AFM®

Activated Filter Media

Instructions for Use

Main 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 water
- Tertiary treatment of waste water
- Cooling tower side-stream filtration

Activated Filter Media AFM®…

- … is a direct replacement for sand in any type of sand filter
- … more than doubles the performance of an existing facility without the need for any other investments
- … is not subject to biodynamic instability and will never allow untreated water to pass through to the product water
- … substantially lowers product water chlorine oxidation demand
- … lowers backwash water demand by an average of 50%
- … is expected to last for the life of the filtration system
- … provides quick return on investment

Content

1. Introduction

Research & Development

AFM® is the product of more than 30 years of research and development by Dr.Howard Dryden. The research was based on a PhD on aluminosiclicate zeolitic sand clinoptilolite for the selective ion exchange filtration of recycled water for intensive closed (RAS) aquaculture systems. Sand rapidly biofouls and coagulates, which results in bio-dynamic instability of the sand bed followed by transient channelling of un-filtered water passing into the product water. This happens in all sand filters, and in aquaculture it will lead to fish mortalities. In drinking water, it leads to disease. AFM® (an activated filter media) was developed as a means of resolving the deficiencies incumbent with all sand filters. The technology is perfectly adapted to any type of sand filter or application, ranging from; drinking water to industrial process water. AFM® will improve performance, reduce risk and stabilise the systems, by providing a predictable repeatable and sustainable performance.

Dryden Aqua guarantee statement

The performance of AFM® has been independently tested and verified. Test reports are available on our website. Dryden Aqua guarantee that after 10 years the performance of AFM® will be within 10% of the “as new performance” measured under ISO standard conditions. AFM® must be used in accordance to Dryden Aqua specifications.

There will be no reduction of performance or AFM® properties when the media is back-washed at a rate that fluidises the bed by a minimum of 20% for a period of 5 minutes or until the water runs clear. AFM® installed on systems 20 years ago is still performing to specification.

Key Points about AFM®

Technical key points

- AFM® can double the performance of a sand filter, up to 100 times better at removing sub-5 micron particles
- AFM® Grade 1 is verified to achieve log 3 reduction (1000 times) down to 4 microns with no coagulation or flocculation
- Stable and predictable performance, AFM® is not subject to biodynamic instability and will never allow untreated water to pass through to the product water
- No biofouling means greatly reduced Legionella risk from the filter
- Product water will have at least 50% lower chlorine oxidation demand than an equivalent sand filter, so lower concentration of disinfection by products including THMs
- AFM® is expected to last for the life of the filtration systems

Quality and certification

- AFM® is an engineered product manufactured to a precise specification under ISO9001-2008 conditions
- Certified under Reg31, NSF50 & NSF61, Environmental standards, HCAAP and others

dwi

Reg 31
UK drinking water
DRINKING WATER INSPECTORATE

ISO 9001:2008
REGISTERED FIRM

TESTED AND CERTIFIED
Water Quality
NSF 50 & 61
UNDER INDUSTRY STANDARDS

GreenLabel
SINGAPORE

Production facility and videos

Dryden Aqua has invested €8 million on a new AFM® production facility in 2014. View a video of our facility from our website at www.drydenaqua.com

2. What is AFM®

Description

AFM® is an amorphous alumino-silicate (glass) manufactured by up-cycling post-consumer green and amber glass bottles in a dedicated factory designed and operated specifically for the production of activated glass water filtration media.

The particle shape and size distribution are optimised for filtration. AFM® is not a passive filter media, the surface is activated by an IP protected, SolGel like process, where the surface structure of each grain of media is altered to control:

- surface area
- charge density
- catalytic properties
- molecular sieve properties

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 controlled to within very tight tolerances. We control the sphericity and uniformity coefficient of the grains to maximise particle filtration.

While a high sphericity is beneficial for sand this is not 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® product specifications

Specification	Grade 0	Grade 1	Grade 2	Grade 3
Particle size	0.25 to 0.5mm	0.4 to 1.0mm	1.0 to 2.0mm	2.0 to 4.0mm
Undersized	<5%	<5%	<10%	<10%
Oversized	<5%	<5%	<10%	<10%
Effective size (expressed as d10)	0.3 mm	0.45 mm	1.1 mm	2.1 mm
Hardness	>7 mohs	>7 mohs	>7 mohs	>7mohs
Sphericity (average range)		0.75 - 0.80		
Uniformity coefficient (d60/d10)	1.3 to 1.4	1.6 to 1.8	1.4 to 1.5	1.4 to 1.5
Aspect ratio	2 – 2.4	2 - 2.4	2 - 2.4	2 - 2.4
Organic contamination	<50g/tonne	<50g/tonne	<50g/tonne	<50g/tonne
Coloured glass (green/amber)	>98%	>98%	>98%	>98%
Specific gravity (grain)	2.4 kg/l	2.4 kg/l	2.4 kg/l	2.4 kg/l
Embodied energy	<72kw/tonne	<65kw/tonne	<50kw/tonne	<50kw/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)	<1%	<1%	<1%	<1%

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
Ferric	0.15	Manganese	0.1
Inorganic undefined	<0.0005	Organic undefined	<0.0005

There will be no metal ion leaching between pH4 and pH10. AFM® will adsorb some heavy metals and release on back-wash, AFM® provides drinking water and food security and is HACCP and NSF 61 certified.

Chemical tolerance

Oxidising agents

AFM® may be exposed to high concentration of oxidising agents:

Hypochlorous	10 g/l
Chlorine dioxide	10 g/l
Ozone	10mg/l
Hydrogen peroxide	10 g/l

Acids and alkali

AFM® is stable over a wide range of pH conditions, but strong acids and caustic conditions should be avoided:

pH range	pH4 to pH10

Salinity & TDS

Salinity and high TDS concentrations have no chemical effect on AFM®. AFM® is used for marine applications with up to 40g/l salinity and for many systems up to 100 g/l.

Salinity / TDS range	0 to 100 g/l

Temperature

AFM® is not affected by temperature, as long as the water is liquid then AFM® may be used.

Temperature range	0 to 100 deg C

Water quality

AFM® is chemically resistant to all solvents, oxidising agents and hydrocarbons.

3. Product packaging, delivery, storage and disposal

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

Packaging & Delivery

AFM® is supplied in bags of the following size:

a. 1000 kg (2.200 lbs) big bag with bottom discharge.
b. 25 kg (55 lbs) plastic bag/40 bags per pallet
c. 21 kg (46 lbs) plastic bags/40 or 45 bags per pallet
d. 11.4 kg (25lbs) plastic bags/80 bags per pallet

AFM® is delivered in multiples of 1 tonne pallets, normally in full truck loads of 24 tonnes or in container loads of 20 tonnes.

AFM® robotic bagging system

Bags & Labelling

Each bag is printed during packaging with the following information:

1. Lot batch number
2. Size Grade
3. Production Date
4. Uniformity coefficient
5. 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® 21 kg (46 lbs) bag	10030	10031	10032	10033
AFM® 25 kg (55 lbs) bag	10000	10001	10002	10003
AFM® 1 tonne (2,200 lbs) big bag	10010	10011	10012	10013

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

The largest swimming pool in Scandinavia, on full AFM® system

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 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. Sunlight will not affect AFM®, however the polythene bags may suffer UV damage and the plastic will degrade. Avoid storage out-side for long period of time unless protected from UV radiation.

Disposal of waste and spillage

AFM® normally lasts 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 recycled at a glass collection site or it may be sent to an approved solid waste disposal. AFM® is a circular economy product and should ideally not be sent to landfill.

4. Filter loading and commissioning

Disinfection of AFM®

During the manufacturing process, AFM® is exposed on two occasions to temperatures over 1000ºC. The product is cleaned and sterilised, and heavy metals and organics are reduced to less than 50ppb (50 grams/ton). All production takes place in a secure building and the product is always protected.

Dust

Silica sand contains free silica and a mineral called Tremolite, which is a form of Asbestos. The dust from silica sand can therefore be harmful to health and exposure to dust must be avoided, it is for this reason that silica sand is not permitted for use in sand blasting.

All dust is dangerous, but AFM® dust contains no "free silica" and it does not contain any toxic minerals. AFM® has a very low dust content, however when product is moved some dust may be generated. From a Health & Safety perspective, handling AFM® is much safer than sand. However, all the usually precautions should be taken when handling the material, especially in confined spaces. Appropriate breathing apparatus should be used.

Filter bed depth and type of filter

The depth of the filter bed is a function of the filter design. We recommend the use of filters that are in compliance with the German DIN standards but AFM® may be used in any type of sand filter.

Filter bed depth may range from 300mm to 3000mm, if the filter complies to German DIN, it will have a bed depth from 1200mm to 1400mm. AFM® may be used in any type of 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.

There will be a variation in quality and performance of different types and manufacturers of sand filters. It is always best to use filters from a reputable manufacturer. Regarding performance, vertical filters are better than horizontal filters, and filters with a nozzle distribution plate are preferred over laterals.

Transferring the AFM® to the filter

AFM® may be transferred manually to the filters by emptying the plastic bags, or 1 tonne big bags directly into the filter in accordance with the filter manufacturer's filling instructions or the procedure below.

AFM® may alternatively be transferred to filters from a bulk tanker using water. Do not use compressed air or transfer the AFM® in a dry condition. Under high air pressure and at high velocities, the AFM® would damage the transfer hose which would cause contamination of the product.

How to fill pressure filters

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. See Table 1 for layering details. 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 rarely required, but with a new installation there could 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 a drinking water network, it is good practice to conduct an analysis of the water in accordance with Annex .

Squares Pharmaceuticals in Dhaka Bangladesh. AFM® treats all the water prior to the RO membranes. AFM® replaces sand filters, carbon filters, 5 micron and 1 micron cartridge filters!

Anthracite and multi-layer beds

Anthracite or activated carbon may be used with AFM®, the choice of media depends upon the application of the AFM®. Table 1, provides details on the use of anthracite with AFM® Grade 0 and Grade 1.

AFM® Grade 0 provides an exceptional performance in mechanical filtration of water. Grade 0 can also be used to treat water with a heavy load of solids, or it can be combined with coagulation and flocculation. Under these conditions it is necessary to use a layer of anthracite on top of the AFM® Grade 0 bed to protect the media and to provide a longer run phase cycle between back-washes.

Activated carbon

AFM® is used with activated carbon in combination with chlorine or other oxidising agents. The filter bed will usually be Grade 1 AFM® with a 50mm to a maximum of 100mm layer of activated carbon. It is very important not to use any more than 100mm of activated carbon, to prevent the carbon from becoming a biofilter. A small amount of activated carbon works well as a catalyst, but any more than 100mm could start to cause issues resulting from biofouling of the carbon.

The following reactions will take place on the surface of the activated carbon. In the first stage, the hypochlorous will oxidise the surface of the carbon to form very active CO* sites. By this mechanism, activate carbon will remove some of the hypochlorous from the water.

Stage 1. $HOCl + C^* \rightarrow CO^* + H^+Cl^-$

The chlorine will also react with chemicals in the water such as ammonium to form inorganic chloramines such as mono-chloramine, and organic matter to form organic chloramines.

Mono-chloramine $HOCl + NH_3 \leftrightarrow NH_2Cl + H_2O$

In addition to mono-chloramine, other inorganic chloramines including:
- Di-chloramine and tri-chloramine, but this is a function of pH and water chemistry.
- Organic chloramines, formed by reaction with protein and amino acids.

The mechanism by which chloramines are catalytically oxidised by activated carbon in the presence of chlorine are as follows:

Stage 2a $NH_2Cl + H_2O + C^* \rightarrow NH_3 + CO^* + H^+ + Cl^-$
Stage 2b $2NH_2Cl + CO^* \rightarrow N_{2(g)} + C^* + H_2O + 2H^+ + 2Cl^-$

The end products will be nitrogen gas, hydrochloric acid and water as well as carbon dioxide with organic matter.

