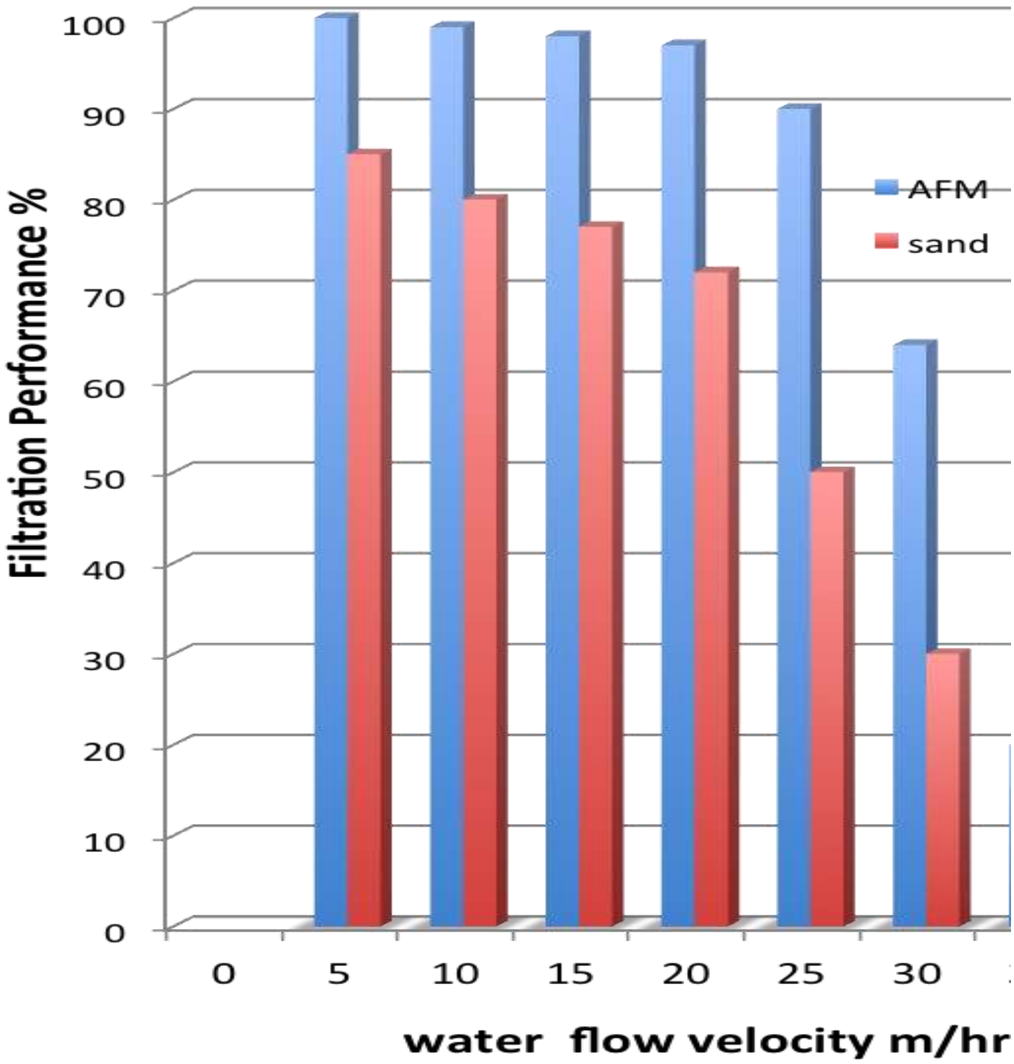
Run Phase

The filtration performance of any media bed varies inversely in proportion to the velocity of water passed through the filter. It is always best to operate the filter at the slowest possible flow rate in order to maximise performance. This is particularly important in regions where there may be a high concentration of cryptosporidium oocysts.

Different filtration media and sand from different countries / deposits will have a different performance this is a function of particle size distribution, sphericity, chemical composition and uniformity coefficient. Typically RGF fitters operate at 6m/hr and pressure filters at 12m/hr. AFM® filters should be operated at exactly the same water flow rates.

The flow rate for an AFM® filter depends upon the design of the filter and the application. For most RGF and pressure filter applications the filtration velocity should be below 12m/hr. This equates to a water flow rate of 12m^3/hr of water, for every 1m^2 of filter bed surface area. RGF filters will be operated at a slower flow rate due to pressure head limitations, typically the water flow velocity should be 6m/hr.

Fig 1 Filtration performance at removing 5 micron particles at different water flows



Pressure filters can operate at a higher water flow rate than RGF filters because a higher pressure is available to push the water through the filter bed. However the differential pressure across the filter bed should be limited to 4m head (0.4 bar or 6psi).

Recommended and maximum run phase water flow for different applications

Table 2. Run phase water flows for different applications	Recommended Run phase water flow m/hr	
	Pressure	Gravity flow & Moving bed
Drinking water		
Recommended water flow	<10	<5
Maximum water flow	<20	<15
Municipal wastewater		
Recommended water flow	<5	<5
Maximum water flow	<15	<10
Aquaculture and Aquaria		
Recommended water flow	<20	<5
Maximum water flow	<30	<10
Swimming pools		
Recommended water flow	<20	<10
Maximum water flow	<30	<20
Process water (examples)		
Borehole water treatment for ferric, manganese and arsenic	<10	<5
Treatment prior to membranes	<15	<10
Cooling towers	<20	<10

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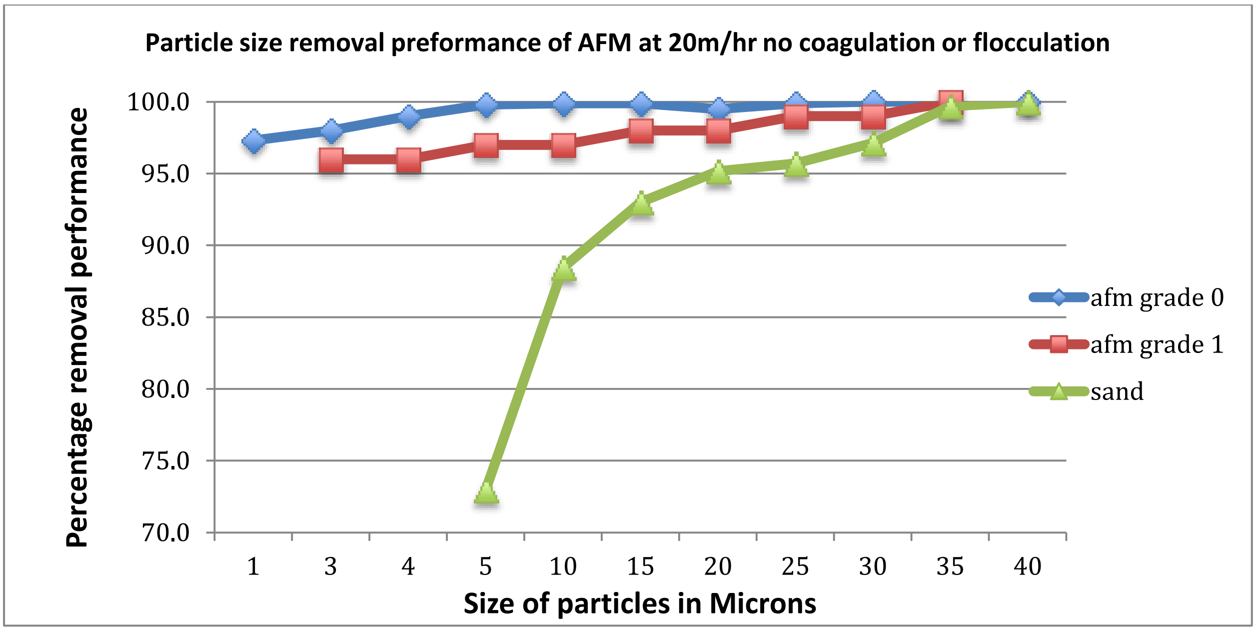
Filtration performance and grade of filter media

The standard grade of filter media used in most pressure and RGF filter is a sand of 16 x 30 mesh size, AFM® grade 1 is equivalent to this grade of sand. However, because AFM® does not biofoul this gives the opportunity to use a much finer grade of media, grade 0 which has a particle size distribution 0.25 to 0.50mm. This is half the size of 16 x 30 sand and grade 1 AFM®.



Filtration performance of AFM® and sand at 20m/hr

Refer to Table 1, AFM® grade 0 may be used as a 20% layer on top of grade 1, or as a 70% layer. AFM® grade 0 is used when filtration down to 1 micron is required without the use of coagulation and flocculation chemicals. AFM® grade 0 may be used with electrolytes, but when used with polyelectrolytes there is a risk of blinding the filter bed. AFM® grade 0 is therefore suitable for pre-treatment prior to membranes or when high quality water is required.

How to backwash

Backwash water flow is critical for the continued high performance of AFM®. Backwashing is accomplished by reversing the water flow through the filter bed to up-flow. The water flow should be sufficient to fluidise the filter bed by 20% to 30%. The transition from run-phase to up flow on backwash should be as gentle as possible and over a period of 30 seconds. It is important to lift the bed evenly and gently for the most effective backwash.

Bed fluidisation should continue for a period of 3 to 5 minutes, or until the backwash water runs clear. The backwash efficiency data presented results from tests carried out by an accredited laboratory showing that AFM® has completed a backwash in less than 3 minutes.

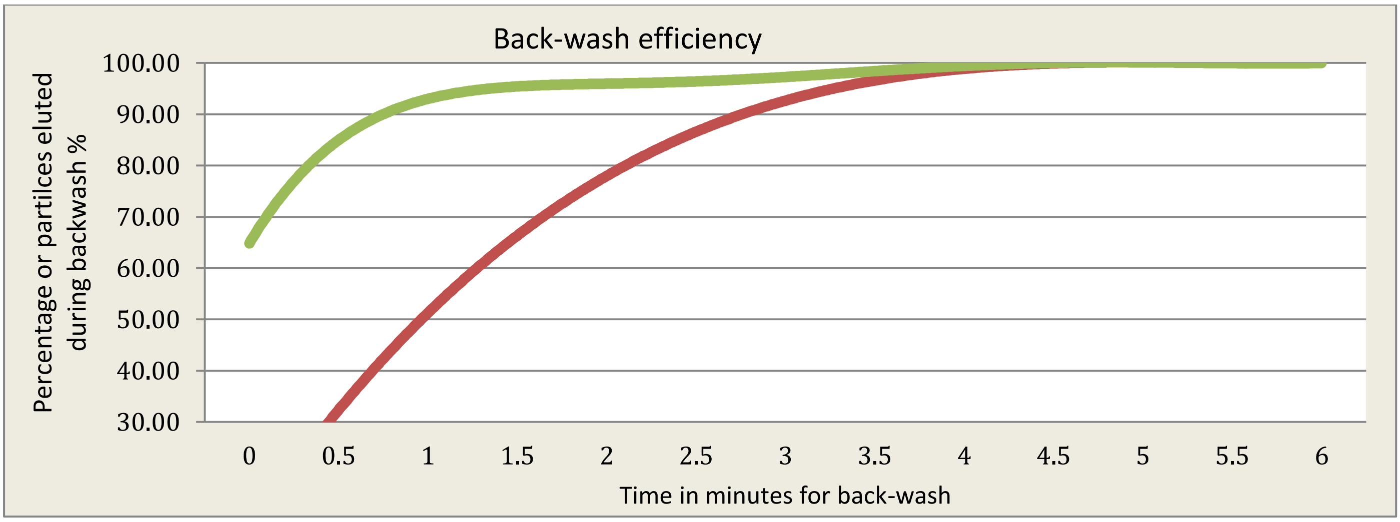
Backwash velocity for pressure and RGF filters

The backwash water flow rate is a function of water temperature and water salinity or TDS.

