DRYDEN AQUA TECHNOLOGY

SUSTAINABLE WATER QUALITY

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®...

- **AFM® is a direct replacement for sand in any type of sand filter.**
- **AFM® can double the performance of a sand filtered system by way of a simple media change**.**
  - **AFM® Grade 0 : Verified to achieve 97% filtration down to 1µ with no coagulation or flocculation, 1000mm bed depth, 20m/hr velocity.**
  - **AFM®ng grade 1 : Verified to achieve 95% filtration down to 1µ 1 with no coagulation and flocculation at 20m/hr velocity.**
  - **AFM® grade 1: Verified to achieve 95% filtration down to 4µ, with no coagulation and flocculation at 20m/hr velocity.**

- **Standard AFM® has a high surface negative charge density, works in synergy with coagulants and flocculants to remove dissolved components.**
  - **When used with flocculants, AFM® grade 1 can achieve nominal filtration down to 0.1µ, 1000mm bed depth, 20m/hr velocity.**

- **AFM®ng has a neutrally charged hydrophobic surface, requiring less coagulants and flocculants to remove dissolved organic components, oils/fats, microplastics etc., and, is well adapted to difficult, soft water filtration applications.**

- **AFM® provides a mechanical filtration solution for effective removal of most protozoa, fungae and encysted oocysts such as Cryptosporidium and bacterial floc.**
  - **Product water will have a much lower oxidation demand than an equivalent sand filter.**
  - **SDI will be lower with AFM® in comparison to sand filtration.**

- **AFM® is bio-resistant, will not support bacterial growth.**
  - **no bacteria => no biofilm.**
  - **is resistant to channelling and passage of unfiltered water through the filter bed.**
  - **offers an average of 50% reduction in backwash water consumption.**

- **AFM® is an engineered product manufactured to a precise specification under ISO9001-2015 conditions.**
  - **offers stable and predictable performance in freshwater and marine systems.**
  - **delivers quantifiable risk reductions in a range of applications.**
  - **infinitely scalable for even the largest applications.**
  - **Certified under ISO 9001, 14001, 45001, BS EN12902, UK Reg31, NSF50 & NSF61, HACCP approval etc......**

- **AFM® performance is guaranteed for 10 years and lifespan has already been proven in many systems to exceed 15 years.**

* *AFM® 's performance advantage increases as particle size reduces.*

Performance may be similar to sand for very large particles but will be several fold greater than sand for removal of sub-20 µ particles.

Contents

1. Introduction

Research & Development

AFM® is the product of more than 30 years of research and development by Dr. Howard T Dryden. The research was based on a PhD on aluminosilicate 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 unfiltered 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 backwashed 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® standard can double the performance of a sand filter and, will be several fold better at removing sub-5µ particles.
- The use of AFM®ng Grade 1 or AFM® Grade 0 will give further performance advantages depending on application.
- Stable and predictable performance, AFM® is not subject to bio-dynamic instability and will resist channelling of untreated water through to the product water.
- No biofouling means greater bio-security and greatly reduced Legionella risk from the filter.
- Product water will have a much lower chlorine oxidation demand than an equivalent sand filter, so lower concentration of disinfection by-products including THMs.
- AFM® performance is guaranteed for 10 years.