AFM® works very well as a support layer for activated carbon, and if any bacteria are released as floc, AFM® will capture and prevent their release into the product water. AFM® is used in combination with carbon for indoor swimming pool water treatment to reduce the combined chlorine concentration and as a mechanical support with BACs drinking water systems to reduce the risk to the distribution network.

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, AFM® grade 2 is used to fill the space and cover the laterals to a depth of at least 50mm. In filters larger than 1m diameter, 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 given in the Table 1.

Vertical Pressure Filter, media ratios

The make-up of pressure and RGF filter bed depends upon the size of the filter and configuration of the base.

Anthracite may be used on top of the AFM® to extend the run phase cycle and allow the AFM® to cope with high loadings of solids. Activated carbon may be used for de-chloramination, removal or other applications discussed in the next section.

Table 1. Vertical pressure filters

AFM® filter bed depths as a percentage for each grade for vertical pressure filters.
Bed depth may range from 600mm to 1400mm.

	Grade 3	Grade 2	Grade 1	Grade 0	Anthracite (particle size)	Backwash velocity
With or without flocculation						
Pressure filters, with laterals	15%	15%	70%	0%		>45m/hr
Pressure filters, with nozzle plate	0%	30%	70%	0%		>45m/hr
multi-layer with anthracite:						
Pressure filters, with nozzle plate	0%	20%	60%	0%	20% 1.18 - 2.5mm	>45m/hr
Without flocculation						
Pressure filters, with laterals	15%	15%	50%	20%		>45m/hr
Pressure filters, with nozzle plate	0%	30%	50%	20%		>45m/hr

Horizontal Pressure filter, media ratios

Horizontal pressure filters provide more filter bed surface area at a lower cost than vertical pressure filters. However, the bed depth is usually lower, and because the bed depth varies across the diameter of the filter, there is a variable water pressure gradient across the bed. The distance water travels through the filter bed from the outside is greater than the distance from the centre of the filter to the under drains. The greater the distance the water travels, the greater the pressure drop. This means the flow rate down through the centre of the filter bed will be faster when compared to the side of the filter bed.

The differential flow of water through a horizontal filter leads to rapid biofouling of sand down the sides of the filter. When the filter is placed in backwash the same situation happens in reverse, preferentially most of the water goes up through the centre of the filter bed. This in turns means that more organic matter and food for bacteria remain in the sand bed down the sides, which servers to accelerate the rate of biofouling and bed compaction.

Horizontal sand filters have the advantage that you get a lower cost filter for the surface area, but when used with sand, performance may be seriously sacrificed. When AFM® is used in horizontal pressure filters, the biofouling, bed compaction and channelling problems are solved, because AFM® resists biofouling and is much easier to backwash than sand.

Table 2. Horizontal pressure filters

AFM® filter bed depths as a percentage for each grade for horizontal filters.
Bed depth may range from 300mm to 1400mm

	Grade 3	Grade 2	Grade 1	Grade 0	Anthracite (particle size)	Backwash velocity
With or without flocculation						
Horizontal, lateral under-drain	20%	10%	70%	0%		>45m/hr
Horizontal, with nozzle plate	0%	10%	90%	0%		>45m/hr
multi-layer with anthracite:						
Horizontal, lateral under-drain	20%	10%	50%	0%	20% 1.18 - 2.5mm	>45m/hr
Horizontal, with nozzle plate	0%	10%	70%	0%	20% 1.18 to 2.5mm	>45m/hr
Without flocculation						
Horizontal, lateral under-drain	20%	10%	50%	20%		>45m/hr
Horizontal, with nozzle plate	0%	10%	70%	20%		>45m/hr

Rapid Gravity filter (RGF), media ratios

How to fill an RGF filter with AFM®

Prior to placement of the filter, tests for water retention must have been completed satisfactorily. Backwash pump functional tests should 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 cleaned 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, 15% less AFM ® Grade 1 (by weight) is required compared to sand due to the lower bulk density.

AFM ® Grade 1 (0.40 – 1.00mm) is used to replace 16/30 sand (US: #20 silica 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 3 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 should be marked in a waterproof medium to withstand submergence during the first backwashes.

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 during a back-wash 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 (only with 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 if 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 20% of the design depth to accommodate room for bed expansion during back-wash.

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 AFM® rapid gravity filters! Air will displace the support grades and will not be reclassified during a back-wash.

The first step, unless the material was placed into 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 sill.

Raise the backwash rate to the maximum design value over a period of 60 to 90 seconds, and continue until the water clears. Skim off any extraneous material. The wash can then be repeated with air scour as per the intended procedure.

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.

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.

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 must 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 annex 1.

Rapid gravity filter

Table 3. RGF Rapid Gravity Filters

AFM® filter bed depths as a percentage for each grade for RGF filters, bed depth may range from 600mm to 1400mm

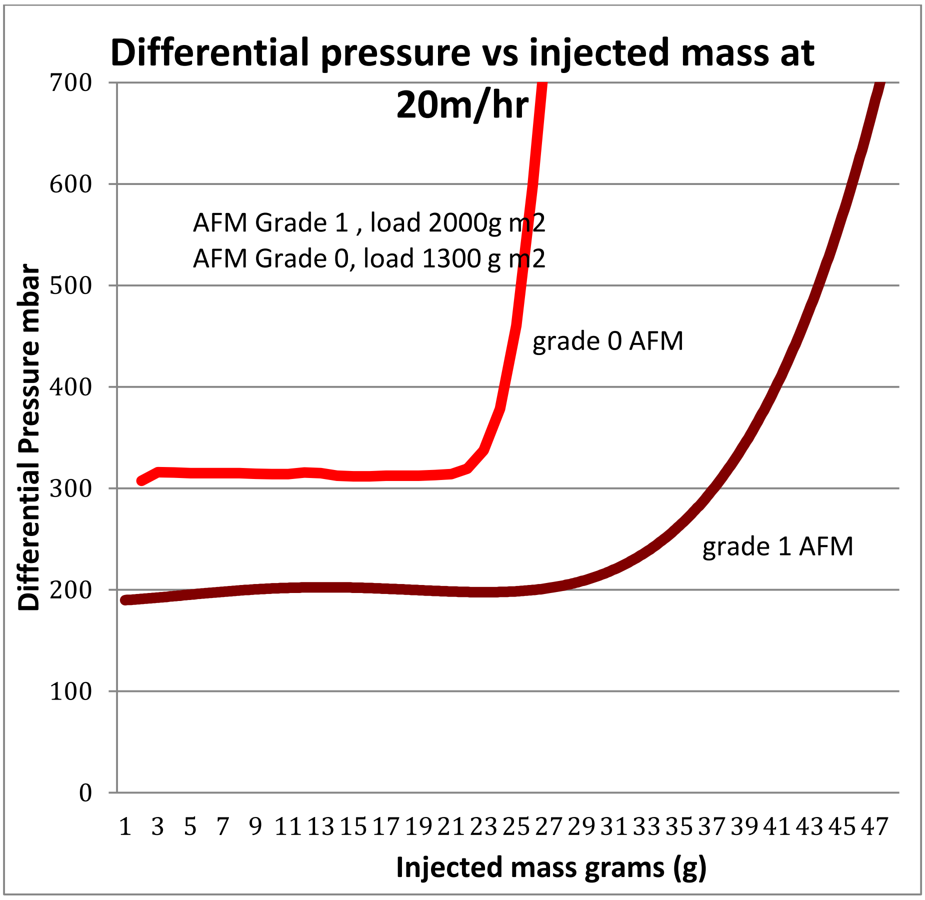
	Grade 3	Grade 2	Grade 1	Grade 0	Anthracite (particle size)	Back-wash velocity
With or without flocculation						
RGF filters, with laterals	10%	10%	80%	0%		>45m/hr
RGF filters, with nozzles or screened floor	0%	10%	90%	0%		>45m/hr
multi-layer with anthracite:						
RGF filters, with laterals	10%	10%	60%	0%	20% 1.18 - 2.5mm	>45m/hr
RGF filters, with nozzles or screened floor	0%	20%	60%	0%	20% 1.18 - 2.5mm	>45m/hr
Without flocculation						
RGF filters, with laterals	10%	10%	60%	20%		>45m/hr
RGF filters, with nozzles or screened floor	0%	20%	60%	20%		>45m/hr
Grade 0 optimised filters						
RGF, lateral under-drain filter	10%	10%	10%	70%		>20m/hr
RGF, nozzle plate filters	0%	10%	10%	80%		>20m/hr

Run phase differential pressure

AFM® is a mechanical filter with the primary function to remove solid particles from the water. AFM® gives exceptional performance and can remove 99.93% of all particles down to 3 microns using grade 0 AFM® at 2m/hr filtration velocity (IFTS verified). AFM® can be used to treat potable clean water as well as municipal waste water or industrial water.

If AFM® will be exposed to high concentrations of solids, the limitation is related to the rate of change of pressure and the back-wash frequency. Depending on the application, AFM® should be back-washed when the pressure differential reaches 0.5 bar, or after a period of 1 week.

The following graphs present the run phase delta P across the bed at 20m/hr, and the mass of solids removed by the AFM®. The loadings relate to engineered particles; in practical applications, the loading rate may be greater than 2 kg/m2 and 1.3kg/m2 for Grade 1 and Grade 0 respectively. The loading capacity will relate to the size of the particles and their mechanical properties



Differential pressure against water flow for a clean bed, 900mm bed depth

m/hr	AFM® Grade 1	AFM® Grade 0
	mbars	mbars
5	10	40
10	60	120
15	120	220
20	200	310
30	310	450

Suspended solids loading capacity

In practical terms, the shortest back-wash frequency for grossly polluted waste water, industrial water or for a river in spate conditions, is likely to be in the region of 4 hours. Taking 4 hours as the shortest back-wash frequency the maximum solids load capacity is given in the following table.

Maximum SS mg/l suspended solids concentration for AFM® filtration

Water flow velocity m/hr	Grade 1		Grade 0	
	AFM®	AFM® + 300mm anthracite	AFM®	AFM® + 300mm anthracite
	mg/l SS	mg/l SS	mg/l SS	mg/l SS
5	100	400	65	250
10	50	200	32	120
15	33	120	22	80
20	25	100	16	60
25	20	80	13	50
30	16	60	10	40

Anthracite depth filtration

Anthracite may be used on top of the filter bed to increase solids load or run phase duration. AFM® is a fine polishing filter media perfect for the removal of sub 20 micron particles. For heavy loads of solids above 20 microns, then a 100mm to 300mm layer of anthracite is a good solution.

Grade 1 AFM® + 1.18 to 2.5mm anthracite
Grade 0 AFM® + 0.6 to 1.18mm anthracite

Turning off and starting up a media bed filter

AFM® media bed filters should be operated continuously. They should not be stopped for longer time or allowed to go anaerobic. If the filters must be turned off for a protracted period, 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, as much water should be drained off from the filter 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.

5. Run phase filtering

The fine particle retention performance of any media bed is inversely proportional to the velocity of water passed through the filter. It is always best to operate the filter at the slowest possible flow rate to maximise performance. This is particularly important for drinking water, especially when 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 sand filters operate at 6m/hr and pressure filters at 12m/hr. RGF AFM® filters should be operated under the same conditions, however when possible, slow the flow rate down to the slowest practical rate.