Table 3. Water type	AFM® backwash velocity, recommended flow rates			
	Sand 16 x 30 grade 15% bed expansion	AFM® grade 1 15% expansion	*AFM® grade 1 with 20% grade 0 20% expansion	AFM® grade 0 20 % bed expansion
Freshwater 30°C	>65 m/hr	>50 m/hr	>45 m/hr	>17m/hr
Freshwater 20°C	>60 m/hr	>45m/hr	>40 m/hr	>14m/hr
Seawater at 10°C	>55 m/hr	>38 m/hr	>36 m/hr	>12m/hr
Seawater at 35ppt 30°C	>55 m/hr	>50 m/hr	>44 m/hr	>16m/hr
Seawater at 35ppt 20°C	>50 m/hr	>45 m/hr	>38 m/hr	>12m/hr
Seawater at 35ppt 10°C	>45 m/hr	>38 m/hr	>32 m/hr	>11 m/hr

- Extra headroom is required for bed expansion of grade 0 which may otherwise be lost from the filter during backwash.

Seawater filtration is included in this report because filtration of seawater is required prior to desalination by RO membranes to provide drinking water. The density of water is a function of TDS, the greater the density the easier it is to fluidise the filter media and as such water flow rates can be reduced as TDS is increased. The same logic applies to water temperature as warm water is less dense than cold water, flow rates should be increased as water temperature is increased.



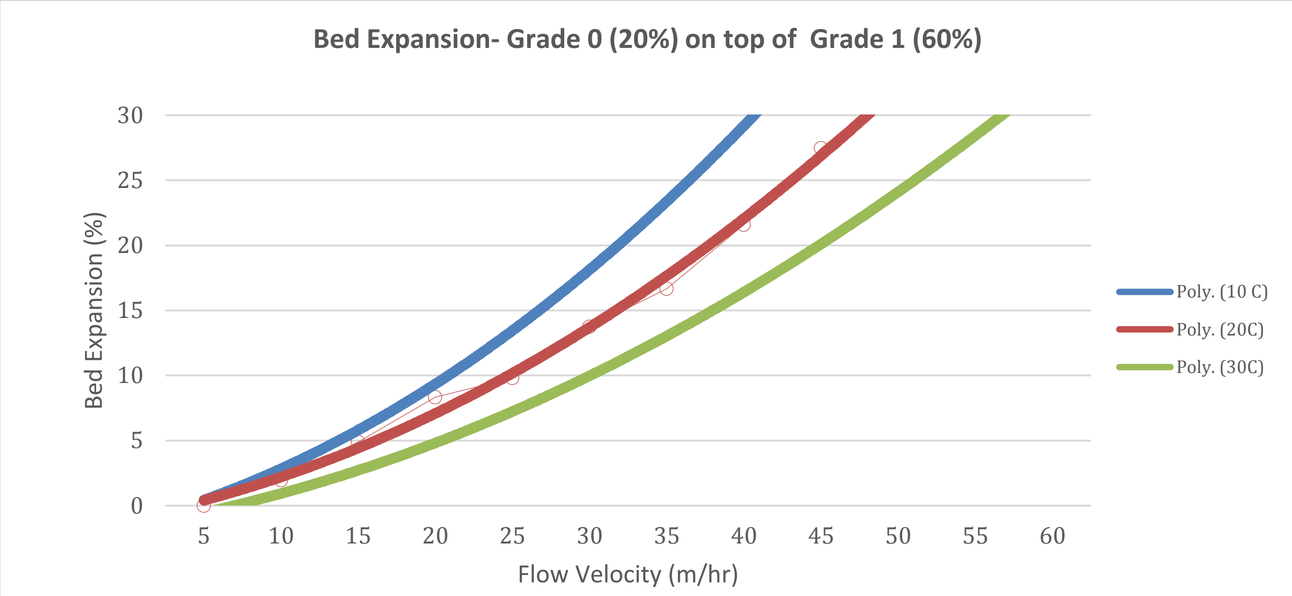
It is essential to operate AFM® filters at the correct backwash water flow rate. Please note that we aim for 20% bed expansion at the flow rates given in Table 3. Some filters may not be able to take the full flow rate, in which case reduce the flow to the maximum possible without losing the media in the backwash water.

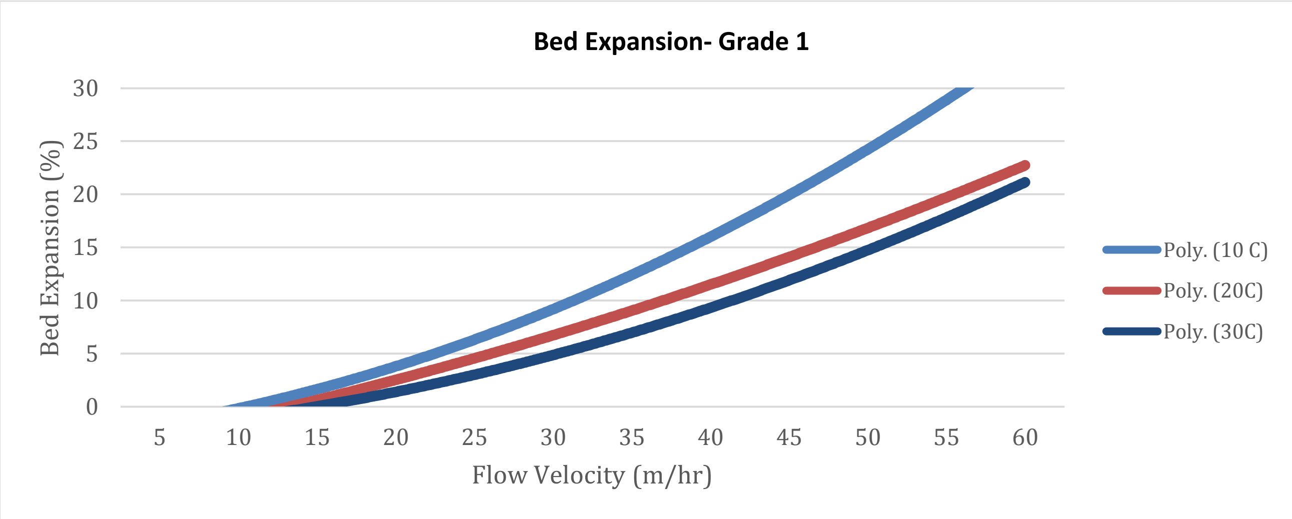
AFM® has a 15% lower bulk bed density when compared to sand, so it is much easier to backwash. However, some filters may be deficient with regards to backwash velocities. It is very important that AFM® is backwashed at the correct water flow rate.

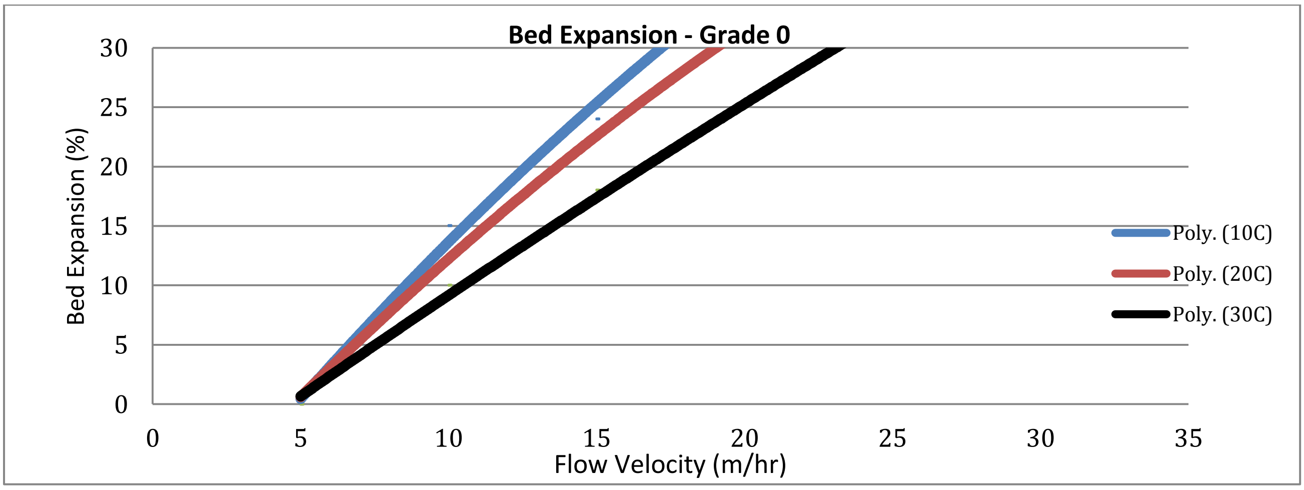
Air scour.

AFM® filtration systems do not require air scour, however if air scour is applied, then it is possible to reduce the velocity of backwash water. This is a practical solution for installation that cannot backwash at the required water flow rate.