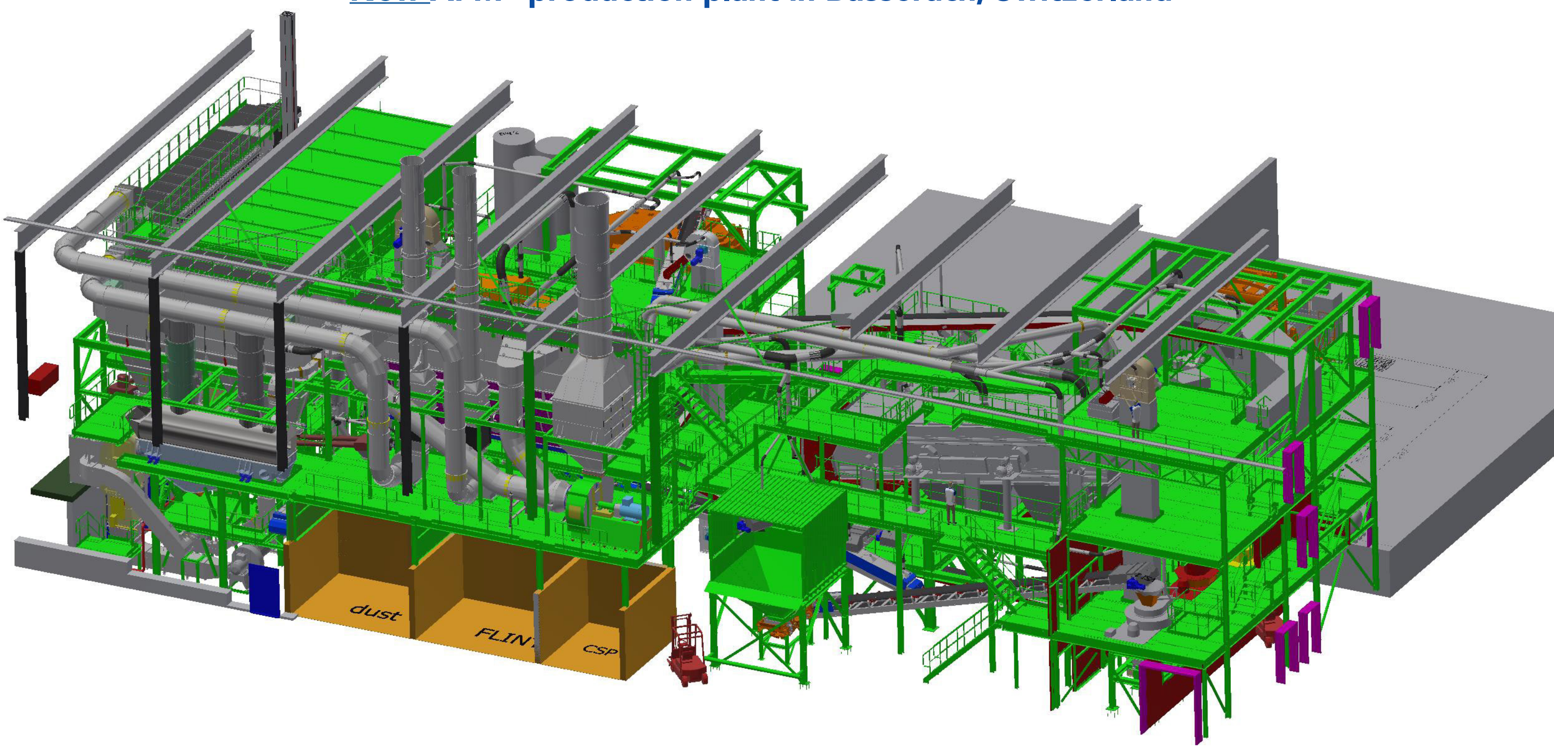
Quality and certification

- AFM® is an engineered product manufactured to a precise specification under ISO9001-2015 conditions.
- Certified under DWI Reg31, BS EN12902, NSF50 & NSF61, ISO 14001, 45001, HACCP and others