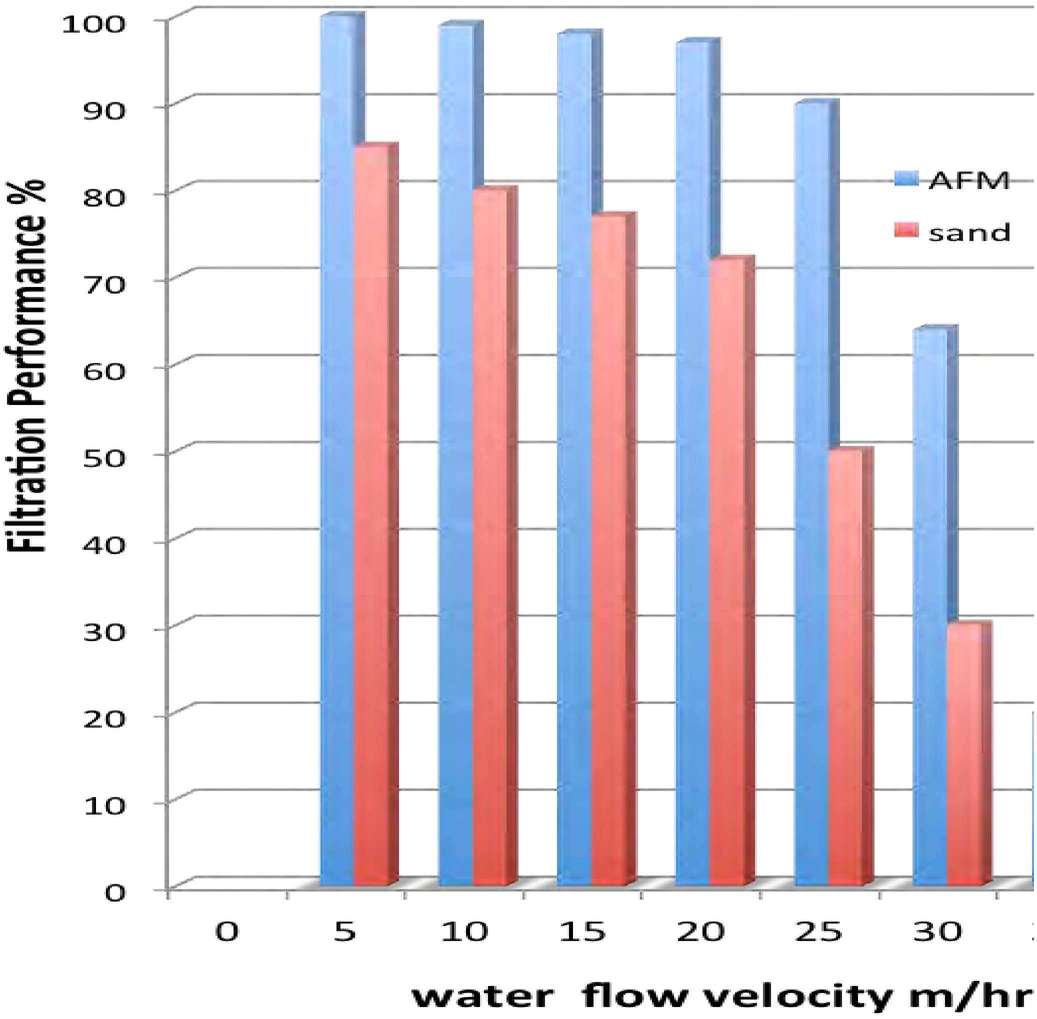
The flow rate for an AFM® filter depends upon the design of the filter and the application. For most RGF and pressure filters, the filtration velocity should be below 12m/hr. This equates to a water flow rate of 12m^3/hr of water for every 1m^2 of filter bed surface area. RGF filters will be operated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

AFM® an Activated Filter Media

The following graph demonstrates the relationship between 16 x 30 grade sand and AFM® Grade 1 at different flow velocities. By way of example, if we take a water flow velocity at 30m/hr, fresh sand will remove 30% of all particles down to 5 microns. The sand used was Leighton Buzzard sand from England, which is an exceptionally high quality sand. Other types of sand are likely to have an inferior performance.

If the flowrate is reduced from 30m/hr to 20m/hr, the 30% reduction in water flow results in more than 100% improvement in performance. It is therefore a false economy to operate filters at too high a water flow.

Filtration performance in removal of 5 micron particles at different filtration velocities



Recommended and maximum run phase water flow for different applications using AFM®

Table 3. 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	<30	<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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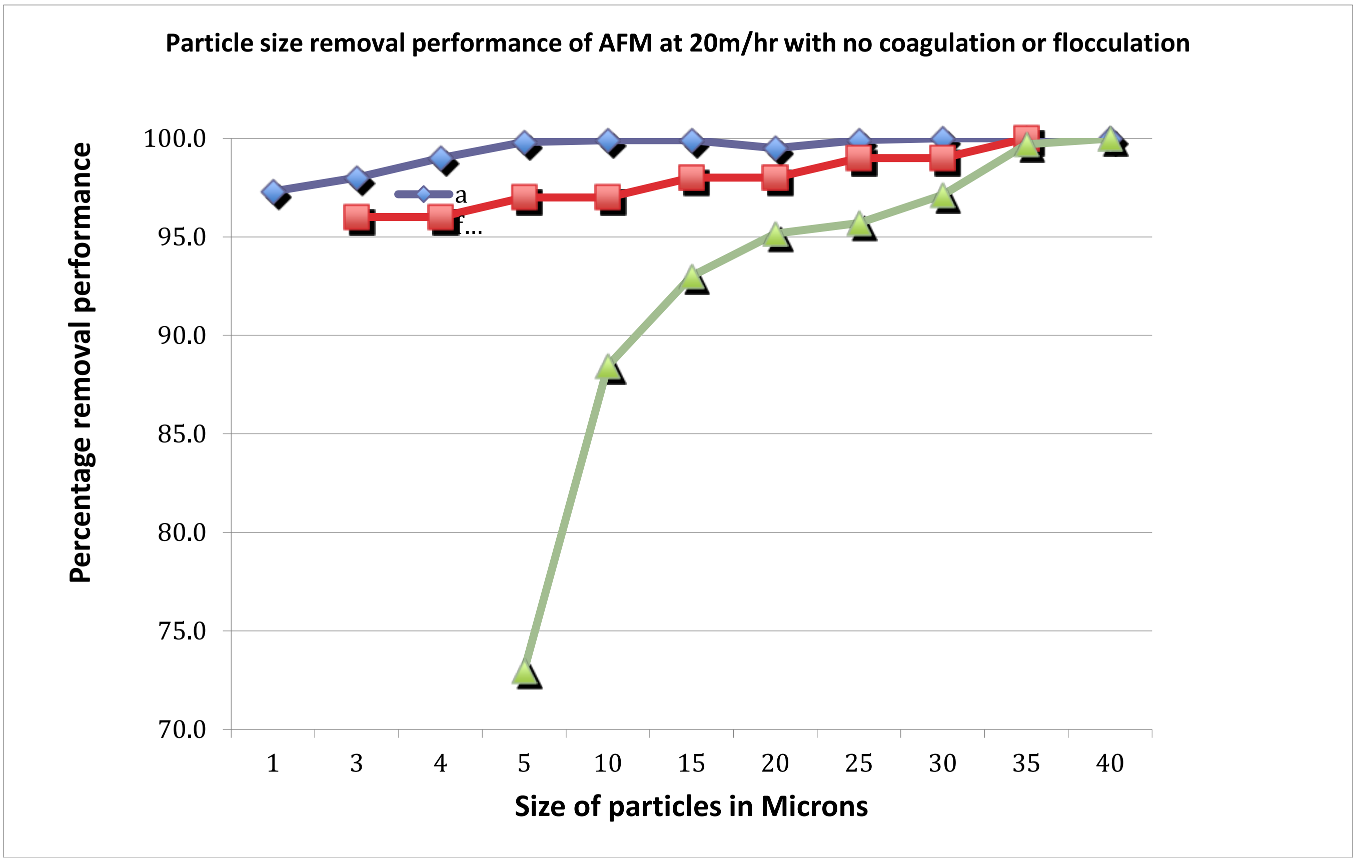
Filtration performance and grade of filter media

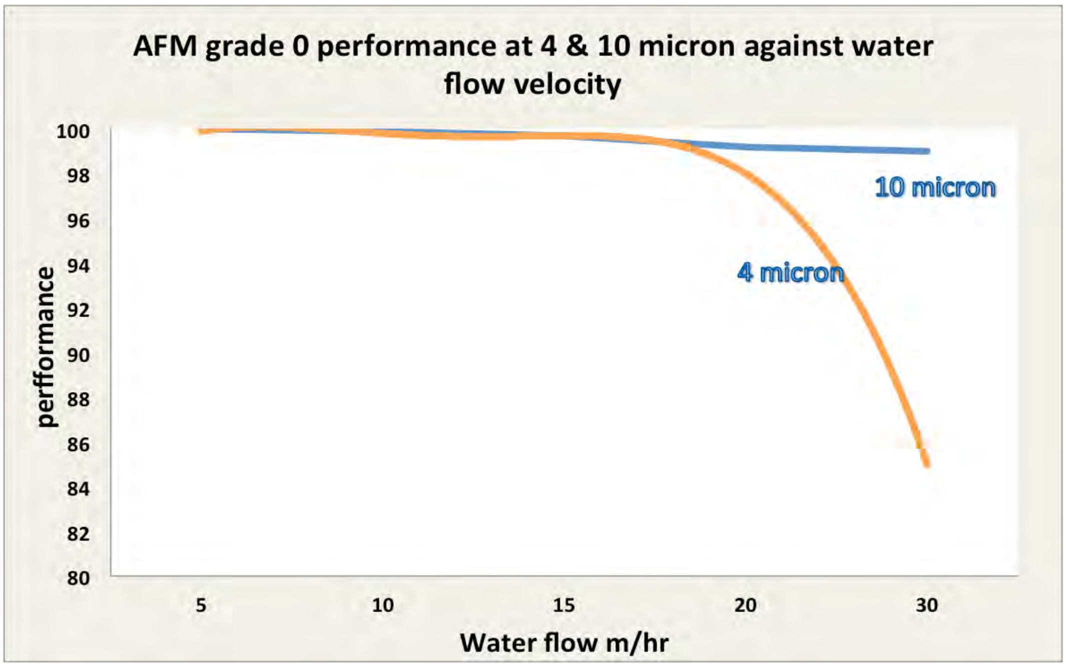
The standard grade of filter media used in most pressure and RGF filter is a sand of 16 x 30 mesh size, AFM® Grade 1 is equivalent to this grade of sand. However, because AFM® does not biofoul, this gives the opportunity to use a much finer grade of media, AFM® Grade 0, which has a particle size distribution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

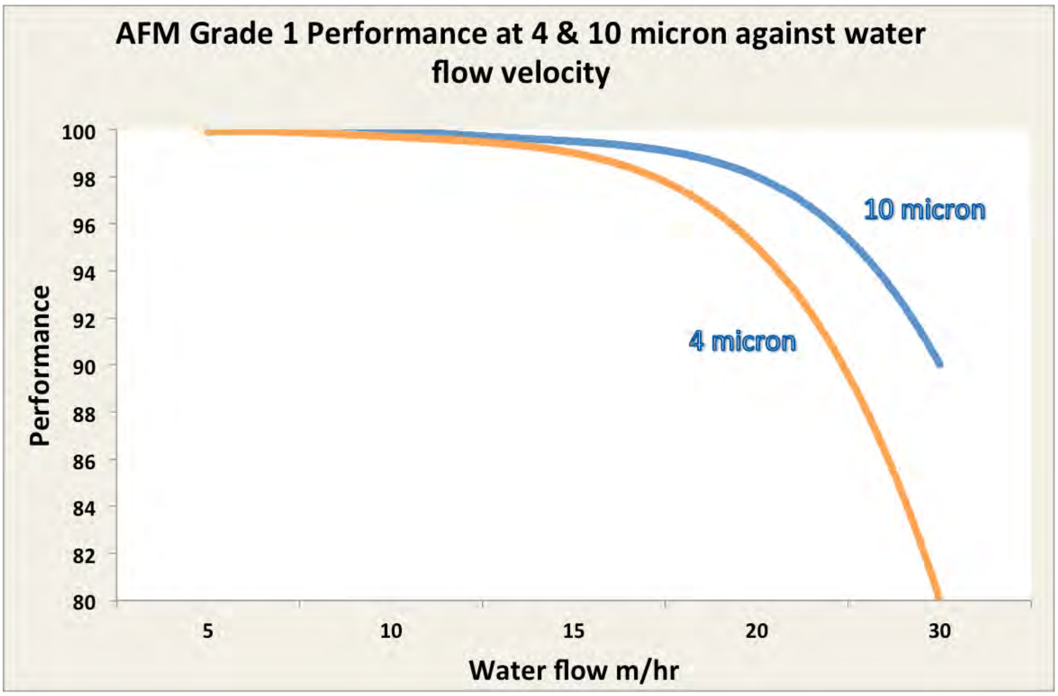
At a flow velocity of 20m/hr, sand removed 73% of all 5 micron particles. Grade 1 AFM® removed 97% and Grade 0 removed more than >99.9%.