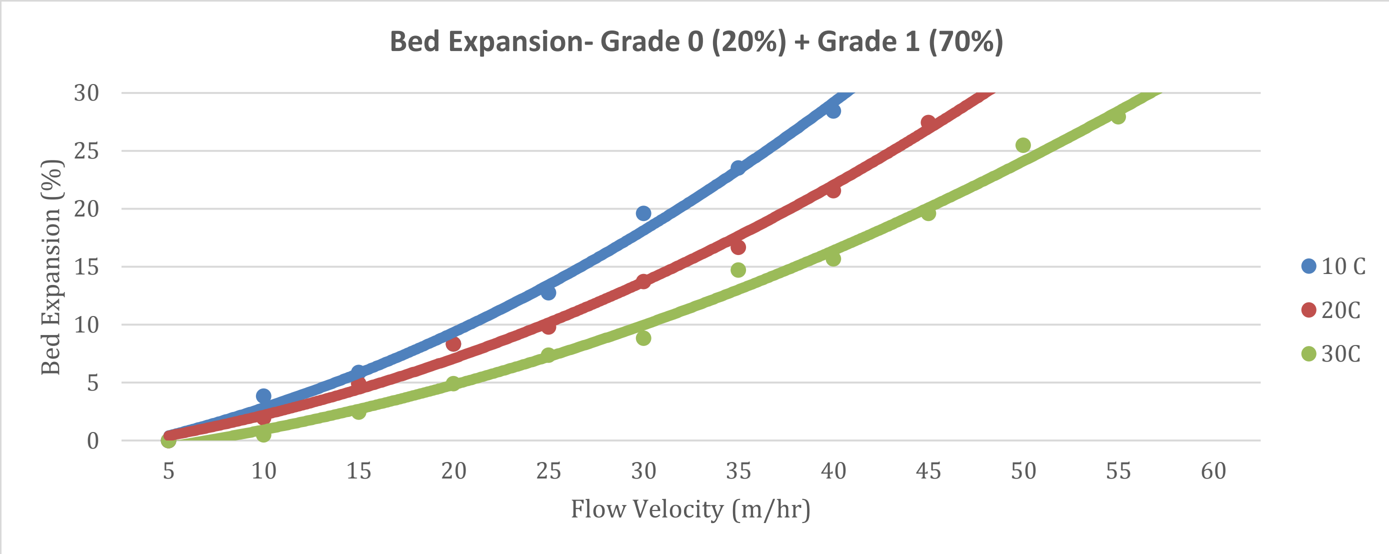
Bed Expansion freshwater

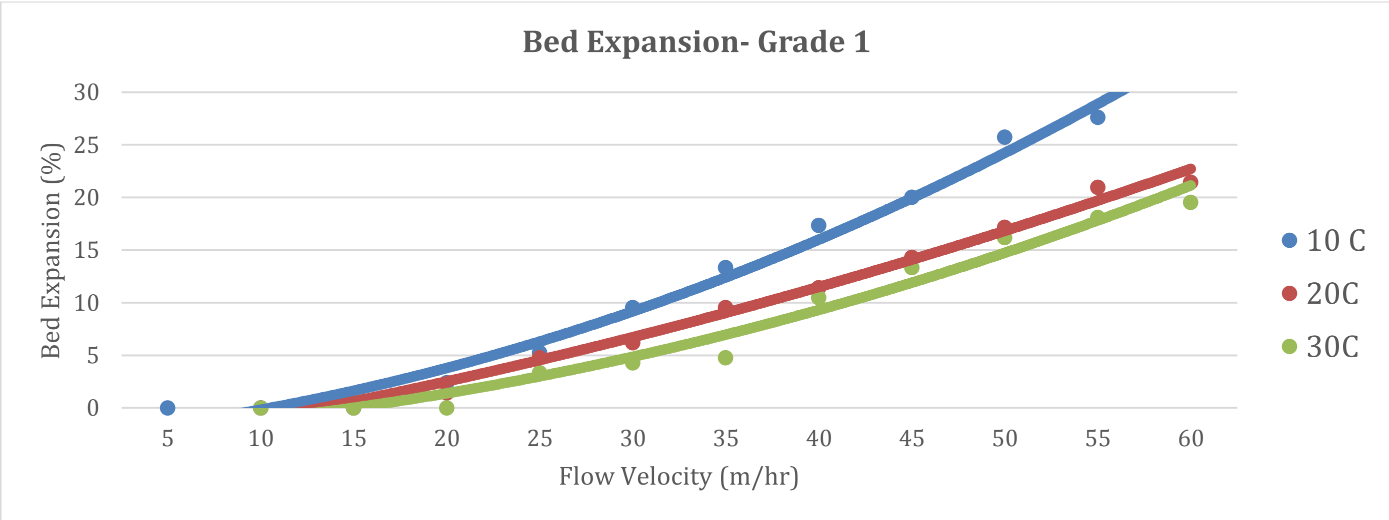


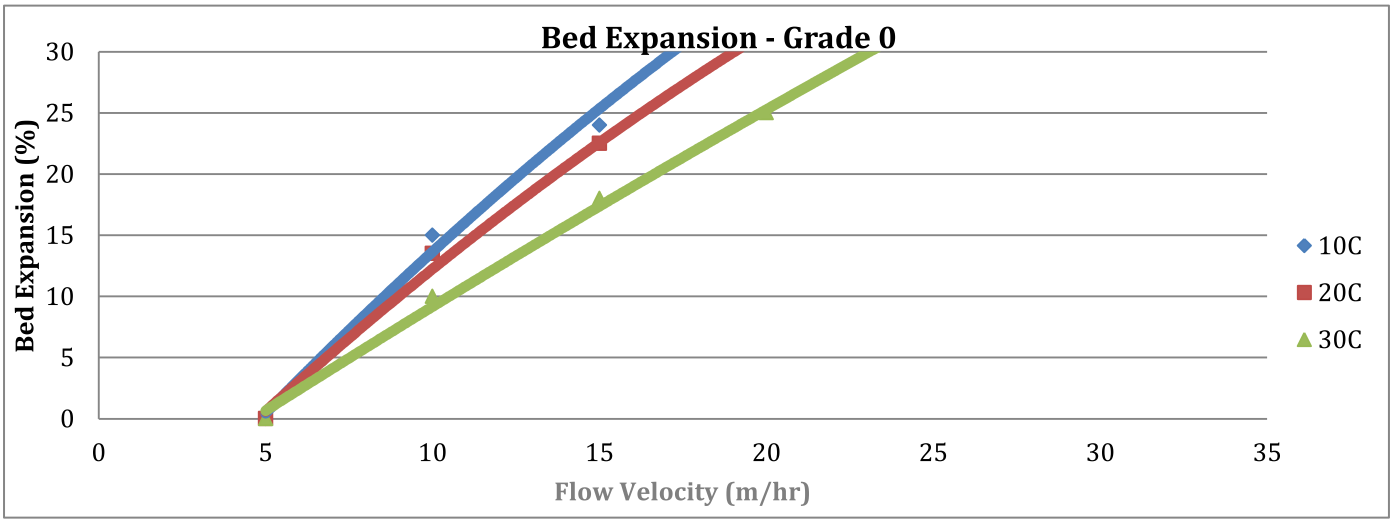


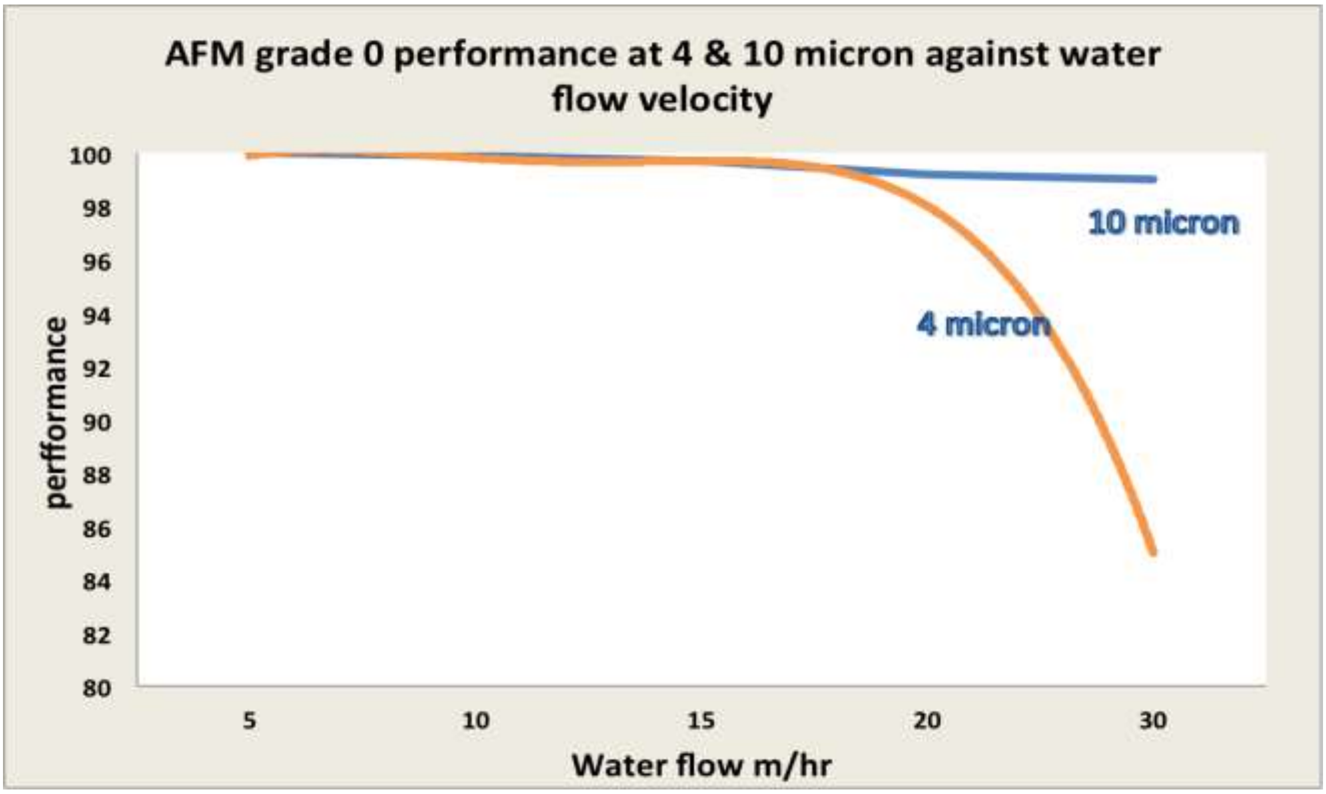


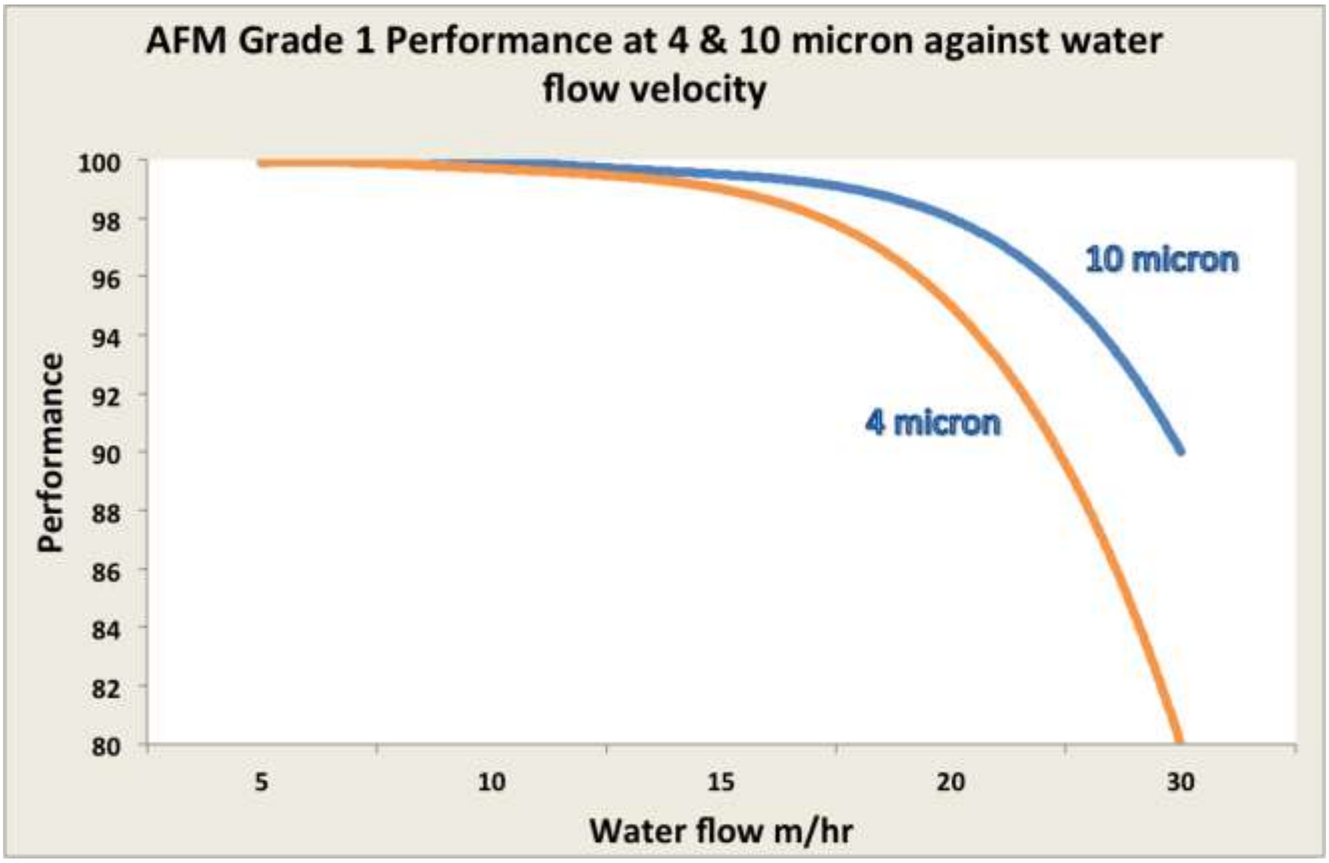
Bed Expansion Seawater at 35ppt











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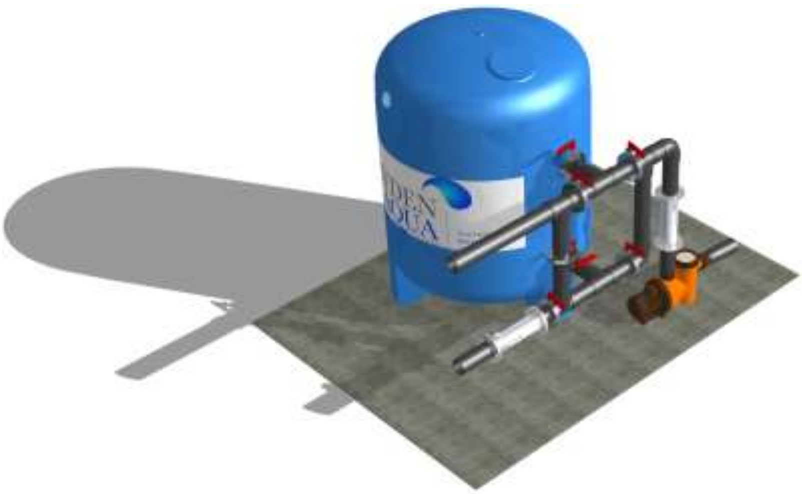
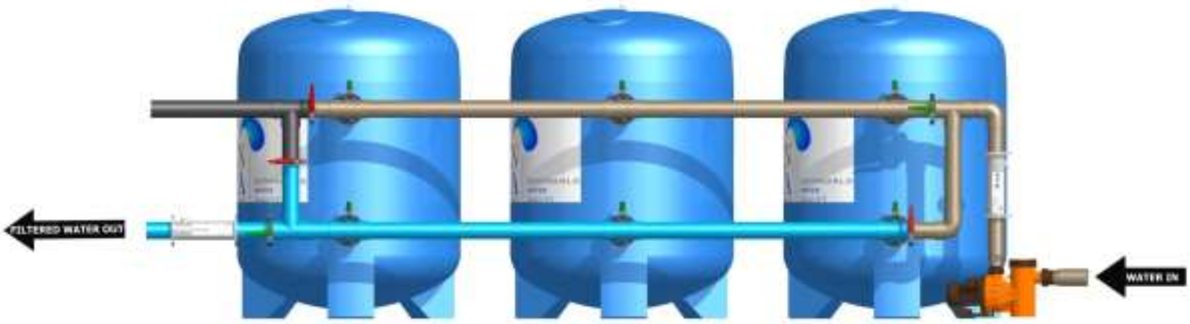
Pressure filter System Schematics

The following section provides 3 dimensional drawings of filter manifolds. The Dryden Aqua Web site at www.DrydenAqua.com provides some additional information and 3D animations of filter configuration.

5 Valve – Single Filter layout



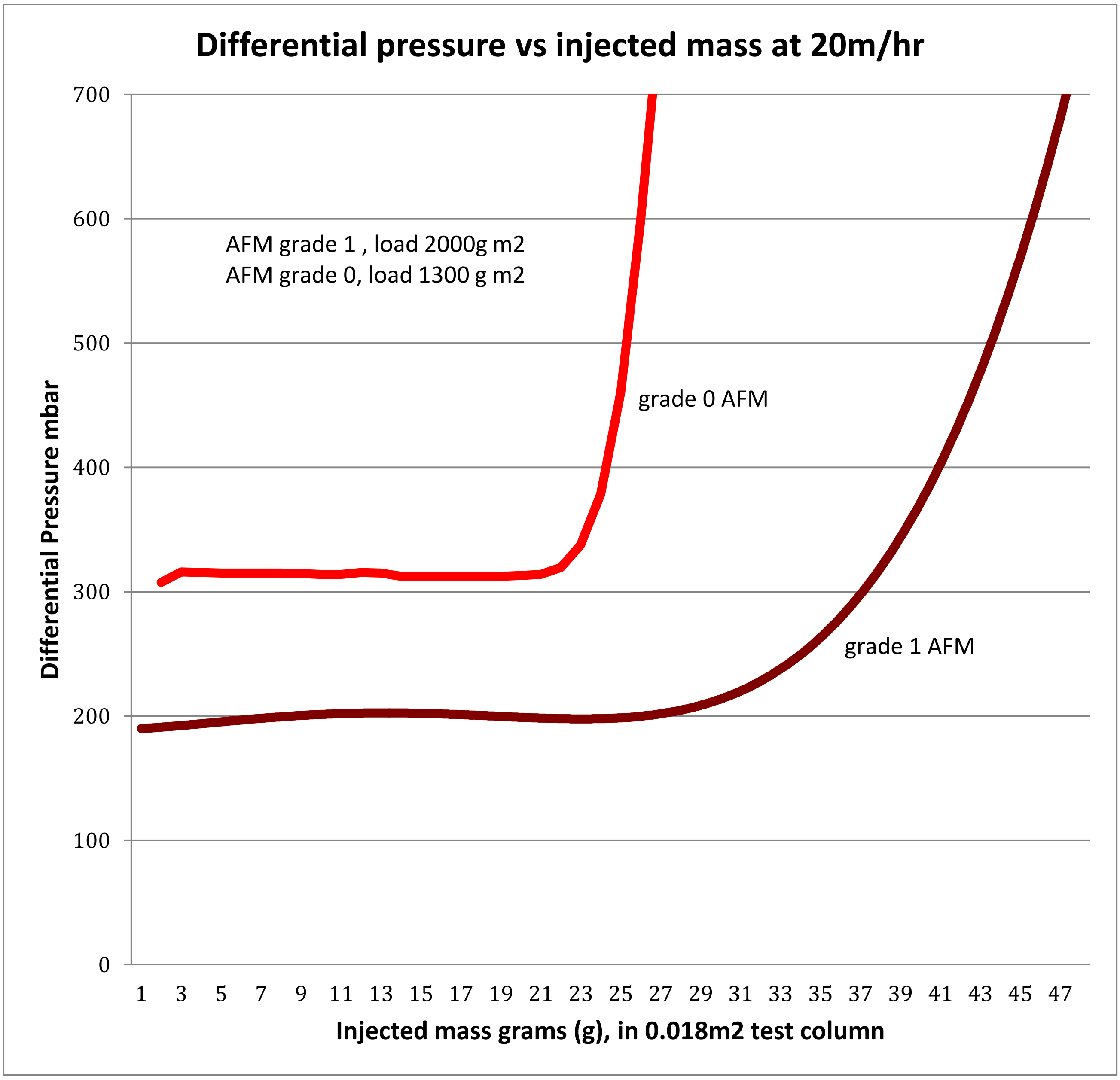
Typical multi filter manifold



Besgo Valve arrangement one filter

Differential pressure and injected mass

The graph below of differential pressure verses injected was performed at 20m/hr filtration velocity.



Pressure Filter backwash procedure

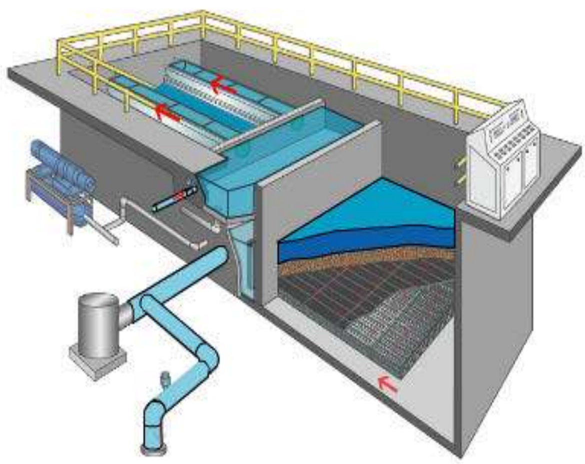
Pressure filters may be in a single of multi filter manifold arrangement; there may be one or more pumps that could be fitted with frequency invertors. Due to the multitude of potential configurations the backwash procedure detailed below is a simple generic procedure that applies to all pressure sand filters.

1. Place the filter into backwash mode.
2. If the filter is to be air purged, drop the water level to a point just above the filter bed.
3. Turn on the air blower, pass clean air through the filter bed at a velocity of 55m/hr for a period of 3 minutes, turn off air blower and isolate air blower from the filter.
4. Turn on backwash pump and slowly build up the water velocity over a period of at least 30 seconds to the required flow rate at detailed in Table 3. If the filter has a viewing window check that the bed rises evenly and that bed expansion is 20%. Continue backwash for a period of 5 minutes, or longer until the water runs clear, or turbidity has dropped below the set point.