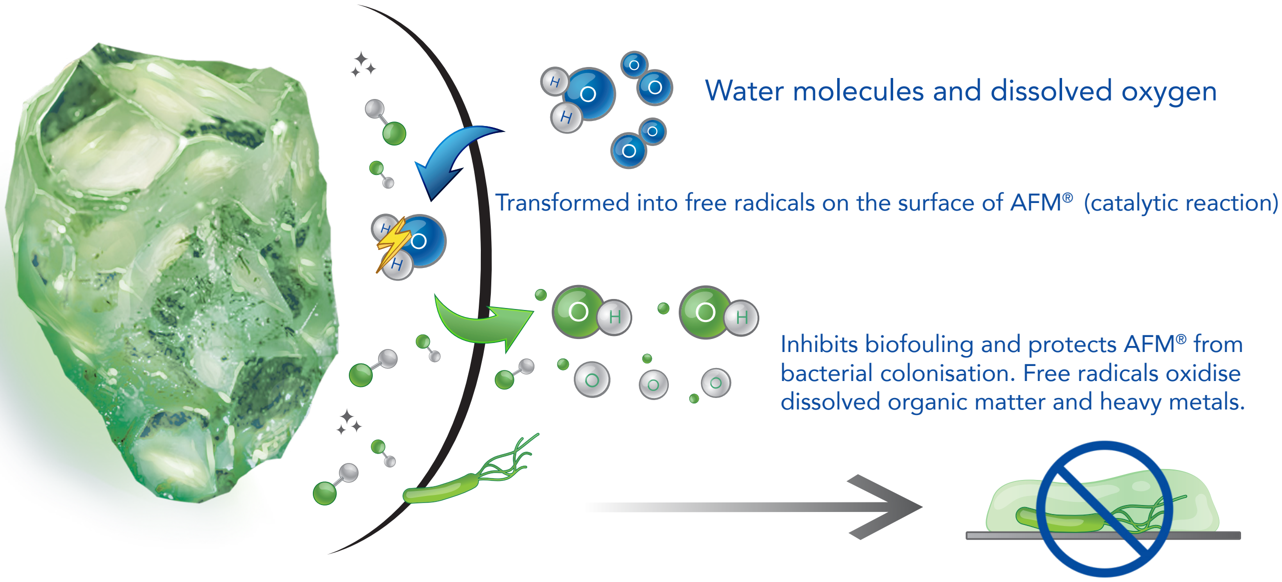
Production facility and videos

Dryden Aqua owns and operates the 2 most sophisticated glass reprocessing facilities in the world in Scotland and Switzerland. View a video of our production facilities via our website at www.drydenaqua.com