AFM® Grade 0 and Grade 1 filtration performance at different water flow for 4 and 10 micron particles.

The following graphs show the performance of Grade 0 and Grade 1 AFM® and the influence of water flowrate on filtration performance over the range 5 to 30m/hr filtration velocity.





AFM® Grade 0 performance

All performance data for AFM® has been established without the application of coagulants or flocculants. It is important to note that AFM® Grade 0 can be used as an effective Cryptosporidium oocysts barrier at water flows of 2m/hr with a 900mm bed depth.

When AFM® is combined with coagulation and flocculation using PAC (polyaluminium chloride) or Polyamide cationic flocculants, the performance and ability to remove cryptosporidium oocysts at 5 microns and sub 1 micron is greatly enhanced. The performance data presented below is without the application of flocculants.

4 micron particle filtration performance

Filtration performance %	Water flow
99.96%	2m/hr
99.89%	5m/hr
99.85%	6m/hr
99.75%	7m/hr
99.54%	10 m/hr

3 micron particle filtration performance

Filtration performance %	Water flow
99.93%	2m/hr
99.80%	5m/hr
99.75%	6m/hr
99.61%	7m/hr
99.30%	10 m/hr

filtration performance at a water flow of 2m/hr

Filtration performance %	Micron rating
99.96%	4um
99.93%	3um
99.80%	2um
99.60%	1um

6. How to back-wash a filter

Back-washing an RGF (rapid gravity filter) or a pressure filter is a very simple procedure, however it must be conducted properly to ensure that the filter will have optimal performance during the run phase. This applies to all media bed filters, irrespective of the media contained within the filter vessel.
The process has 6 stages.

1. Air purge at 60m3/hr/m2 of air for a period of 5-10 minutes (air purge not required with AFM)
2. At the start of water back-wash, slowly wind-up water flow to 100%
3. Back-wash water flow to achieve 10% to 20% bed expansion for single bed and multi media beds
4. Back-wash duration to insure completion of the back-wash process
5. Rinse phase to prevent solids entering the product water
6. Run phase

Air purge

Air purging a filter bed will help to scrub and clean the filter media. This is particularly important for filter media that provide a good substrate for bacterial growth such as;

- Sand
- Most mineral based filter media
- Zeolites
- Activated carbon

Air purging was developed as a means or minimising the amount of back-wash water. For example, in the water industry a typical 16 x 30 grade Rapid Gravity sand filter, will normally be air purged at an air flow of approx. 60m^3/hr of air per 1 m^2 of filter bed surface area for a period of 5 to 10 minutes. The filter will then be back-washed at a flow velocity of 30m/hr (30m^3/hr per 1 m^2 of filter bed surface area) for up to 10 minutes.

A flow velocity of 30m/hr is insufficient to expand the bed, but it is sufficient to remove ***most*** of the solids that were trapped in the sand and lifted to the surface of the sand bed by the air purge. The operative word is “most”, but not all the solids will be removed from the sand bed, some will remain and act as a food source for bacteria. Also, if the filter bed has a graded size range of media, then the air purge will serve to mix the grades, and because the water flow does not expand the bed, the grades will not re-classify. The net results, is that all the grades get mixed together in a filter bed that is not back-washed properly. Performance of the filter will therefore be compromised.

It is our opinion that an air purge should only be applied when filter media can be backwashed at a water flow that can expand the bed by at least 15%, which is sufficient to re-classify the media. For sand this means a typical backwash velocity of 50-60 m/hr.

AFM® should only be air purged if the backwash velocity with water is at least 45 m/hr to allow reclassification of the filter bed.

Backwash wind-up

If 100% water flow is immediately applied to a filter, there may be a water-hammer which could damage the pipework or the filter internals. The fluid hydraulics are never perfect, especially with filters using laterals in the “spokes of wheel, radial” configuration, or with most horizontal filters.

Taking horizontal filters; at the start of a back-wash, water will rush into the filter towards the back-end and proportionally there will be a slightly greater flow velocity at the end of the filter and laterals. The water will therefore kick up the media at the end of the filter and at the edges. The pressure drop is reduced and more water will pass through the ends and sides of the filter vessel.

The filter now goes onto the run phase, and most of the water will initially go through the ends and sides of the filter, because it has been back-washed more effectively due to the high flow velocity. As the sides and ends block, the water flow moves towards the centre of the filter. Next time the filter is back-washed, slightly less water will go through the sides and ends, because there was more bio-coagulation due to earlier solids/organic penetration at the start of the run-phase. Gradually the flow pattern will shift towards the centre of the filter and the ends and edges will become compacted, coagulated and eventually blocked.

The above is a generalisation, the flow hydraulics, bio-coagulation and compaction will vary between different filter designs. However, for all filter designs and types of media, if the filter is not back-washed properly filter performance will always be compromised. It is important to use a high-quality filter media such as AFM®. It is equally important to use a properly designed filter vessel and to operate the equipment properly.

Type of filter	**Time in seconds to 100%, maximum back-wash water flow**
German DIN standard vertical filter with nozzle plate	30
Vertical filter with standard lateral arrangement	60
Horizontal filters with nozzle plates or laterals	90

Back-wash water flow to achieve 10% to 20% bed expansion

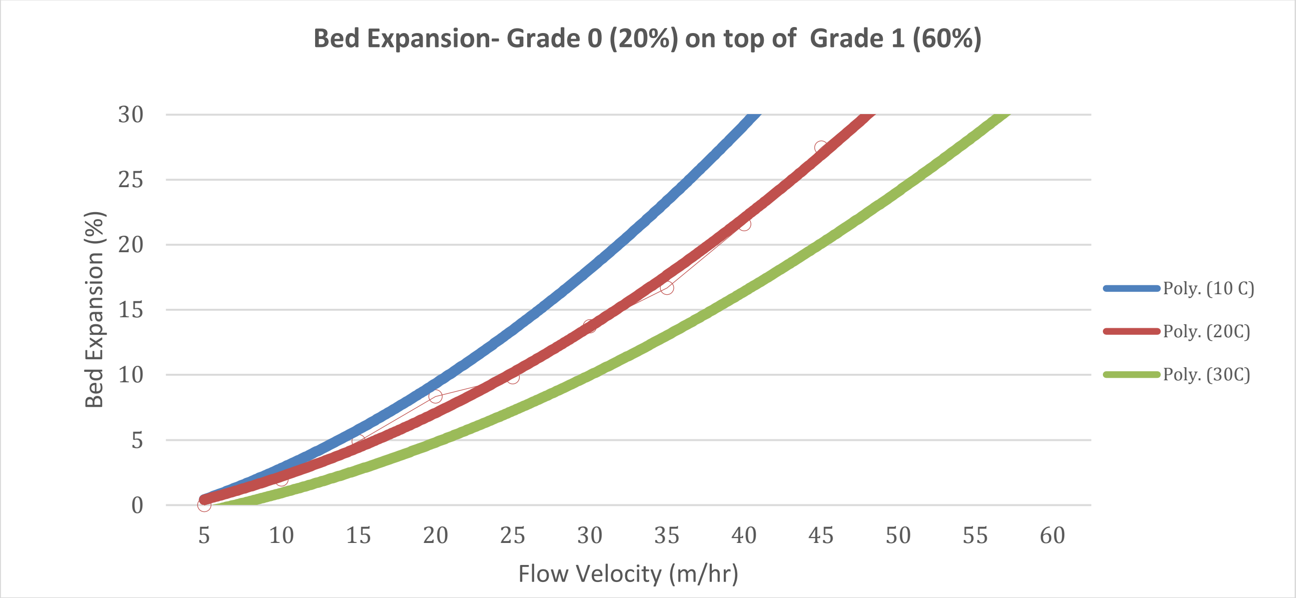
The minimum back-wash velocity should expand the bed by 10%, but 20% bed expansion is recommended, especially for multimedia beds. If activated carbon is used, because it has a lower density than sand, the 20% bed expansion may result in a lower flowrate than the figures given below which equate with 20% expansion for a single media.

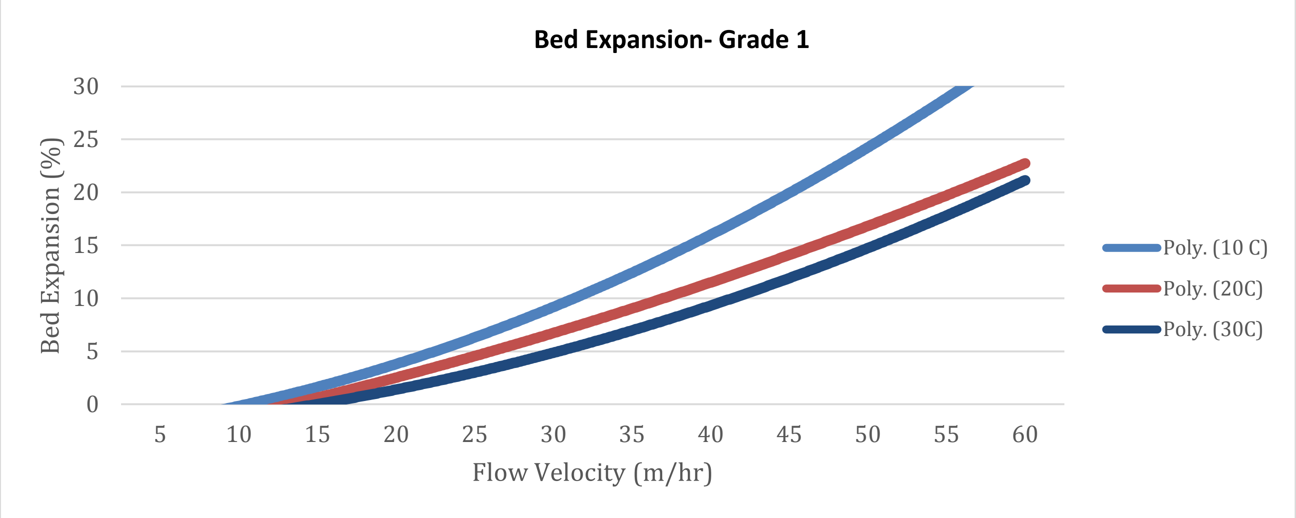
The back-wash velocity depends on several factors, including;