5. Place the filter into run phase mode with the water going to waste, wind up pump velocity over a period of 30 seconds to the required velocity. This is referred to as the rinse phase, continue to discharge water to waste for a period of 5 minutes, this allows the bed to compact.
6. Check that there is no air or vent the air on top of the filter.
7. Place the filter on-line.

RGF Rapid Gravity Filter backwash procedure

The following sections relate to the operational protocols for RGF rapid gravity filters for drinking water. The backwash procedure will vary depending upon the manufacturer's instructions. The following is a generic backwash procedure.

Backwash steps, rapid gravity filter:



1. Turn off pumps or stop water flow through the filter.
2. Place filter into backwash mode.
3. Air purge is not required for AFM®, but if it is used, air flow velocity is 55m/hr for 3 minutes. If air purge is applied, drop water level 100mm below the cill before turning on the air blowers. We do not recommend running the air blower and backwash at the same time, this strategy results in loss of too much of the filter media.
4. Turn off air supply and start up backwash pump. The objective is to achieve a 20% bed expansion for a period of at least 3 minutes. Gradually increase backwash flow rate over a period of 30 seconds to the full flow rate. See Table 3 for flow rates. Flows are in accordance with European Standards. For filters in accordance with UK procedures when air scour is used the water flow rate for backwash may be reduced.
5. Continue the backwash for a period of at least 3 minutes at full backwash flow-rate, or until the water runs clear.
6. Clean, filtered water should be used to backwash the filter.