New AFM® production plant in Busserach, Switzerland



2. What is AFM®

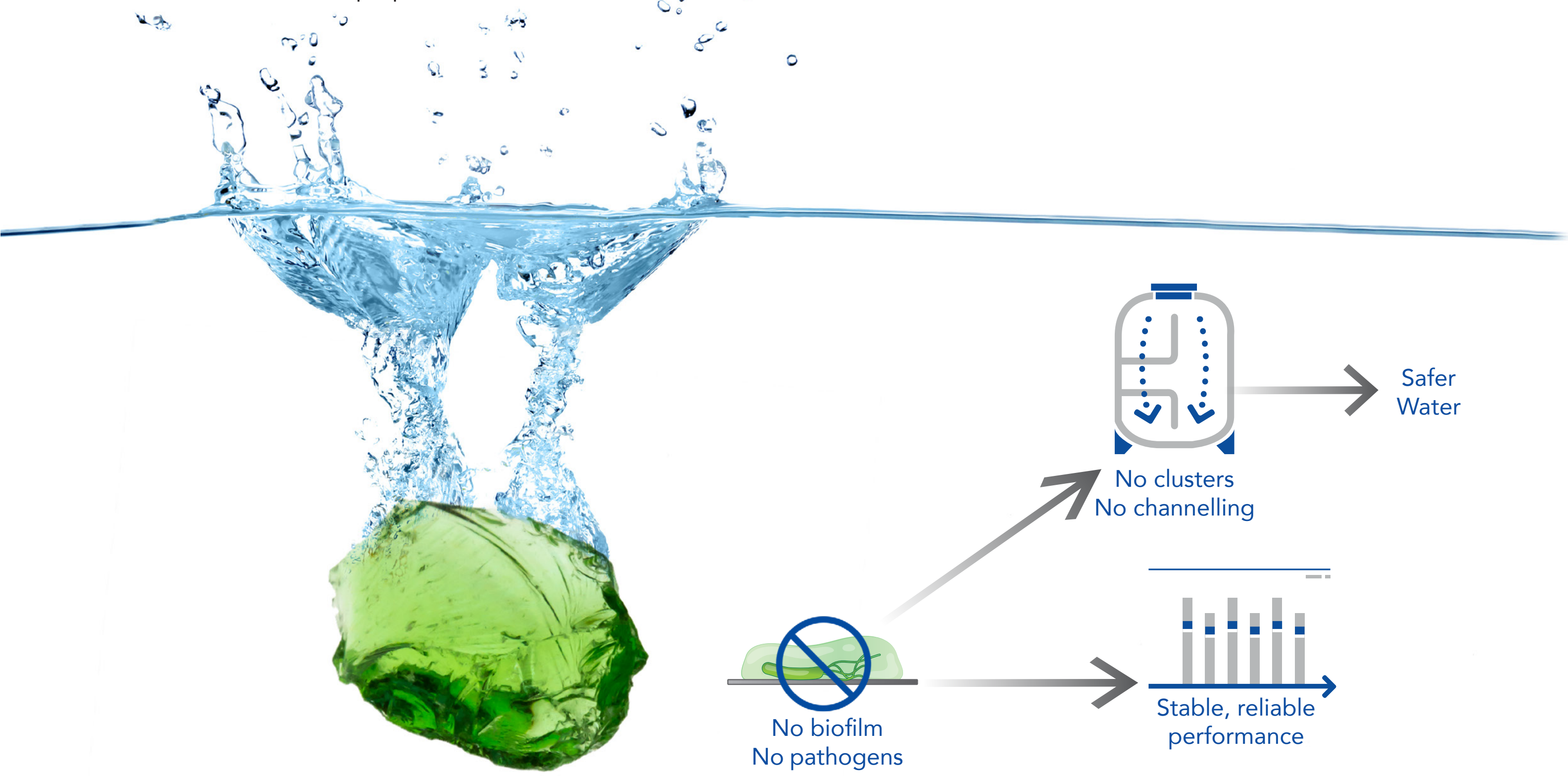


Description

AFM® is an amorphous aluminosilicate (glass) manufactured by up-cycling post-consumer green and amber glass bottles in a dedicated, state of the art 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:

- character of charge, currently negative or neutral (hydrophobic)
- surface area
- charge density
- catalytic properties
- bio-resistance
- 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. AFM® can now be produced with a negative or neutral surface charge

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 - 0.5 mm	0.4 - 0.8 mm	0.7 - 2.0 mm	2.0 - 4.0 mm
Undersized	< 5 %	< 5 %	< 10 %	< 10 %
Oversized	< 5 %	< 5 %	< 10 %	< 10 %
Effective size (expressed as d10)	0.27 mm	0.44 mm	0.82 mm	2.3 mm
Hardness	> 7 mohs	> 7 mohs	> 7 mohs	> 7 mohs
Sphericity (average range)	0,77	0.78	0.81	0.82
Uniformity coefficient (d60/d10)	<1.5	<1,5	<1,5	<1,5
Aspect ratio	2 : 2.4	2 : 2.4	2 : 2.4	2 : 2.4
Organic contamination	< 50 g/tonne	< 50 g/tonne	< 50 g/tonne	< 50 g/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	< 72 kW/tonne	< 65 kW /tonne	< 50 kW/tonne	< 50 kW/tonne
Porosity (%) (calculated, uncompacted)	50	44	42	40
Porosity (%) (calculated, compacted)	40	38	37	37
Bulk bed density	1.28 kg/l	1.26 kg/l	1.23 kg/l	1.22 kg/l
Attrition, (50 % bed expansion, 100 hour's 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