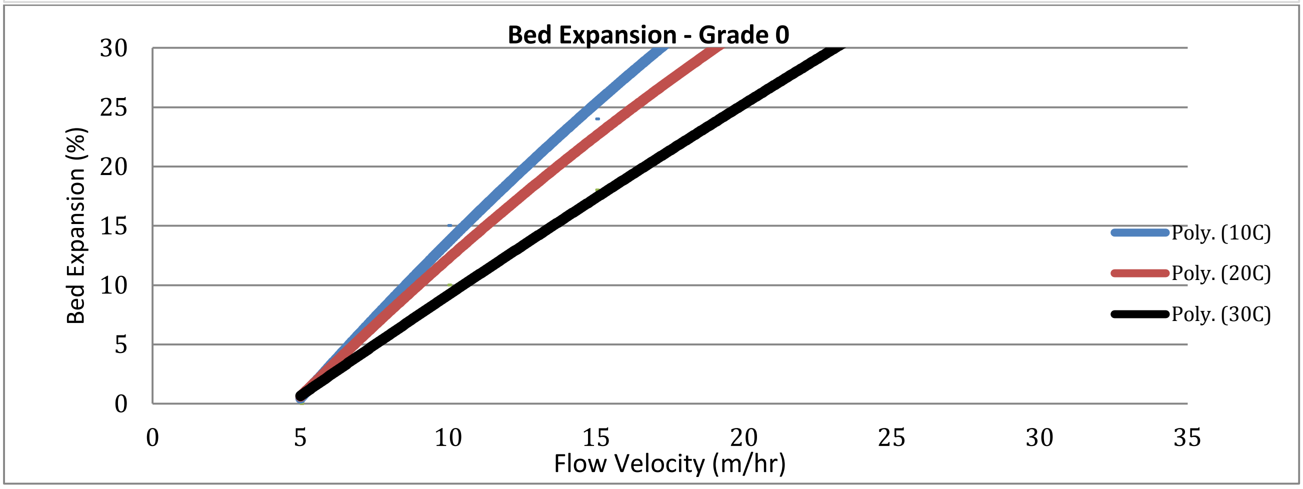
- Particle size distribution
- Uniformity coefficient
- Density of the media
- Water temperature
- TDS / salinity of the water

Filter media	**Water flow velocity m/hr for 10% and 20% bed expansion at different water temperature**					
	10 deg C		20 deg C		30 deg c	
	10%	20%	10%	20%	10%	20%
AFM® grade 0 (0.25 to 0.50mm)	8	12	9	14	10	16
AFM® grade 1 (0.4 to 1.0mm)	31	45	36	55	42	57
Silica Sand 16 x 30 grade	39	50	46	58	53	66

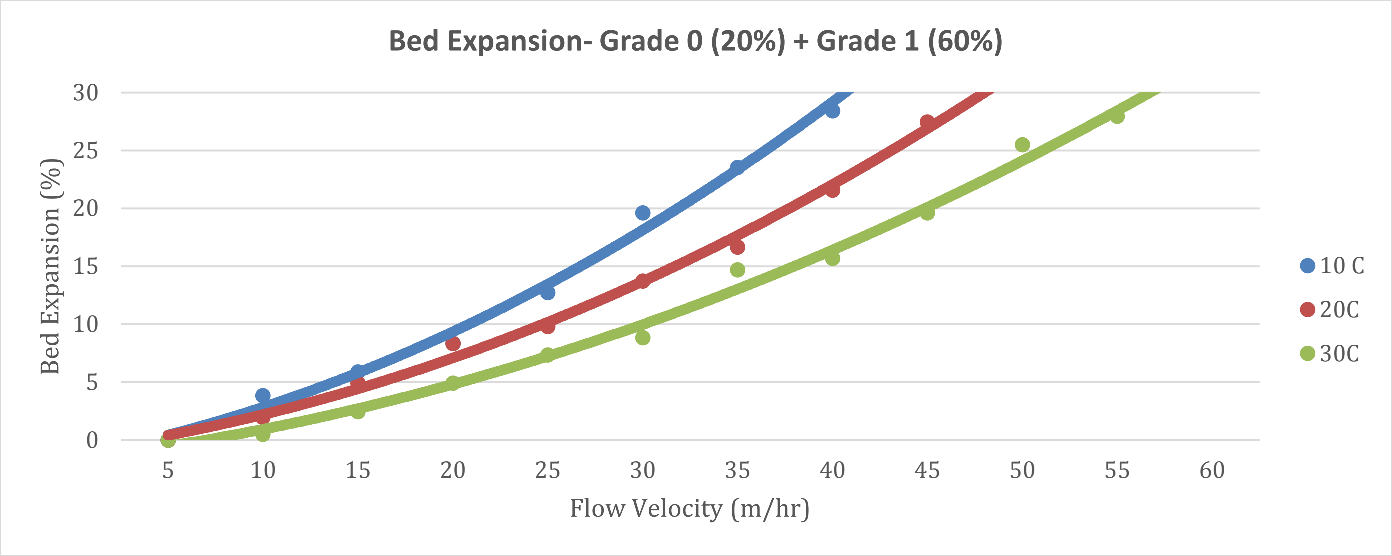
Bed Expansion freshwater

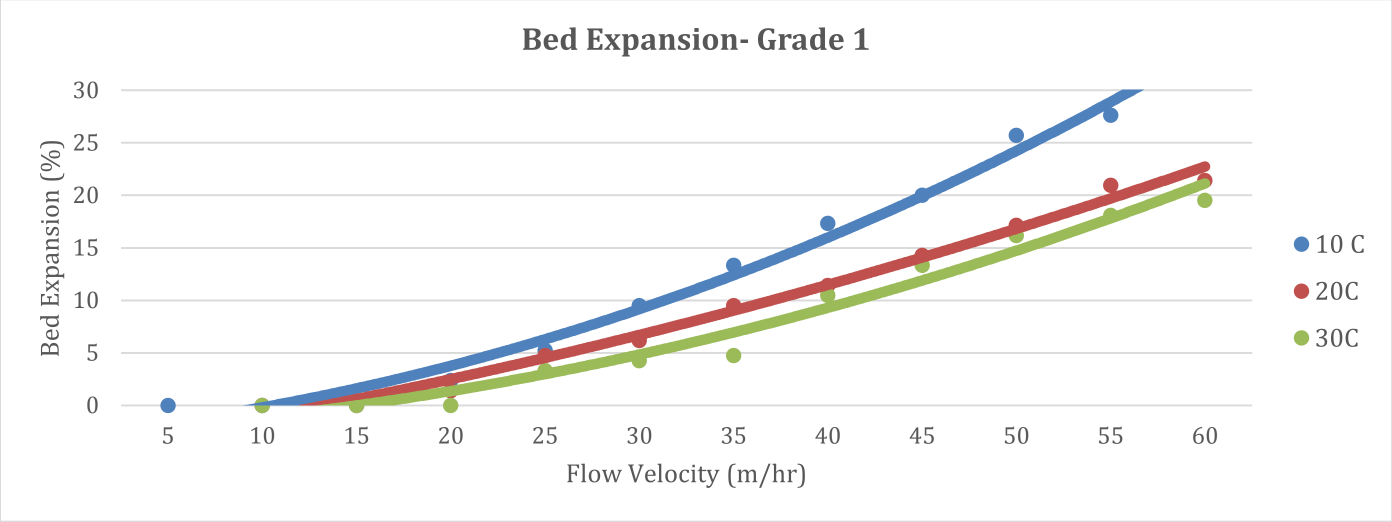


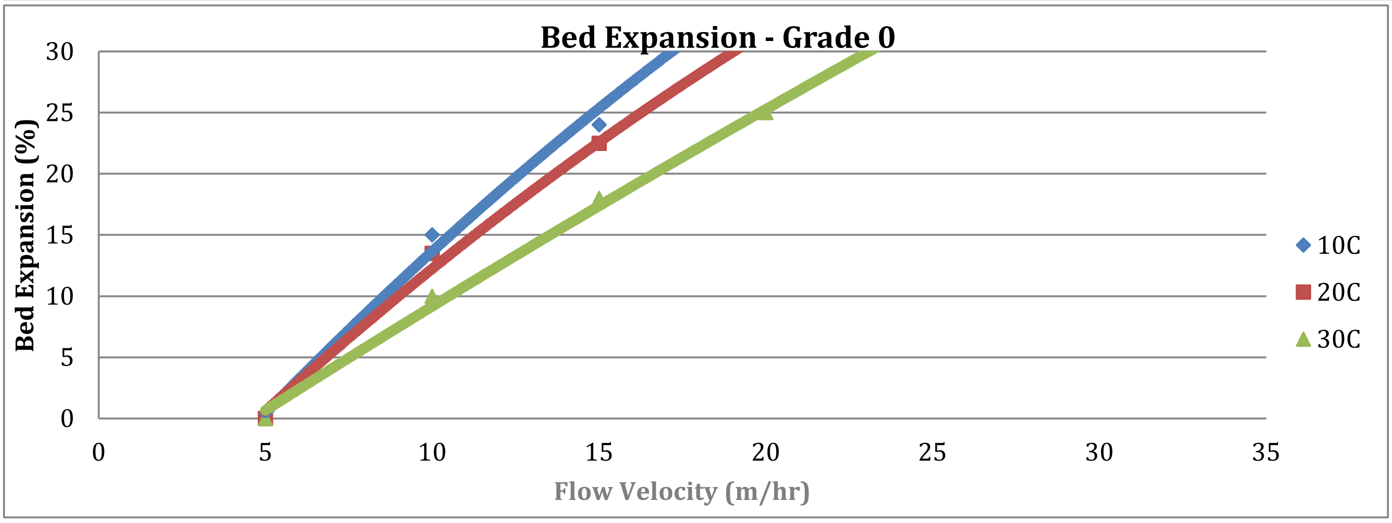




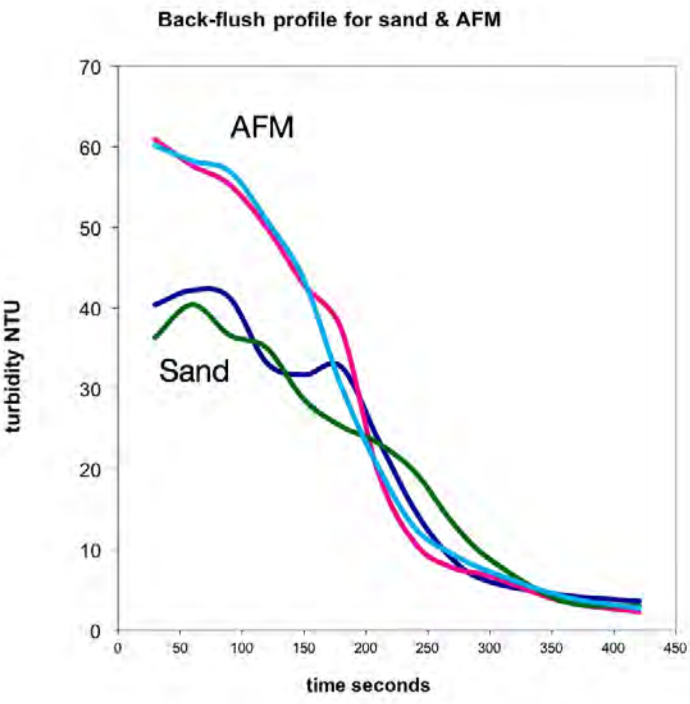
Bed Expansion Seawater at 35ppt







Back-wash duration

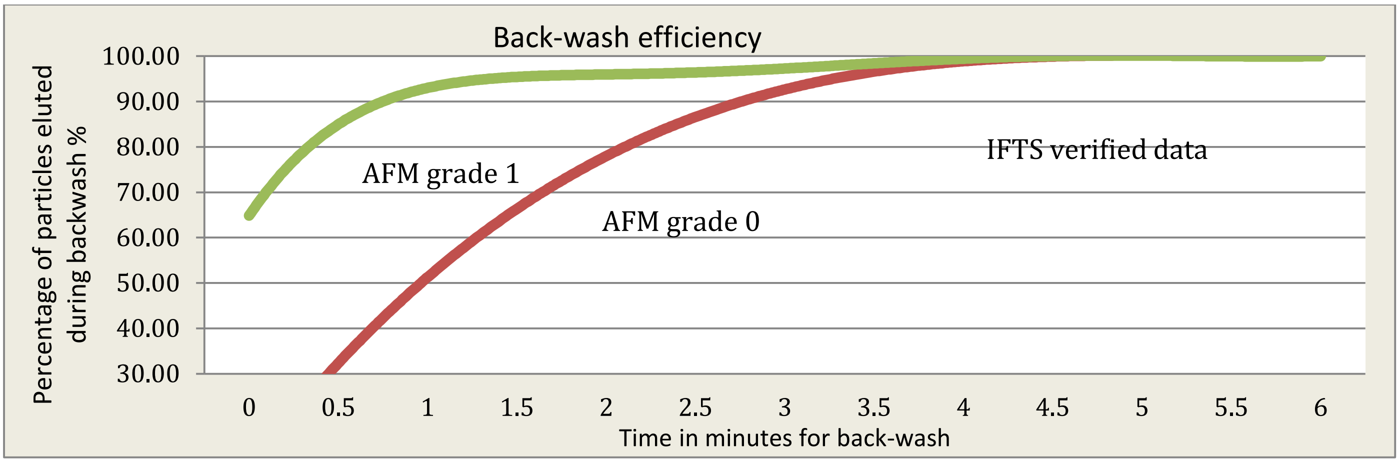


The back-wash must progress until the solids are removed from the filter bed, and evacuated from the water above the filter bed. To achieve this task, the bed must be expanded by at least 15% to release the solids, if this is not achieved, the filter bed will never be cleaned, irrespective of how long the bed is back-washed.