7. After backwash place the filter onto rinse cycle and run for a period of 5 minutes to waste before going back on-line with the system.

6. Storage

Precautions for safe handling

No special precautions should be necessary. Avoid the generation of airborne dust. Provide sufficient ventilation at places where airborne dust is generated and wear a prescribed dust mask. The appropriate precautions as detailed in the SDS data sheet for AFM® must be observed.

Conditions for safe storage

Store in a cool (room temperature), dry place. AFM® may be stored outside immediately prior to filling the filters. However if it is stored outside for a protracted period of time it should be protected from the elements by covering with a tarpaulin. The AFM® should also be stored in a secure location and protected from any intruder interference and contamination by any animals.

7. Disposal of waste and spillage

As an inert material, AFM® may be sent to an approved solid waste disposal or landfill site for disposal. AFM® is a circular economy product and should ideally not be sent to landfill.

AFM® will last for the life of the filtration system and should never need to be replaced. However if AFM® is removed from the filters due to decommissioning of the filter, it may be returned to Dryden Aqua. The media should be analysed prior to returning to Dryden Aqua to ensure there has been no contamination.

Annex 1. Some Key Applications for AFM

Application	Water source	Advantages
Wastewater **Municipal** • Municipal wastewater	Tertiary treatment after activated sludge, solids load to be reduced to <100mg/l prior to AFM.	• Will more easily comply with discharge legislation • Product water of a higher quality more suitable for second use applications • No chlorine or less required when the water is used for class 1 irrigation • Return in capital from revenue is always under 2 years and often under 1 year.
Wastewater **Process water** • Textiles • Leather • Oil in water • Food washing	The wastewater will be from a variety of sources. AFM is usually used as part of the water treatment process.	**Textiles**. AFM applied after the fluidised bed biofiltration. Advanced coagulation and flocculation systems have been developed and optimised for AFM to remove the dyes and facilitate recirculation of the water. **Leather**. The industry generation a hexavalent chromium wastewater, with pre-reduction of the water and conversion of Cr5+ to Cr3+ gives good performance with AFM **Oil in water**. AFM can filter oil in water up to 100mg/l and remove >99% of the oil in a sustainable manner. Higher concentrations require an alginate flocculent. Permits AFM to be used up to 2000mg/l and achieve >99% removal.

Clean water
 	
Single pass
• Drinking water
  ○ Ground water
  ○ Surface water
• Process feed water
• Drinks industries
• Food processing
• Pharmaceuticals
• Hospitals
• Electronics,
• Boiler feed
	Ground water	AFM offers a continuous and sustainable solution for the removal of metals and metaloids, such as ferric, manganese and arsenic to a concentration in accordance to the European directive and WHO

	Surface water	Will remove 50% more sub 5 micron solids from the water. No subject to biofouling and transient wormhole channelling. High security against the passage of copepods, oocycsts and other parasites. Perfect for removing cyanobacteria, diatoms and most freshwater phytoplankton as well as zooplankton without any blockage issues.
	Municipal drinking water supplies	AFM is used to treat municipal water prior to use in Hospitals, and food industries to minimise the risk from Pseudomonas. Already used in hospitals in the UK and Asia. Example, Belfast maternity hospital when tragically several babies succumbed from Pseudomonas, problem solved with AFM
	Ultra pure water, pre-treatment. Water from a variety of sources	Ultra pure water treatment usually involves a 3-stage process. 1.sand filtration, 2. Carbon filtration, 3. one micron cartridge filtration. AFM can replace all three stages as a single one-pass stage prior to the reverse osmosis membranes. Water flow is usually under 10m/hr velocity
Clean water **Marine and brackish water** • Drinking water • Drinks industry	Seawater, brackish water or ground water with a high TDS. Water supply for reverse osmosis	One of the problems with membrane filtration is fouling from the coagulants and flocculants. The use of grade 0 AFM gives a very high performance and negates the need to use chemicals. If coagulants and flocculants are used, then grade 1 AFM is applied. AFM does not coagulate, or allow channelling so as long as the chemicals are dosed properly in accordance to turbidity they will never reach the membranes. System performance is superior to UF because AFM grade 1 with controlled flocculation will give nominal filtration better than 0.1 microns and will remove chemicals from solution such as soluble reactive silica, phosphate and dissolved organics that would otherwise foul the membranes
Clean water **Recycling or multi-pass** • Swimming pools • Aquaculture • Aquaria • Fountains • Water features • Cooling towers	Recycled water around a process. This is one of the main applications for AFM with over 100,000 systems currently running in Europe. Cooling tower applications are becoming of increasing importance, especially to reduce cost and Legionella aerosol risk from the towers	**Swimming pools, water features fountains and marine mammal systems** can use AFM as part of the DAISY system (Dryden Aqua Integrated System). DAISY provides the ultimate in water treatment with a visibility through the water in excess of 25m and turbidity usually less than 0.05NTU. **Aquaculture and Aquaria**, require the best possible water quality. AFM provides at least double the performance of sand and reduces the viral parasitic and bacterial risk **Cooling towers**, AFM provides a much better quality and reduces the nutrient load and bacterial cell biomass as measure by ATP in the circuit. The result is reduced cost, reduced corrosion and lower risk from Legionella.

Annex 2 AFM for the tertiary treatment of Waste water

AFM is used for the tertiary treatment of wastewater in gravity flow of pressure filters. AFM has many benefits over sand filtration, which include the following;

- AFM does not biofoul, coagulate or experience transient channelling
- Predictable and repeatable performance
- Turbidity and TSS reduction better than 90%
- Perfect for ferric removal as such AFM is also very good at removing phosphate and arsenic
- Many priority chemicals such as herbicides are hydrophobic and are adsorbed onto sub 10 micron particles. AFM will remove 97% of all particles down to 4 microns, independent confirmation by IFTS
- Should never need to be replaced

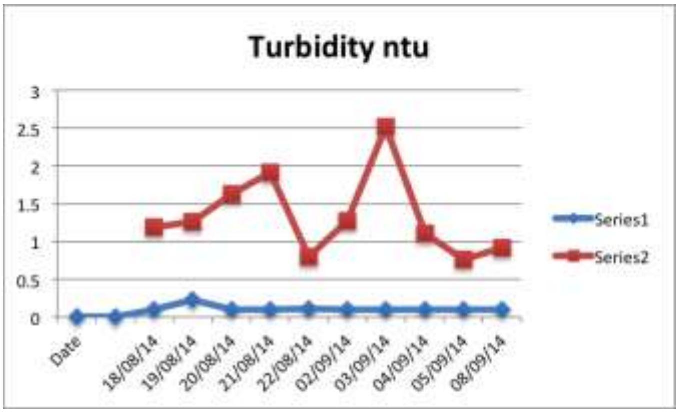
Operational criteria	range		notes
Bed depth AFM	500mm	2000mm	Typical bed depth is 1200mm with 200mm of 1 to 2mm anthracite on top of the bed
Run phase water flow	1 m/hr	20 m/hr	The slower the flow rate the better the performance
Running pressures (differential)	0.1	0.4	Do not exceed 0.4 bar differential
Back-wash water flow	>50m/hr	60m/hr	Back-wash for 5 minutes, or until the water runs clear. Air purge not required
Rinse phase duration	5 minutes	Or until water runs clear	It takes a few minutes for the bed to stabilize after a back-wash
Back-wash frequency / hours	4	40	Depends upon solids load in wastewater
Water quality			Ideally the dissolved oxygen level should be above 2mg/l or redox potential above 300mv entering the AFM filter bed

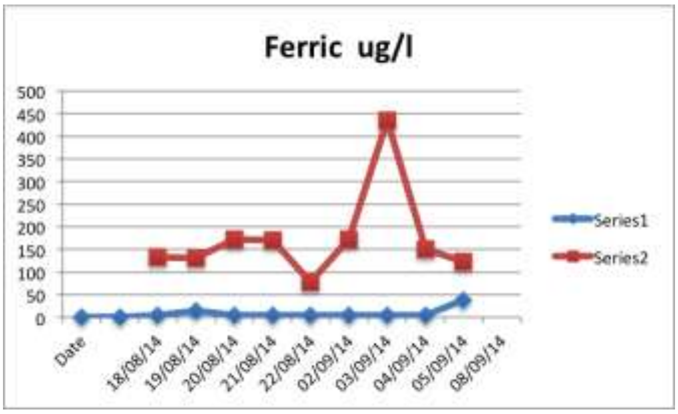
UK Municipal wastewater treatment

Results from UK water utility show showing exceptional performance before and after AFM filtration in a gravity flow sand filter.
Series 2 = influent to AFM RGF filter
Series 1 = product water provided by AFM

The results demonstrate what can be achieved when a flocculent is used prior to AFM filtration for the tertiary treatment of wastewater.

Turbidity reduction >99%
Ferric reduction >99%





Phosphate Arsenic

Ferric chloride is a useful coagulant as well as flocculent to add to waste water in order to improve turbidity removal, as well as the reduction of DOC dissolved organics, orthophosphate and Arsenic. Ferric will co-precipitate with phosphate and arsenic, to give better than 90% reduction.