Chemical tolerance

Oxidising agents

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

Hypochlorous	10 g/l
Chlorine dioxide	10 g/l
Ozone	10 mg/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°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

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. Type of AFM®
3. Size Grade
4. Production Date
5. Uniformity coefficient
6. Effective particle size

Product codes

	Product order codes			
	Grade 0 0.25 to 0.50mm	Grade 1 0.40 to 0.8mm	Grade 2 0.7 to 2.0mm	Grade 3 2.0 to 4.0mm
AFM® 21 kg (46 lbs) bag	10030	10031	10032	10033
AFM®ng 21 kg (46 lbs) bag	n/a	10021	n/a	n/a
AFM® 25 kg (55 lbs) bag	10000	10001	10002	10003
AFM®ng 25 kg (55 lbs) bag	n/a	n/a	n/a	n/a
AFM® 1 tonne (2,200 lbs) big bag	10010	10011	10012	10013
AFM®ng 1 tonne (2,200 lbs) big bag	n/a		n/a	n/a

When supplied in 1 tonne 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 outside for long periods of time unless protected from UV radiation.

Disposal of waste and spillage

AFM® normally lasts for the life of the filtration system and has a guaranteed minimum 10 year lifespan. 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 returned to Dryden Aqua or, 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 500°C. The product is cleaned and sterilised, and heavy metals and organics are reduced to less than 50ppm (50 grammes/tonne). 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 from reputable manufacturers 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 always better than horizontal filters, and filters with a nozzle distribution plate are preferred over laterals for any filter media.

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 and, do not transfer the AFM® in a dry condition. Under high air pressure and at high velocities, the AFM® would damage the transfer hose and filter lining which will also 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 - 3 for layering details. For all filters with laterals, 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 Tables 1 - 3.

If AFM®ng is specified the filter should be filled and allowed to soak overnight prior to commissioning and first backwash.

After the backwash, 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 backwash, 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 9.

Squares Pharmaceuticals in Dhaka, Bangladesh.
AFM® treats all the water prior to the RO membranes.

In this, and many other RO filtration projects sand filters, carbon filters and, 5 µ + 1 µ cartridge filters have been replaced by AFM® alone.

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®. Tables 1 - 3, provide details on the use of anthracite with AFM® Grade 0 and Grade 1.

AFM® Grade 0 offers exceptional performance in mechanical filtration of water. Grade 0 can also be used to treat water with a heavy load of solids. 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 backwashes.

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 50 mm to a maximum of 100 mm layer of activated carbon. It is very important not to use any more than 100 mm 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 100 mm 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 $CO^\bullet$ sites. By this mechanism, activate carbon will remove some of the hypochlorous from the water.

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

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 include di-chloramine and tri-chloramine, in function of pH and water chemistry.

Organic chloramines are also 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 $NH_2Cl + H_2O + C^\bullet \leftrightarrow NH_3 + CO^\bullet + H^+ + Cl^-$

Stage 2b $2NH_2Cl + CO^\bullet \leftrightarrow N_2(g) + C^\bullet + H_2O + 2H^+ + 2Cl^-$

The end products will be nitrogen gas, hydrochloric acid and water as well as carbon dioxide in the case of organic matter.

- AFM® works very well as a support layer for activated carbon, and if any bacteria are released as floc, then 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.

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 or other applications discussed in the next section.

The following table is for guidance only as percentages will differ depending on manufacturer. It is always best to use filter manufacturer's original data, if available, to determine media volumes and ratios of support media:finer grades.

Notes.
Filters from different manufacturers will have different dimensions.
With respect to filters that have a lateral arrangement; for filters under 800mm in diameter, AFM® grade 2 is used to fill the space and cover the laterals to a depth of at least 50 mm. 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.