A useful technique to evaluate backwash performance is to measure the back-wash profile. This is achieved by taking a sample of water at the very start of a back-wash, and then every 15 seconds until completion of the back-wash.

If the filter media is stable and not subjected to compaction, or coagulation by bacteria or chemicals in the water, the back-wash profile will be a smooth curve. If the filter is not stable as in the sand backwash profile (see right), there will be an irregular back-wash profile that can be attributed to coagulated lumps of media breaking up during the back-wash process. The area under the curve can be measured and is proportional to the total mass of solids discharged in backwash for each media tested; the greater the area, the more solids are discharged. This means that more solids were removed by AFM® than by sand during the run phase in the above tests.

In most cases the back-wash will be complete within 300 seconds, however if the bed is not fluidised, the curve will be flat and very protracted. If there is deep solids penetration into the bed, or if there is a large head space above the media, then a longer back-wash will be required, not only to clean the media but also to evacuate all the water above the bed.



Rinse phase

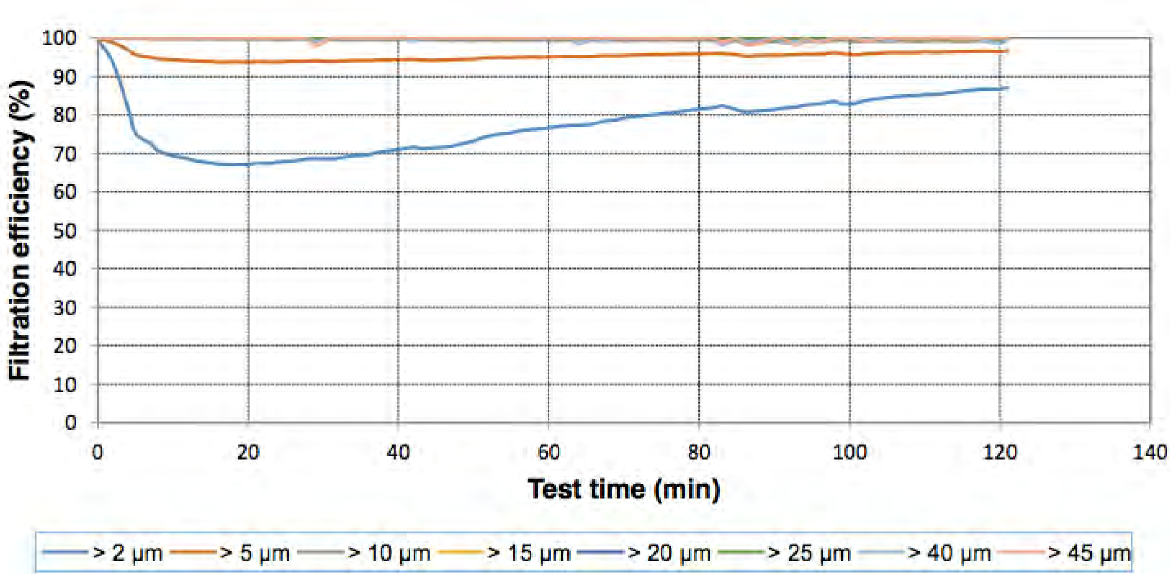
After the back-wash, the filter bed needs to settle and compact slightly. Any dislodged solids near the base of the filter bed also need to be discharged to waste. Normally the rinse phase lasts only a few minutes however for, drinking water treatment to reduce the risk of solids such as Cryptosporidium parasites passing into the product water, or for discharge of solids that might foul or block a membrane, the water from an unstable sand filter needs to be sent to waste for up to 30 minutes before the filter can be placed back online.

If the back-wash profile defines the bed as unstable, then the rinse phase will need up to 30 minutes in duration. The instantaneous filtration performance can also be measured. The following data from IFTS (Institute of Technical Separation in France), presents measurements for AFM® Grades running at 20m/hr and sand at 20m/hr.

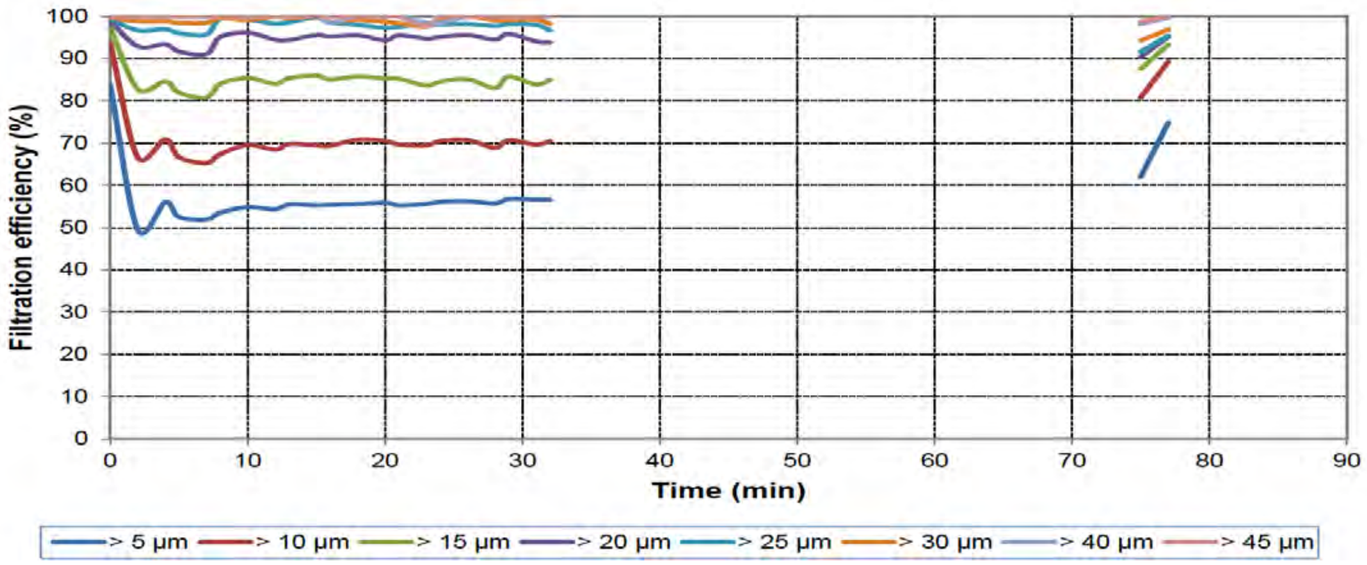
In the following two graphs, note the much higher performance of AFM® in terms of percentage removal of 5 micron particles. Also note that the smallest particles measured with AFM® was 2 microns compared to 5 microns with sand.

Instantaneous filtration performance after a back-wash

AFM® grade 1 Instantaneous filtration performance at a water flow at 20m/hr no floculation down to 2 microns



Sand instantaneous filtration performance at a water flow velocity of 20m/hr 16 x 30 grade (Leighton Buzzard deposit England) at 20m/hr, no flocculation, down to 5 microns



Taking 5 um particle size, there was a gradual decrease in performance of AFM® which stabilised at approx 92% removal efficiency. Sand experienced a rapid drop in performance to 50% efficiency then stablised at approx 55%. At 5 um and a water flow of 20m/hr, AFM® removed 6 times more effective than sand. In relation to a waer treatment risk analysis, the results confirm the greater securty afforded by AFM® over sand.

Run Phase

Once the rinse phase has completed, the filter may be placed back into service mode. The transition should be slow; a minimum time of 30 to 60 seconds should be taken to avoid any disturbance of the bed.

The water flow through media bed filters should never be turned off to avoid the development of anoxic conditions. By way of example, if a filter was removing arsenic from the water, the arsenic is in the form of As5+ which is insoluble. If the filter flow was stopped, organic matter and bacterium growing on the media and in the filter, would consume the oxygen, the redox potential would drop and the arsenic would be reduced to As3+ which is soluble. When the filter goes back-on-line, the arsenic would be released into the product water. The issues are not as serious for media that do not biofoul. However, it is good practice never to turn off the water flow.

If the filters are turned off for a long period, it is best to backwash before they are turned off and/or when they are turned back on again. Water flow through the filters should be smooth and constant, if a change of flow is required, then take at least 30 seconds to regulate the flow down or up.