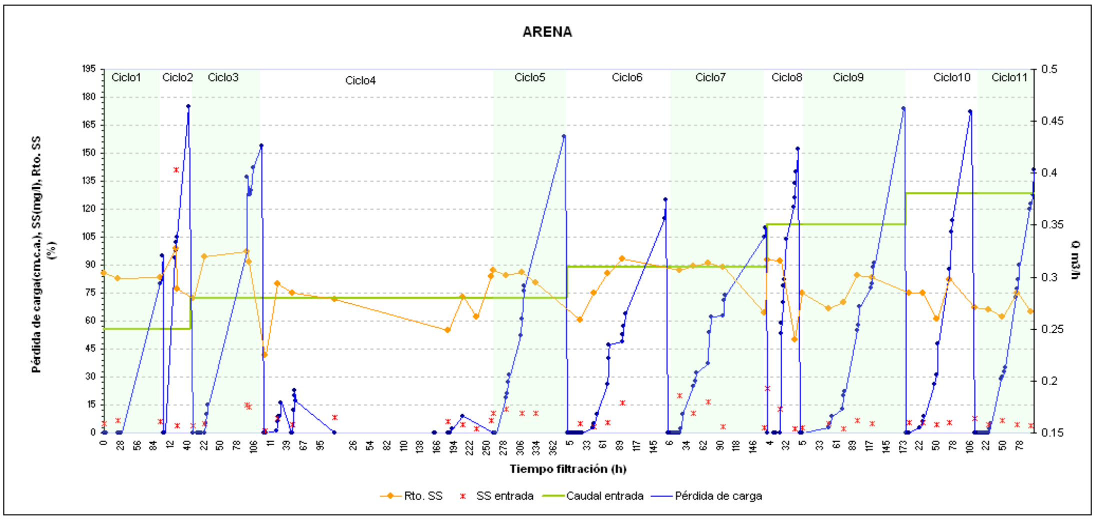
Municipal wastewater

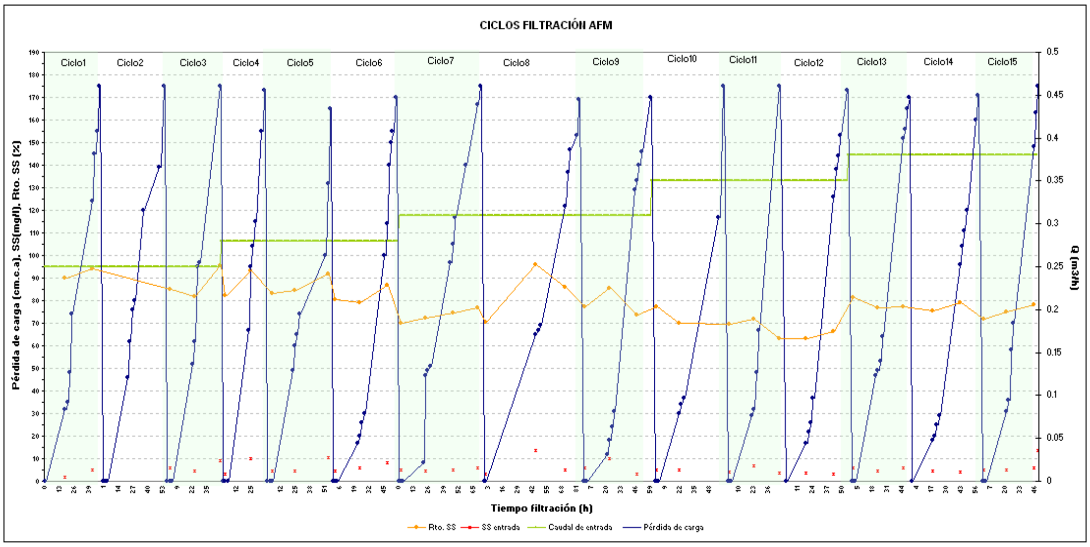
The following is published data by a Spanish Water Utility on the treatment of wastewater for second use. The data shows the backwash profile from the gravity flow sand filter and then the AFM filter. The data confirms the stability and high performance of AFM in comparison to sand.

The sand filter was unstable and the large interval between the back-wash peeks confirms channelling of water through the sand bed.

The AFM filter was like clock-work, each run phase and every back-wash was the same. The data confirms the stability of AFM and the high quality of product water that may be achieved.

Data published
Technologia del Agua, No 334 November 2011, I.S.S.N. 211/8173





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Waste water treatment, results for AFM

Wastewater	Typical Performance advantage
Suspended solids	>90% reduction
COD/BOD/TOC	
Turbidity	>90% reduction
Ammonium	No change with AFM
Bacteria TTC	50% reduction
THMs	50% to 90% reduction
Back-wash profile	Used to check performance

TYPE OF FILTER	SS. (mg/l)		Performance %	Turbidity ntu		Performance %	bacteria		Performance %	Filtration Velocity
	inlet	outlet		inlet	outlet		inlet	outlet		m3/m2/h
RGF sand filter with sand	7.14	2.2	69	3.5	2.23	36	23120.0	12300.0	46	1.2
Pressure filter with sand	8.18	3.82	53	5.87	4.76	18	22311	18023	19	4.96
Moving bed sand filter with sand	7.08	3.82	46	2.13	1.79	16	14067	10307	26	5.4
Drum filter 10 micron	14.66	7.33	50	7.16	3.88	45	56712	38460	32	3.23
Disc Filter 10 micron	5.6	3.1	44	2.22	2.06	7	30450	21138	30	2.12
Ring Filter 10 micron	7.41	3.98	46	3.01	3.17		9447	7761	17	2.5
AFM® Pressure filter	10.60	0.89	**96%**	2.98	0.24	**92 %**	23000	**10000**	**58 %**	3.59

Independent tests conducted by Spanish Water Company and reported in Technology del Agua , December 2009, page 47.

Annex 3. The removal of Arsenic, Ferric and Manganese

Chemical parameter	Soluble fraction	Insoluble	Drinking water standard	AFM performance
Manganese	Mn2+	Mn4+	50 ug/l	>80%
Ferric	Fe2+	Fe3+	200 ug/l	>95%
Arsenic	As3+	As5+	10 ug/l	>90%

Iron, manganese and arsenic are often found in borehole / tube wells and ground-water at varying concentrations depending upon the geology of the ground. The process used by Dryden Aqua to remove the chemicals is as follows;

Process

1. Oxidation reactions to convert metals from soluble ionic form to insoluble oxidized precipitate, pH correction and redox correction.
2. Decantation may be required if the concentrations are above 5 mg/l, if not proceed to AFM® filtration
3. AFM® filtration to remove the suspended metal oxide solids, there will also be adsorption reactions and surface oxidation reactions.

Procedure

Oxidation;

This is achieved through aeration of the water. The water is aerated for a period of no less than 30 minutes. If water flow is 50 m3/hr the aeration level is 50m3/hr of air and tank volume is 25m3 of water. Dryden Aqua manufacture fine bubble drop in air diffusers for this application.

pH;

The pH of the water should be increased to a value over pH 7.5

Redox;

The aeration system should increase the redox potential of the water. It is important to raise the potential to as high a value as possible. Certainly it should be over 300mv for ferric and arsenate. Manganese needs an additional oxidising agent to raise the potential to 500mv. A ZPM between the pump and AFM filters should also be fitted.

- **Manganese** oxidation requires aggressive aeration and an additional oxidising agent, such as hypochlorite, chlorine dioxide, hydrogen peroxide or ozone in order to raise the Redox potential to 500mv +/- 25mv.
- **Ferric** oxidation is simple, the aeration system will more than suffice.
- **Arsenic** oxidation also benefits from the addition of ferric to the water. Arsenic is removed by oxidation and co-precipitation with ferric, example 0.1 mg/l As requires up to 1 mg/l of ferric (as ferric chloride)

AFM® filtration

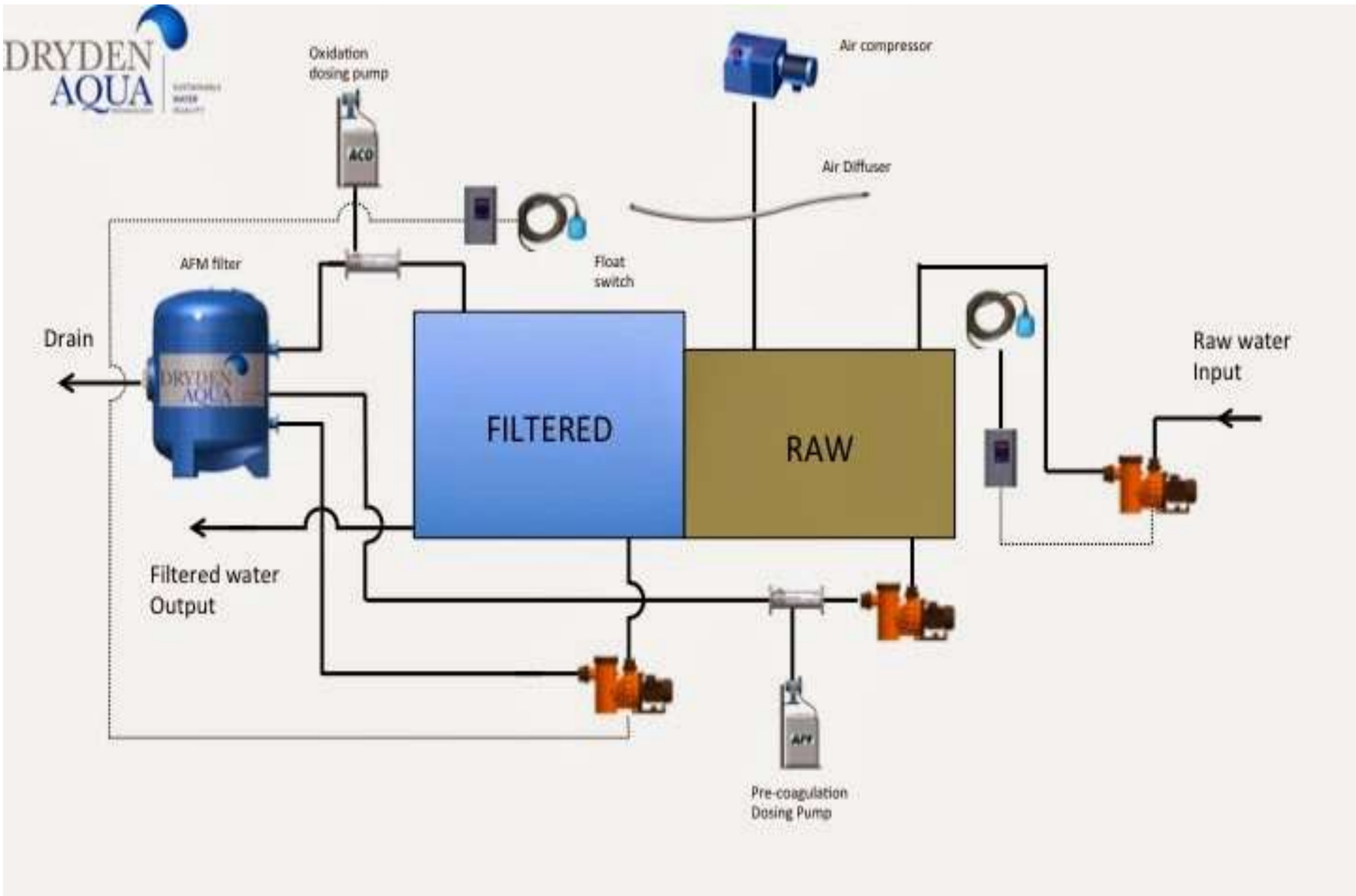
Pretreatment of the water prior to filtration by AFM® is very important. AFM® will remove the metals and metalloid by the following mechanisms;

- Oxidation and adsorption (similar to greensands and ferric media)
- Adsorption of sub-micron metal oxide particles
- Physical filtration of most particles down to 1 micron.

Operating parameters

AFM® filtration performance will depend upon the operating parameters. It is important to use good quality filters, we recommend filters in compliance to the German DIN standard. The follow represent the optimum filter bed operating conditions.

		range	notes
Bed depth AFM	1200mm		Bulk bed density 1.25 to 1
Run phase water flow	5 m/hr	10 m/hr	The slower the flow rate the better the performance
Running pressures (differential)	0.3	0.4	Do not exceed 0.4 bar differential
Back-wash water flow	>45m/hr	60m/hr	Back-wash for 5 minutes, or until the water runs clear. Air purge not required
Rinse phase duration	5 minutes	Or until water runs clear	It takes a few minutes for the bed to stabilize after a back-wash
Back-wash frequency / per week	1	7	Reduce back-washing to a minimum.