Table 1: Vertical pressure filter

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

	Grade 3	Grade 2	Grade 1	Grade 0	Anthracite (particle size)	Backwash velocity
With or without flocculation						
Pressure filters, with laterals	20%	10%	70%	0%		>45 m/hr
Pressure filters, with nozzle plate	0%	30%	70%	0%		>45 m/hr
Multi-layer with anthracite						
Pressure filters, with nozzle plate	0%	20%	60%	0%	20% 1.18 - 2.5 mm	>45 m/hr
Without flocculation						
Pressure filters, with laterals	20%	10%	50%	20%		>45 m/hr
Pressure filters, with nozzle plate	0%	30%	50%	20%		>45 m/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 per m^2 of filter 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 300 mm to 1400 mm

	Grade 3	Grade 2	Grade 1	Grade 0	Anthracite (particle size)	Backwash velocity
With or without flocculation						
Horizontal, lateral under-drain	30%	10%	60%	0%		>45 m/hr
Horizontal, with nozzle plate	0%	20%	80%	0%		>45 m/hr
Multi-layer with anthracite						
Horizontal, lateral under-drain	30%	10%	40%	0%	20% 1.18 - 2.5 mm	>45 m/hr
Horizontal, with nozzle plate	0%	20%	60%	0%	20% 1.18 - 2.5 mm	>45 m/hr
Without flocculation						
Horizontal, lateral under-drain	30%	10%	40%	20%		>45 m/hr
Horizontal, with nozzle plate	0%	20%	80%	20%		>45 m/hr

N.B. Figures for media volumes and ratios are estimates only and may vary dramatically from one manufacturer to another. It is always best to use filter manufacturer's original data, if available, to determine media volumes and ratios of support media:finer grades.

Rapid Gravity Filters (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 media 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 (0.4 – 0.8mm) is used to replace 0.4 - 0.8 (DIN standard) 20/35 sand and/or 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 depth gauge sticks can be used. The expected quantities of material for each layer should be calculated and included in the method statement. Table 3 provides the recommended percentages of the different grades of media. The various layers should 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 backwash and should be laid to design depth.

The filtration layers (grades 1 and grade 0) should also be placed carefully to avoid displacement of the top support layer. If the filtration layers are 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 filtration layers after 150mm has been placed is of less concern if the bed is dry. The filtration layers need not be levelled accurately. The backwash procedure will perform this task. Depth of filtration layers should allow for (bed depth + bed expansion) +17.5% during backwash.

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

RGF Bed Conditioning Procedures

AFM® rapid gravity filters do not normally require air scouring! Air will displace the support grades and will not be reclassified during a backwash unless backwash velocity is greater than 45m/hr.

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 according to normal backwash protocol.

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 and, may cause some penetration of fines through to the under drain. Temporary arrangements to fill the clean wash water tanks are recommended in this case.