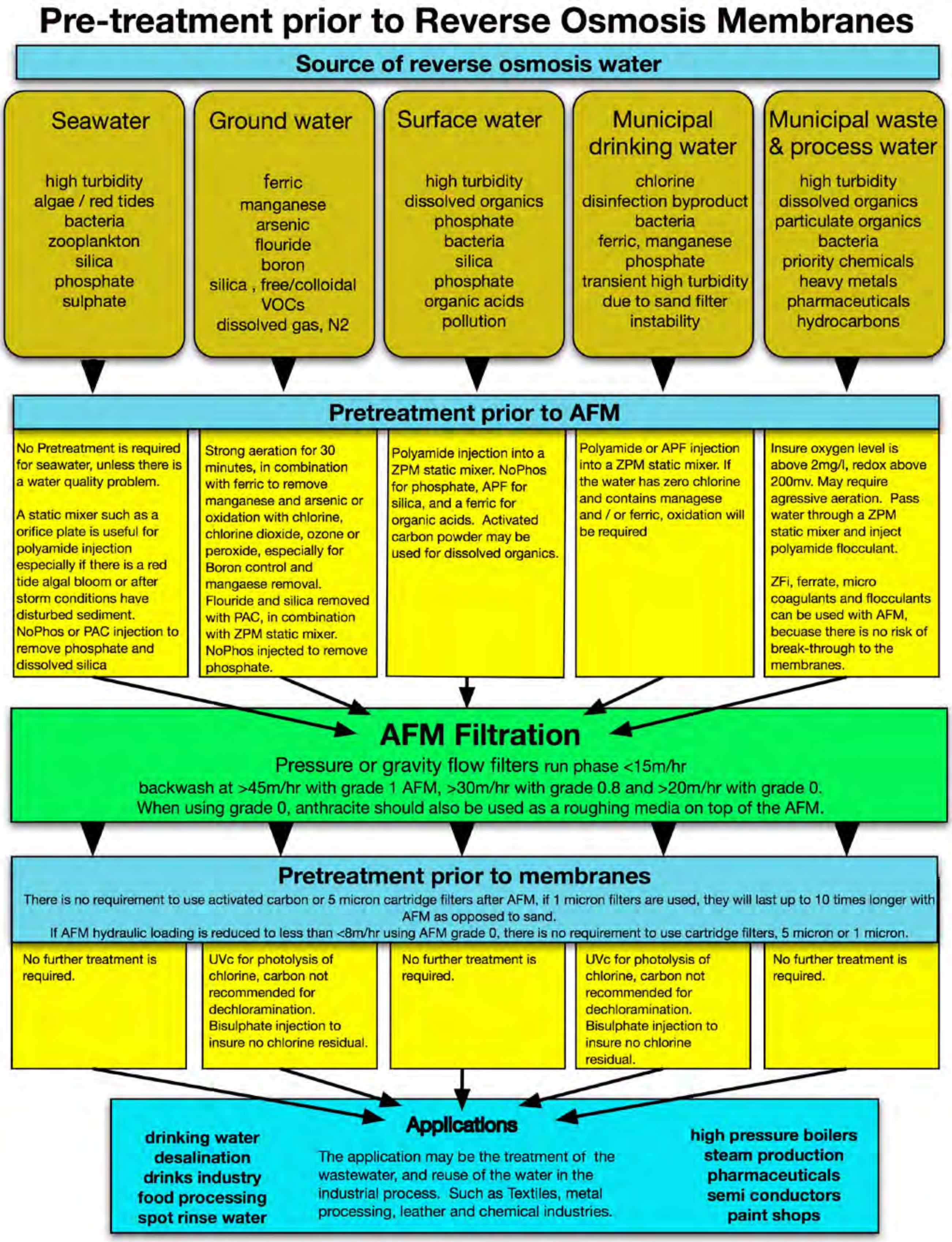
7. Annex Index

Annex 1: Applications overview for AFM®

Application Type	Associated Processes		PSF Typical flow m/hr		%age reduction
Drinking water			min	max	
Arsenic removal	Oxidation 30 mins by aeration	FeCl coagulation prior to AFM filtration	>5	<20	90% reduction
Iron removal	Oxidation 30 mins by aeration prior to AFM filtration		>10	<20	95% reduction
Manganese removal	Oxidation 500mV with H2O2 or NaHOCl + 30 mins aeration	FeCl coagulation prior to AFM filtration	>10	<20	98% reduction
Membrane pre-filtration	AFM filtration to 5µ (AFM Gd1) or 1µ (AFM Gd0)	1 micron cartridge filter	>10 >5	<15 <10	SDI <5
Municipal Wastewater	Phosphorous & Bacteria, BOD, COD & TOC				
Tertiary Treatment	Pre-filtration to <100 µ + FeCl coagulation then AFM	Oxidation 30mins with NaHOCl after AFM filters	>5	<15	-98% COD -95% COD
Industrial Process Water	Organic pollutants & oils, TSS, VSS & particles >1 micron				
Cooling tower sidestream filtration	Filtration 15 - 20m/hr with AFM		>10	<20	
Industrial Wastewater					
Low conc' mineral oil (<50mg/l) removal	Oxidation 30 mins by aeration	Coagulation & PAC flocculation prior to AFM			98% reduction
Medium conc' mineral oil (<500mg/l) removal	Oxidation 30 mins by aeration + Coagulation & PAC flocculation	Dissolved Air Flotation prior to AFM filtration at 5 - 15m/hr max.	>5	<15	98% reduction
Chromium or Copper removal	pH correction 7.0-7.5 by MgO_2 or 8.5 (caustic). Reduction by dosage of Calcium polysulphide via ZPM + injection of DA GF50 (sub 50 micron glass powder).	Sedimentation 30 mins prior to AFM filtration at 5 - 10m/hr max	>5	<10	95% reduction
Aquaculture / Aquaria					
Seawater Intake Filtration	Pre-screening of macro-algae by mesh or wedgewire screens	AFM filtration	>10	<20	
RAS Systems Hatchery & Ongrowing	Biological Filtration after AFM	Aeration	>20	<30	
Mechanical Filtration in Biological LSS	Biological Filtration Prior to AFM	Side Stream Protein Skimming	>20	<30	
Mechanical Filtration in Chlorinated LSS	Coagulation & Flocculation prior to AFM filtration	Chlorine + ACO in external facilities	>20	<30	

AFM can be substituted for sand in any pressure or rapid gravity sand filter. It is suitable for many applications beyond those identified above and can be substituted for e.g. membrane filtration in many applications. It will significantly outperform sand in terms of particle retention, stability, backwash water consumption and service life.
For further information on AFM applications see the Dryden Aqua IFU document on www.drydenaqua.com and Dryden Aqua Process Application sheets.

Annex 2: AFM® for pre-filtration to membranes



Pre-treatment prior to Reverse Osmosis Membranes

Source of reverse osmosis water

Seawater	Ground water	Surface water	Municipal drinking water	Municipal waste & process water
high turbidity algae / red tides bacteria zooplankton silica phosphate sulphate	ferric manganese arsenic flouride boron silica , free/colloidal VOCs dissolved gas, N2	high turbidity dissolved organics phosphate bacteria silica phosphate organic acids pollution	chlorine disinfection byproduct bacteria ferric, manganese phosphate transient high turbidity due to sand filter instability	high turbidity dissolved organics particulate organics bacteria priority chemicals heavy metals pharmaceuticals hydrocarbons

Pretreatment prior to AFM

No Pretreatment is required for seawater, unless there is a water quality problem. A static mixer such as a orifice plate is useful for polyamide injection especially if there is a red tide algal bloom or after storm conditions have disturbed sediment. NoPhos or PAC injection to remove phosphate and dissolved silica	Strong aeration for 30 minutes, in combination with ferric to remove manganese and arsenic or oxidation with chlorine, chlorine dioxide, ozone or peroxide, especially for Boron control and mangaese removal. Flouride and silica removed with PAC, in combination with ZPM static mixer. NoPhos injected to remove phosphate.	Polyamide injection into a ZPM static mixer. NoPhos for phosphate, APF for silica, and a ferric for organic acids. Activated carbon powder may be used for dissolved organics.	Polyamide or APF injection into a ZPM static mixer. If the water has zero chlorine and contains managese and / or ferric, oxidation will be required	Insure oxygen level is above 2mg/l, redox above 200mv. May require agressive aeration. Pass water through a ZPM static mixer and inject polyamide flocculant. ZFi, ferrate, micro coagulants and flocculants can be used with AFM, becuase there is no risk of break-through to the membranes.

AFM Filtration

Pressure or gravity flow filters run phase <15m/hr
backwash at >45m/hr with grade 1 AFM, >30m/hr with grade 0.8 and >20m/hr with grade 0.
When using grade 0, anthracite should also be used as a roughing media on top of the AFM.

Pretreatment prior to membranes

There is no requirement to use activated carbon or 5 micron cartridge filters after AFM, if 1 micron filters are used, they will last up to 10 times longer with AFM as opposed to sand.
If AFM hydraulic loading is reduced to less than <8m/hr using AFM grade 0, there is no requirement to use cartridge filters, 5 micron or 1 micron.

No further treatment is required.	UVc for photolysis of chlorine, carbon not recommended for dechloramination. Bisulphate injection to insure no chlorine residual.	No further treatment is required.	UVc for photolysis of chlorine, carbon not recommended for dechloramination. Bisulphate injection to insure no chlorine residual.	No further treatment is required.

Applications

drinking water
desalination
drinks industry
food processing
spot rinse water

The application may be the treatment of the wastewater, and reuse of the water in the industrial process. Such as Textiles, metal processing, leather and chemical industries.

high pressure boilers
steam production
pharmaceuticals
semi conductors
paint shops

Introduction

The pretreatment of water prior to membranes is a critical first stage that can make a significant difference to the economics, sustainability and ease of operation of an RO water treatment system. RO membranes for desalination or TDS reduction will always be subject to fouling from biological contamination, organic and inorganic chemical precipitation. Pretreatment usually involves sand filters or Ultra Filtration (UF), followed by 5-micron and 1-micron cartridge filters and activated carbon or UVc irradiation. There are operational costs associated with the pretreatment process and major implications with regards to the security and protection of the membranes. The membranes must be allowed to perform their proper function without excessive demand for maintenance and cleaning chemicals. AFM will reduce the risks, reduce the costs and simplify the process.

Disadvantages of current pretreatment technologies

UF ultra filtration down to 0.03um

UF has better mechanical filtration performance than sand / cartridge filter combination, but UF will not remove dissolved organics or chemicals from solution. UF is purely a mechanical filtration process, dissolved components, or particles smaller than 0.03 microns will pass through the membranes. The dissolved organics lead to biofouling of the membranes. The inorganic components such as free silica or phosphate will form a precipitate and scale up the membranes.

Sand filtration followed by cartridge filters

Sand is effective at removing particulates and dissolved biological nutrients, but the filter will generate bacterial cell biomass, which will foul the membranes. Sand filters also suffer from biodynamic instability leading to transient wormhole channeling and passage of unfiltered water which blocks the cartridge filters. This process takes about 6 months before it starts to impact on system performance. Coagulants and flocculants maybe used prior to sand filters to remove phosphate, but sand has free silica and this will cause a blockage of the membranes, especially if there is aluminum in the water or if aluminum is used as a flocculent.

AFM® filtration as pretreatment prior to RO

AFM is an activated mesoporous aluminosilcate with glass as a structural substrate and a direct replacement for sand with similar operational criteria. AFM has a surface area that is up to 300 times greater than sand. The very large surface area has a negative –ve charge for the adsorption of positive +ve particles that are too small to be mechanically removed from the water. When AFM is combined with pre-coagulation and flocculation, mechanical filtration performance is improved by up to 100 times to a nominal filtration down to 0.1 microns. In addition to removing solids, the coagulation reactions will remove dissolved organics such as proteins, lipids, amino acids and inorganic components including phosphate and free silica. AFM is also excellent at removing hydrocarbons. AFM performance has been independently verified by IFTS (Institute of Filtration and Technical Separation) in France in 2014. See details on pretreatment prior to AFM and pretreatment prior to RO in the chart to the right.

Pretreatment prior to AFM® filtration

Depending on the raw water source, a pretreatment prior to the AFM filtration is necessary. For example: seawater or high TDS water abstracted from the ground via a borehole (tube-well) water, often has the following conditions:

- no oxygen and low redox potential
- high zeta potential and colloidal suspension of silica
- elevated partial pressure of nitrogen gas
- dissolved sulphide, methane and VOC's (volatile organics carbon)
- iron, manganese & arsenic
- heavy metals such as chromium, lead, mercury
- phosphate
- colloidal silica
- Fluoride
- Ammonium, in combination with phosphate and magnesium if forms struvite

If the water has dissolved oxygen content below 5mg/l, or a redox potential under 200mv, the very first step should be aeration to gas strip the water and restore the chemical equilibrium.

Gas stripping will blow off volatile components and stabilize the alkalinity, this is essential for efficient filtration and to allow the zeta potential of the water to drop. The aeration phase should be from 10 to 30 minutes. During aeration, the oxidation potential will increase and most heavy metals will precipitate out of solution. With regards to iron, it will change from Fe2+ to Fe3+, arsenic changes from AS3+ to AS5+.

During the oxidation stage with Fe2+ to Fe3+, the small ferric particles will be suspended by the aeration will grow and react to co-precipitate other heavy metals from solution. The longer the aeration phases the larger the ferric particles making them easier to be remove by AFM. In some cases, we recommend the addition of ferric to the water in order to assist with co-precipitation reactions.