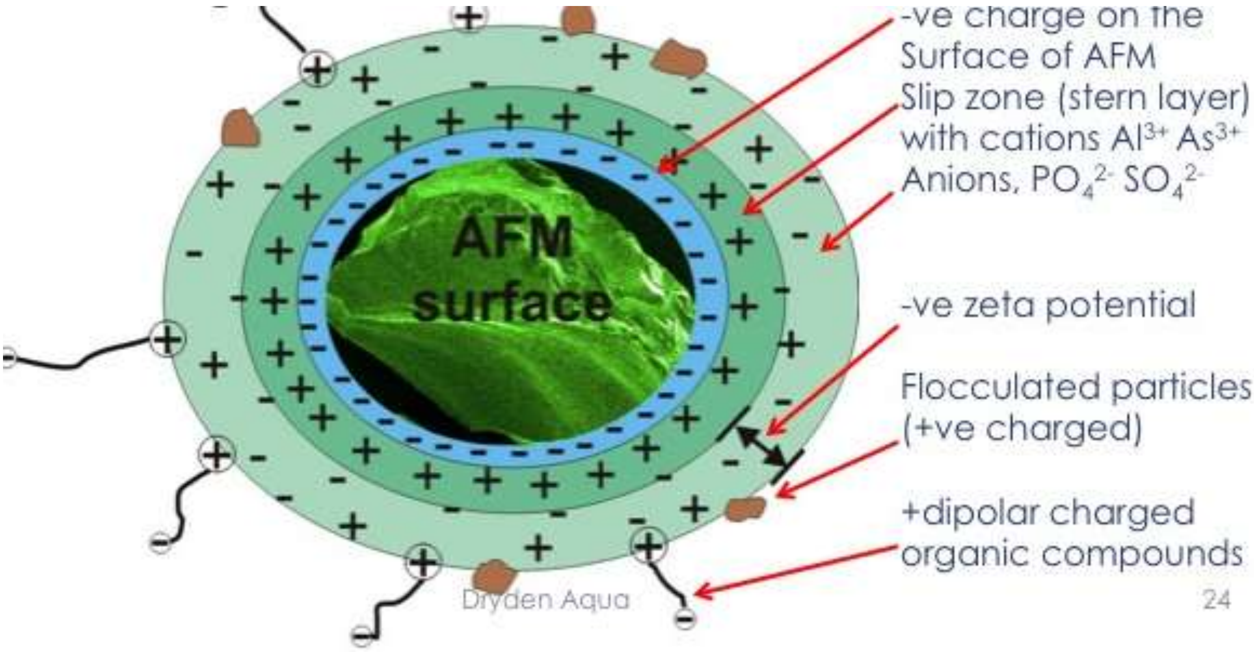

Oxidation
dosing pump
Air compressor
Air Diffuser
AFM filter
Float
switch
Drain
FILTERED
RAW
Raw water
Input
Filtered water
Output
Pre-coagulation
Dosing Pump

Annex 4 Removal of Phosphate from water

Total phosphate includes three forms of phosphate; 1. organic phosphate found in plankton, algae and bacterial cell biomass, 2. inorganic phosphate such as struvite, and 3. soluble reactive phosphate referred to as ortho-phosphate.

AFM will mechanically filter the water down to less than 1 micron when coupled with pre-coagulation and flocculation. The removal of organic and inorganic particulate phosphate will be more than >95%.

AFM will directly adsorb soluble reactive orthophosphate PO_4^{2-} in the AFM stern layer, the capacity for adsorption is low, but sufficient to make an impact on concentrations remaining after a precipitation stage with ferric, lanthanum or magnesium.



While sand can work well for phosphate removal, typically sand filters develop the following problems:

- Sand becomes a biofilter in biologically active water such as municipal wastewater. The bacterial biofilm coagulate the sand and this leads to transient wormhole channeling with passage of unfiltered water through the filter bed, as well as premature blockage of the sand.
- Phosphate forms a hard scale that bonds on to sand. The bed can turn into a solid concrete mass which makes it impossible to filter water, and very difficult to remove the sand.

AFM will:

- Capture the phosphate precipitate
- Does not form a bond with the media surface or turn the filter bed into a concrete mass.
- Regular back washing will remove the precipitate and adsorbed ortho-phosphate, the system is sustainable with no wormhole channeling.
- Secure stable water treatment to a very high standard, typically 95% reduction in total phosphate.

Wastewater treatment

AFM provides a sustainable and efficient means of removing phosphate from wastewater.

There are three main approaches, all of which involve the precipitation of phosphate to form an insoluble salt by the addition of;

(i) ferric to form ferric phosphate
(ii) magnesium to form struvite.
(iii) lanthanum to form lanthanum phosphate

At Dryden Aqua we have been using (iii) Lanthanum salts (NoPhos) to remove phosphate in the aquarium and aquaculture industry for over 20 years. Lanthanum is injected into the water at a 1:1 stoichiometric ratio to remove phosphate down to concentrations below 0.05 mg/l. NoPhos must be injected into the water before AFM using an aggressive static mixer such as our ZPM to insure efficient use of NoPhos and removal of ortho-phosphate.

The process is simple, reliable and sustainable, however Lanthanum is an expensive product. Ferric chloride is a lower cost substitute for Lanthanum chloride. The performance of ferric is not quite as good as lanthanum, in order to compensate for the reduced performance; typically a 2 : 4 excess molar ratio is applied. More ferric may be required if there is a higher concentration of suspended solids or dissolved organics in the water to be treated.

Ferric chloride is injected into the water via a ZPM or aggressive static mixer. Ideally there should be a 10-minute aerated contact tank. The dissolved oxygen content must be kept above 2 mg/l or redox potential above 300mv. AFM is highly effective for the removal of ferric, arsenic and manganese and a good solution for the removal of the ferric phosphate salt.

Chemical parameter	Soluble fraction	Insoluble	Drinking water standard	Performance
Phosphate Soluble reactive	PO_4^{2-}	$(Fe^{3+})_2(PO_4^{2-})_3$ $Mg^{2+}NH^{4+}PO_4^{2-}$	No limit	>95% usually less than 0.1mg/l PO4-P

The details below provides a list of phosphate minerals that will form insoluble precipitates

- triphylite Li(Fe, Mn)PO_4
- monazite (Ce,La, Y,Th)PO_4
- hinsdalite $PbAl_3(PO_4)(SO_4)(OH)_6$
- pyromorphite $Pb_5(PO_4)_3Cl$
- vanadinite $Pb_5(VO_4)_3Cl$
- erythrite $Co_3(AsO_4)_2 \cdot 8H_2O$
- amblygonite $LiAlPO_4F$
- lazulite $(Mg,Fe)Al_2(PO_4)_2(OH)_2$

- wavellite $Al_3(PO_4)_2(OH)_3 \cdot 5H_2O$
- turquoise $CuAl_6(PO_4)_4(OH)_8 \cdot 5H_2O$
- autunite $Ca(UO_2)_2(PO_4)_2 \cdot$10-12H_2O
- carnotite $K_2(UO_2)_2(VO_4)_2 \cdot 3H_2O$
- phosphophyllite $Zn_2(Fe,Mn)(PO_4)_2 \bullet 4H_2O$
- struvite $(NH_4)MgPO_4 \cdot 6H_2O$
- Xenotime-Y $Y(PO_4)$

- Apatite group $Ca_5(PO_4)_3(F,Cl,OH)$
- hydroxylapatite $Ca_5(PO_4)_3OH$
- fluorapatite $Ca_5(PO_4)_3F$
- chlorapatite $Ca_5(PO_4)_3Cl$
- bromapatite

- Mitridatite group:
- Arseniosiderite-mitridatite series $(Ca_2(Fe^{3+})_3[(O)_2|(AsO_4)_3] \cdot 3H_2O$ -- $Ca_2(Fe^{3+})_3[(O)_2|(PO_4)_3] \cdot 3H_2O)$ [1]
- Arseniosiderite-robertsite series $(Ca_2(Fe^{3+})_3[(O)_2|(AsO_4)_3] \cdot 3H_2O$ -- $Ca_3(Mn^{3+})_4[(OH)_3|(PO_4)_2]_2 \cdot 3H_2O)$ [2]

Process

There are three approaches; ortho-phosphate is removed by forming an insoluble precipitate with Lanthanum, ferric, or magnesium. AFM is highly effective for this application because the precipitates formed are efficiently removed without solidifying the filtration bed.

Molar ratios

1. The precipitating salts must be added via an aggressive static mixer, ***after*** the pump but ***before*** the filter
2. Lanthanum addition is stoichiometric at a molar ration of 1:1
3. Ferric addition should be at a ratio of 2-4 to 1 molar Ferric to Phosphate. This will give a surplus of ferric for coagulation and other flocculation reactions. The optimum concentration should be determined on a case-

by-case basis because water with a high concentration of suspended solids, or other chemicals will influence the concentration of ferric required.

4. Struvite. The molar ratio NH3:Mg:PO4 equates with 1:8:3, this is not stoichiometric but it has been found in different water types to give good results. It will be a requirement to adjust the injection of magnesium to determine the optimum ratio.

5. The chemical reactions are rapid, and a period of 15 minutes is sufficient. Dryden Aqua air diffusers are designed to perform the mixing action. It is important to insure that the dissolved oxygen concentration is above 2mg/l or the redox potential exceeds 300mv. Our air diffusers are easy to remove for cleaning and descaling.

6. Decantation may be required if the concentration of phosphate is above 5 mg/l as PO4-P, if not, it is a matter of just proceeding to AFM® filtration

7. The AFM® filtration process to remove the phosphate suspended solids will result in adsorption reactions of phosphate PO_4^{2-} directly onto the AFM. *(N.B. An activated form of AFM designed to be even more selective with higher capacity for orthophosphate is in development.)*

AFM filter operating parameters

AFM® filtration performance will depend upon the operating parameters. It is important to use good quality filters, we recommend filters in compliance to the German DIN standard. The follow represent the optimum filter bed operating conditions.

	range		notes
Bed depth AFM	1200mm	1800mm	Bulk bed density 1.25 to 1
Run phase water flow	5 m/hr	15 m/hr	The slower the flow rate the better the performance
Running pressures (differential)	0.2	0.4	Do not exceed 0.4 bar differential
Back-wash water flow	>45m/hr	<60m/hr	Back-wash for 5 minutes, or until the water runs clear. Air purge not required
Rinse phase duration	5 minutes	Or until water runs clear	It takes a few minutes for the bed to stabilize after a back-wash
Filter grades			Standard ratios of media, typically 10-15% grade 3, 10-15% grade 2 and 70-80% grade 1. Grade 0 is not used for this application.
Back-wash frequency / per week	1	7	Air purge is not required, but may be used to reduce back-wash water consumption.