After 3 backwashes, 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

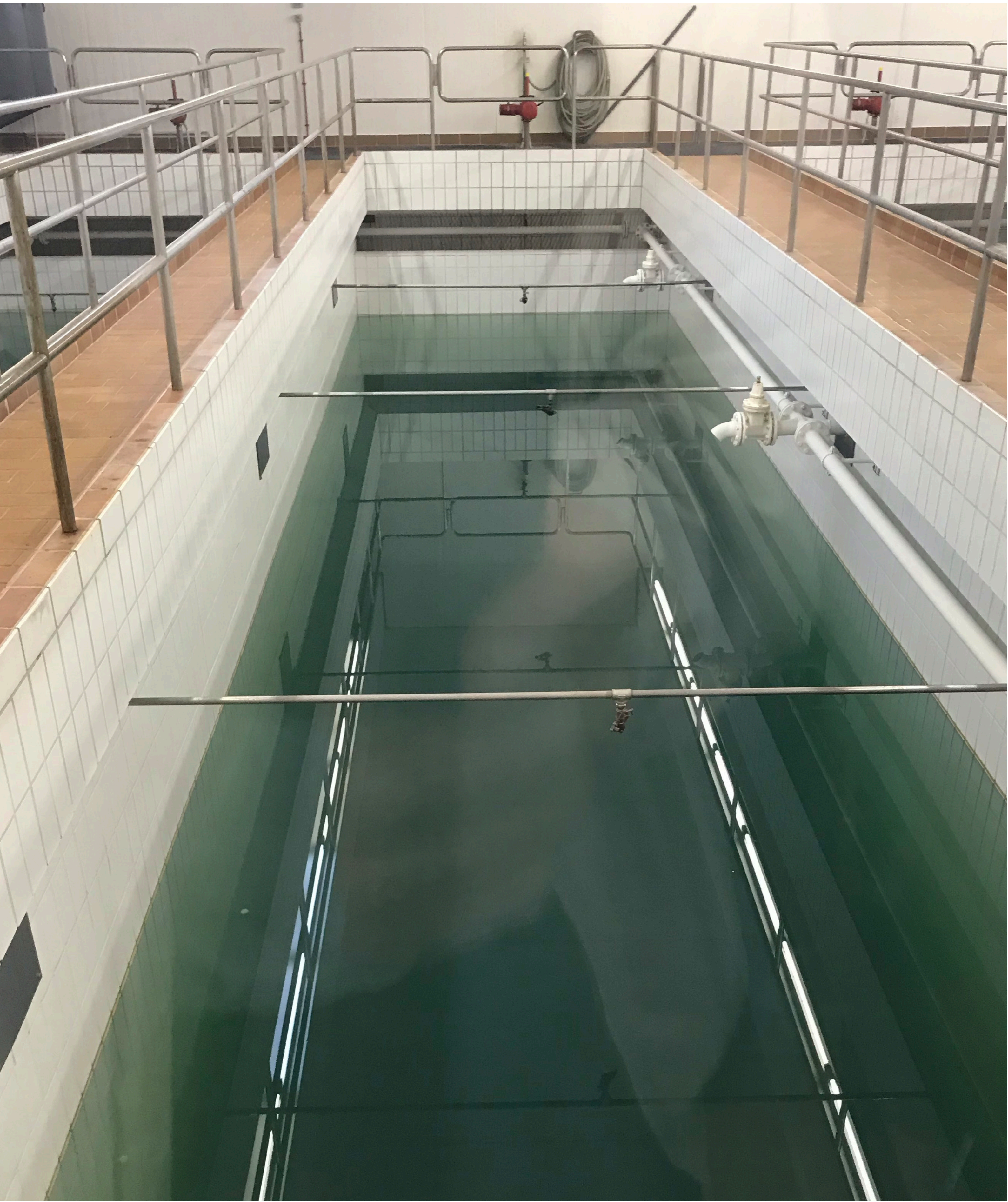


Table 3: RGF Rapid Gravity Filters

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

	Grade 3 2 - 4mm	Grade 2 0.7 - 2.0mm	Grade 1 0.4 - 0.8mm	Grade 0 0.25 - 0.5mm	Anthracite (particle size)	Backwash velocity
With or without flocculation						
RGF filters, with laterals	20%	10%	70%	0%		30 - 50 m/hr
RGF filters, with nozzles or screened floor	0%	20%	80%	0%		30 - 50 m/hr
Multi-layer with anthracite						
RGF filters, with laterals	20%	10%	50%	0%	20% 1.18 - 2.5 mm	30 - 50 m/hr
RGF filters, with nozzles or screened floor	0%	20%	60%	0%	20% 1.18 - 2.5 mm	30 - 50 m/hr
Without flocculation						
RGF filters, with laterals	20%	10%	40%	20%		30 - 50 m/hr
RGF filters, with nozzles or screened floor	0%	20%	60%	20%		30 - 50 m/hr
Grade 0 optimised filters						
RGF, lateral under-drain filter	20%	10%	10%	60%		>30 m/hr
RGF, nozzle plate filters	0%	20%	10%	80%		>30 m/hr