AFM® key performance benefits

- Particle removal of 97% down to 5 microns with Grade 1 and 99.7% down to 3 microns with Grade 0 independently verified
- When combined with coagulation and flocculation, nominal filtration performance is better than 0.1 microns
- AFM will deliver a 50% to 75% lower SDI than a sand filter
- Unlike sand there is no free silica in AFM, so less fouling of membranes
- Performance comparable to UF
- Does not biofoul or channel
- AFM directly adsorbs organics like activated carbon
- Chlorination is not required, so no TCA, THM or hydrobromous acid production
- Regenerated by back-washing with water
- Perfect for ground water filtration and removal of heavy metals

Annex 3: 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	0.5	Do not exceed 0.5 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

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

Municipal wastewater

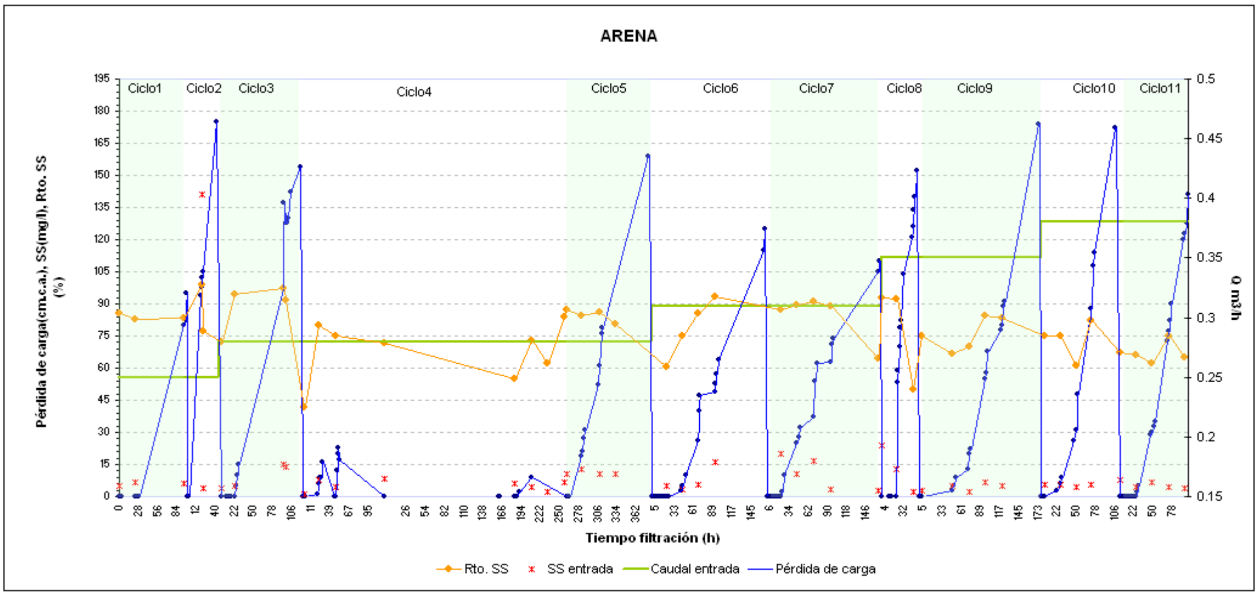
The following is published data by a Spanish Water Utility on the treatment of wastewater for second use. The data shows the backwash profile from the gravity flow sand filter and then the AFM® Grade 1 filter media. The data confirms the stability and high performance of AFM® in comparison to sand.

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

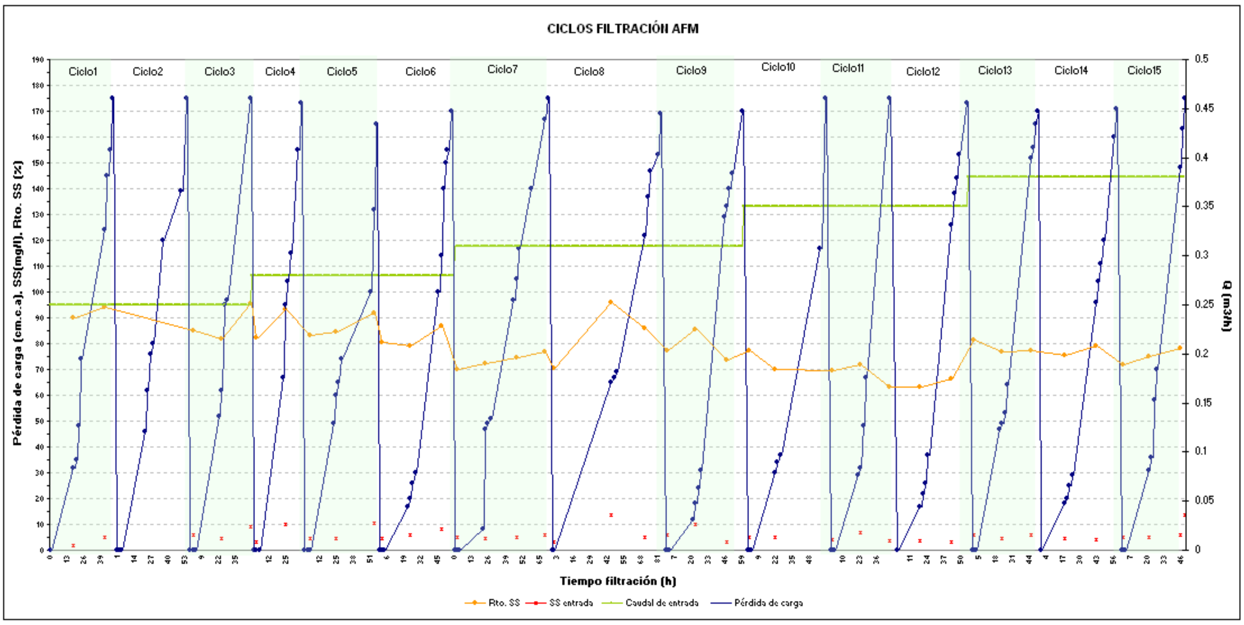
The AFM® filter was like clock-work, each run phase and every back-wash was the same. The data confirms the stability of AFM® and the high quality of product water that may be achieved.

Data published
Technologia del Agua, No 334 November 2011, I.S.S.N. 211/8173
Independent tests conducted by Spanish Water Company and reported in Technology del Agua, December 2009, page 47.

Sand filter tertiary treatment, using 16 x 30 sand



AFM® Grade 1 filter tertiary treatment



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

Water quality before and after AFM®, tertiary treatment of municipal waste water

Annex 4: AFM® for the removal of Arsenic, Ferric and Manganese

Chemical parameter	Soluble fraction	Insoluble	Drinking water standard	AFM® performance
Manganese	Mn^{2+}	Mn^{4+}	50 ug/l	>80%
Ferric	Fe^{2+}	Fe^{3+}	200 ug/l	>95%
Arsenic	As^{3+}	As^{5+}	10 ug/l	>95%

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
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.

Oxidation;

Manganese and Arsenic are removed by co-precipitation and catalytic oxidation by Ferric. For the process to work the ferric needs to be at least 5 times higher concentration than either the arsenic or the manganese. If the concentration of ferric is sufficient, then simple aeration of the water for a period of up to 30 minutes, with co-precipitate the arsenic and manganese and the AFM® will remove from solution.

The process is very simple and easy to reduce the arsenic concentration to less than 10ppb in a sustainable system. If the water is deficient in ferric, it may be compensated for by dosage of ferric chloride.

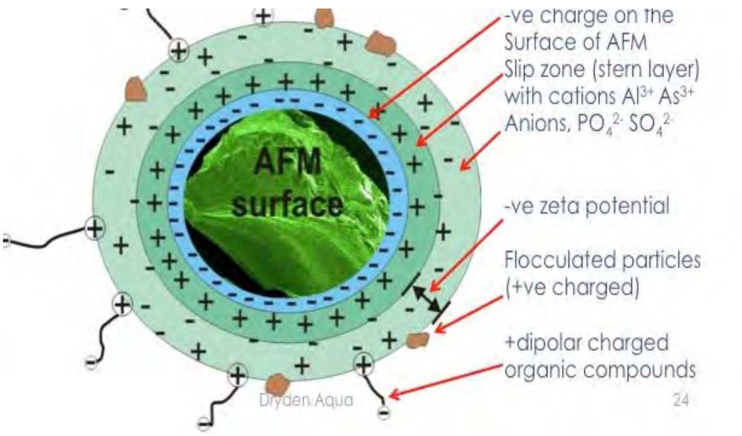
If ferric is not used for catalytic oxidation of Manganese or Arsenic, then an oxidising agent such as chlorine dioxide needs to be added to the water to raise the redox potential to 500mv.

Aeration

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.

	range		notes
Bed depth AFM®	900mm	1400mm	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)	0.1	0.5	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.

Annex 5: AFM® for the removal of phosphate from water



Total phosphate includes three forms of phosphate;

1. Organic phosphate is found in plankton, algae and bacterial cell biomass,
2. inorganic phosphate such as struvite, and soluble reactive phosphate is 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 rate 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 coagulation with ferric, lanthanum or magnesium.

Water & Wastewater treatment to remove phosphate

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 reduce organic phosphates 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 ensure efficient use of NoPhos and removal of ortho-phosphate.

The process is simple, reliable and sustainable when Lanthanum chloride (NoPhos) is used. 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 provide 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** **$Co_3(AsO_4)_2·8H_2O$** - **amblygonite** **$LiAlPO_4F$** - **lazulite** **$(Mg,Fe)Al_2(PO_4)_2(OH)_2$**	- wavellite $Al_3(PO_4)_2(OH)_3·5H_2O$ - turquoise $CuAl_6(PO_4)_4(OH)_8·5H_2O$ - autunite $Ca(UO_2)_2(PO_4)_2·10\text{-}12H_2O$ - carnotite $K_2(UO_2)_2(VO_4)_2·3H_2O$ - phosphophyllite $Zn_2(Fe,Mn)(PO_4)_2•4H_2O$ - struvite $(NH_4)MgPO_4·6H_2O$ - 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 ($Ca_2(Fe^{3+})_3[(O)_2\|(AsO_4)_3]·3H_2O$ -- $Ca_2(Fe^{3+})_3[(O)_2\|(PO_4)_3]·3H_2O$)[1] - Arseniosiderite-robertsite series ($Ca_2(Fe^{3+})_3[(O)_2\|(AsO_4)_3]·3H_2O$ -- $Ca_3(Mn^{3+})_4[(OH)_3\|(PO_4)_2]_2·3H_2O$)[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.

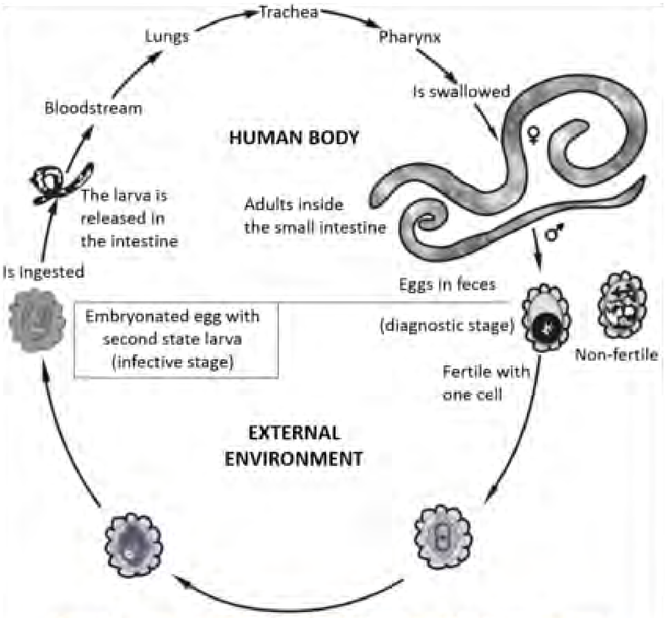
1. The precipitating salts must be added via an aggressive static mixer, ***after*** the pump but ***before*** the filter
2. Lanthanum addition is stoichiometric at a molar ration of 1:1
3. Ferric addition should be at a ratio of 2-4 to 1 molar Ferric to Phosphate. This will give a surplus of ferric 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. There 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 ensure 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.)*

Annex 6: AFM® for 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 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.



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

The parasite larvae infect your blood, internal organs and lungs, and then end up back in your intestine where they 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® provides a solution to these issues.

Annex 7: 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 (@20ºC)	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) @ 22ºC	Yes	Pour plate method
Total Viable Count (TVC) @ 37ºC	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 Organic compounds	Yes	Gas Chromatography with Mass Spectroscopy
Volatile Organic Compounds (VOC)	Yes	Head Space, Gas Chromatography with Mass Spectroscopy
Trihalomethane	Yes	Gas Chromatography with Mass Spectroscopy
Radio-activity		
Gross Alpha and Beta	Optional	Proportional counting
Tritium	Optional	Distillation and scintillation counting

Annex 8: 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)	***	***
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
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
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

Annex 9: Pressure filter system schematics

5 Valve – Single Filter layout and multi filter configuration