Meeting the standard

If it is a requirement to achieve very low concentration of total phosphate consistently below 0.1mg/l as PO4-P it may be necessary to adjust the following parameters;

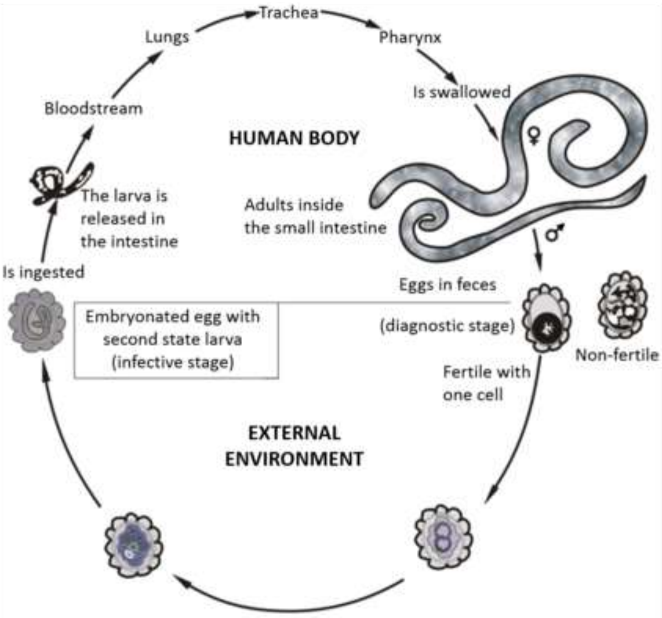
1. Reduce run phase flow velocity
2. Increase ferric concentration
3. Increase bed depth

Reducing run phase water flow rate or increasing bed depth are operational parameters. We recommend filter bed depth in accordance to DIN, which is between 1200 and 1400 for mechanical filtration application. Phosphate removal is a mass balance adsorption reaction so increasing bed depth to 1800 can offer advantages.

AFM makes it much easier to achieve low concentrations of phosphate in the product water. AFM performance is confirmed by IFTS to perform to a higher standard than sand, or any other similar media. AFM is therefore a perfect sustainable solution for Total Phosphate control in clean water as well as wastewater applications.

Annex 5, Parasitic nematode egg removal from waste water, and second use of water for irrigation

Water can often contain parasites such as Cryptosporidium in drinking water, or nematodes including the human parasite *Ascaris* lumbricoides in wastewater.



Ascaris lumbricoides **Life Cycle**, Nematode (Roundworm)

Ascaris infects more than 2 billion people in the world, and is particularly acute and dangerous in the developing world among people that are weakened through poor nutrition or chronic illness. One of the main vectors for the spread of the parasite is the use of wastewater for irrigation that contains the parasitic eggs.

The parasite egg is large at 40 microns and easy to remove by AFM tertiary treatment. Sand will also remove the egg, but because sand suffers from bio-dynamic instability and transient wormhole channelling, the infections eggs will break through the filter. This may explain why almost 1% of the population in Europe and North America, also have the nematode infection.

The parasite infects your blood, internal organs and lungs, and then ends up back in you intestine where it can grow up to 35cm in size.

Case Study
Kaipara District Council Location: Mangawhai, New Zealand

We have been monitoring water quality in Kaipara district in New Zealand since 2009. The municipal wastewater is treated by AFM pressure filters operating at 20m/hr. There are Ascaris eggs in the wastewater, but none have been detected in the product water. The predictable high performance of AFM has allowed the wastewater to be used for irrigation.

In addition to human parasitic nematodes, there are also nematodes that will infect plants.

Waste water will contain heavy metals and metaloids such as hexavalent chromium and arsenic. AFM is very good at removing these components. We have also shown that priority toxic chemicals tend to hydrophobic and are adsorbed onto particles. AFM is up to 10 times more efficient at removing these particles. It is essential that the water is of the highest standard to avoid accumulation of toxins in the plants and in the aquifer. AFM is a solution to these issues.

Annex 6 Analysis of product water prior to connection of drinking water filtration system to a network

General Chemistry	**required**	**Method of water analysis**
pH	Yes	Auto analyser
Conductivity (@20°C)	Yes	Auto analyser
Alkalinity	Yes	Auto analyser
Total dissolved solids	Yes	gravimetry
		Calculation
Suspended Solids	Yes	gravimetry
Colour	Yes	Auto analyser
Nitrate	Yes	Calculation
Nitrite	Yes	Colorimetry
Oxidised nitrogen	Yes	Colorimetry
Phosphate (Soluble reactive)	Yes	Colorimetry
Sulphate	Yes	Inductively coupled plasma with mass spectroscopy or optical emission spectroscopy (ICP/MS or ICP/OES)
Chloride	Yes	Ion Chromatography
		Ion Chromatography
Bromate	Yes	Ion Chromatography
Bromide	Yes	Ion Chromatography
Fluoride	Yes	Ion Chromatography
		Auto analyser
Turbidity	Yes	Auto analyser
Total organic carbon (TOC)	Yes	TOC Analyser
Metals		
Aluminium	Yes	Inductively coupled plasma with mass spectroscopy or optical emission spectroscopy (ICP/MS or ICP/OES)
Antimony	Yes	Inductively coupled plasma with mass spectroscopy (ICP/MS)
Arsenic	Yes	Inductively coupled plasma with mass spectroscopy (ICP/MS)
Boron	Yes	Inductively coupled plasma with mass spectroscopy or optical emission spectroscopy (ICP/MS or ICP/OES)
Cadmium	Yes	Inductively coupled plasma with mass spectroscopy or optical emission spectroscopy (ICP/MS or ICP/OES)
Calcium	Yes	Inductively coupled plasma with mass spectroscopy or optical emission spectroscopy (ICP/MS or ICP/OES)
Chromium	Yes	Inductively coupled plasma with mass spectroscopy or optical emission spectroscopy (ICP/MS or ICP/OES)

Copper	Yes	Inductively coupled plasma with mass spectroscopy or optical emission spectroscopy (ICP/MS or ICP/OES)
Iron	Yes	Inductively coupled plasma with mass spectroscopy or optical emission spectroscopy (ICP/MS or ICP/OES)
Lead	Yes	Inductively coupled plasma with mass spectroscopy or optical emission spectroscopy (ICP/MS or ICP/OES)
Magnesium	Yes	Inductively coupled plasma with mass spectroscopy or optical emission spectroscopy (ICP/MS or ICP/OES)
Manganese	Yes	Inductively coupled plasma with mass spectroscopy or optical emission spectroscopy (ICP/MS or ICP/OES)
Mercury	Yes	Inductively coupled plasma with mass spectroscopy (ICP/MS)
Nickel	Yes	Inductively coupled plasma with mass spectroscopy or optical emission spectroscopy (ICP/MS or ICP/OES)
Potassium	Yes	Inductively coupled plasma with mass spectroscopy or optical emission spectroscopy (ICP/MS or ICP/OES)
Selenium	Yes	Inductively coupled plasma with mass spectroscopy (ICP/MS)
Silica	Yes	Inductively coupled plasma with mass spectroscopy or optical emission spectroscopy (ICP/MS or ICP/OES)
Sodium	Yes	Inductively coupled plasma with mass spectroscopy or optical emission spectroscopy (ICP/MS or ICP/OES)
Zinc	Yes	Inductively coupled plasma with mass spectroscopy or optical emission spectroscopy (ICP/MS or ICP/OES)
Microbiology		
Total Viable Count (TVC) @ 22°C	Yes	Pour plate method
Total Viable Count (TVC) @ 37°C	Yes	Pour plate method
Coliforms	Yes	Membrane filtration using membrane lactose glucuronide agar (MLGA)
E.Coli	Yes	Membrane filtration using membrane lactose glucuronide agar (MLGA)
Cryptosporidium	Optional	Immunomagnetic separation and microscopy
Organic Chemistry		
Solvent extractable Oganic compounds	Yes	Gas Chromatography with Mass Spectroscopy
Volatile Organic Compounds (VOC)	Yes	Head Space, Gas Chromatography with Mass Spectroscopy
Trihalo-methanes	Yes	Gas Chromatography with Mass Spectroscopy
Radio-activity		
Gross Alpha and Beta	Optional	Proportional counting
Tritium	Optional	Distillation and scintillation counting

Annex 6. Water quality standards
Standards European and WHO drinking water quality

	WHO standards	EU standards
	1993	1998
Suspended solids	***	***
COD	***	***
BOD	***	***
Oxidisability		5.0 mg/l O2
Grease/oil	***	***
Turbidity	***	<5
pH	***	6.5 – 8.5
Conductivity	250 microS/cm	250 microS/cm
Color Pt-Co	***	15
Dissolved oxygen	***	>75% sat
Hardness CaCO3	***	150 – 500
TDS	***	***
cations		
(positive ions)		
Aluminium (Al)	0.2 mg/l	0.2 mg/l
Ammonia (NH4)	***	0.50 mg/l
Antimony (Sb)	0.005 mg/l	0.005 mg/l
Arsenic (As)	0.01 mg/l	0.01 mg/l
Barium (Ba)	0.3 mg/l	***
Berillium (Be)	***	***

	WHO standards	EU standards
Boron (B)	0.3 mg/l	1.00 mg/l
Bromate (Br)	***	0.01 mg/l
Cadmium (Cd)	0.003 mg/l	0.005 mg/l
Chromium (Cr)	0.05 mg/l	0.05 mg/l
Copper (Cu)	2 mg/l	2.0 mg/l
Iron (Fe)	No guideline(6)	0.2
Lead (Pb)	0.01 mg/l	0.01 mg/l
Manganese (Mn)	0.5 mg/l	0.05 mg/l
Mercury (Hg)	0.001 mg/l	0.001 mg/l
Molibdenum (Mo)	0.07 mg/l	***
Nickel (Ni)	0.02 mg/l	0.02 mg/l
Nitrogen (total N)	50 mg/l	***
Selenium (Se)	0.01 mg/l	0.01 mg/l
Silver (Ag)	No guideline	***
Sodium (Na)	200 mg/l	200 mg/l
Tin (Sn) inorganic	No guideline	***
Uranium (U)	1.4 mg/l	***
Zinc (Zn)	3 mg/l	***
anions		
(negative ions)		
Chloride (Cl)	250 mg/l	250 mg/l
Cyanide (CN)	0.07 mg/l	0.05 mg/l
Fluoride (F)	1.5 mg/l	1.5 mg/l

	WHO standards	EU standards
Sulfate (SO4)	500 mg/l	250 mg/l
Nitrate (NO3)	(See Nitrogen)	50 mg/l
Nitrite (NO2)	(See Nitrogen)	0.50 mg/l
microbiological		
parameters		
Escherichia coli	***	<1 in 250 ml
Enterococci	***	<1 in 250 ml
Pseudomonas aeruginosa	***	<1 in 250 ml
Clostridium perfringens	***	<1 in 100 ml
Coliform bacteria	***	<1 in 100 ml
Colony count 22oC	***	<100 in 1 ml
Colony count 37oC	***	<20 in 1ml
other parameters		
Acrylamide	***	0.0001 mg/l
Benzene (C6H6)	***	0.001 mg/l
Benzo(a)pyrene	***	0.00001 mg/l
Chlorine dioxide (ClO2)	0.4 mg/l	
1,2-dichloroethane	***	0.003 mg/l
Epichlorohydrin	***	0.0001 mg/l
Pesticides	***	0.0001 mg/l
Pesticides – Total	***	0.0005 mg/l
PAHs	***	0.0001 mg/l

	WHO standards	EU standards
Tetrachloroethene	***	0.01 mg/l
Trichloroethene	***	0.01 mg/l
Trihalomethanes	***	0.1 mg/l
Tritium (H3)	***	100 Bq/l
Vinyl chloride	***	0.0005 mg/l

Drinking water Standards

(1) Desirable: Less than 5 NTU
(2) Desirable: 6.5-8.5
(3) Desirable: 15 mg/l Pt-Co
(4) Desirable: less than 75 % of the saturation concentration
(5) Desirable: 150-500 mg/l
(6) Desirable: 0.3 mg/l
*** required but parameters have not been set