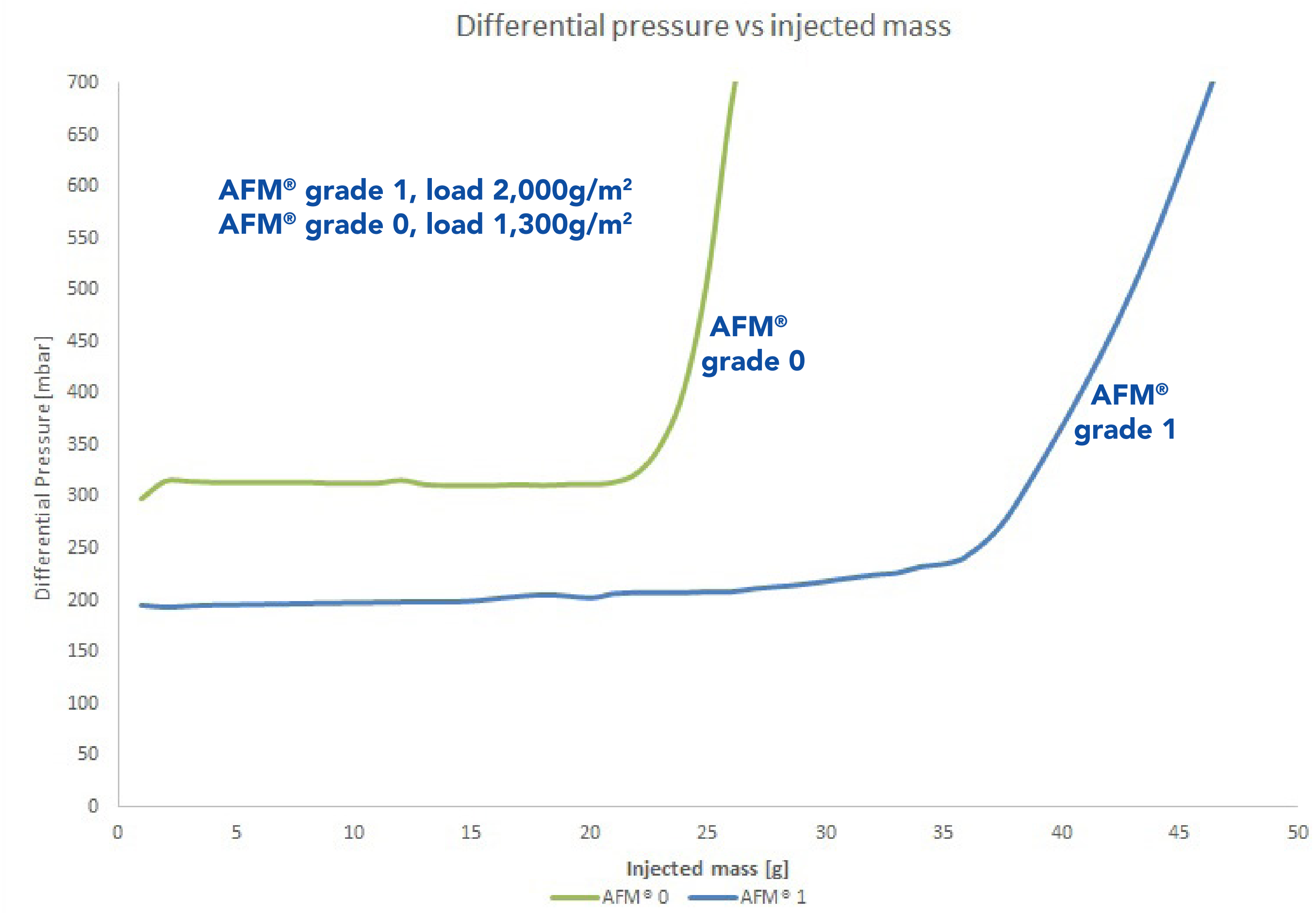
Run phase differential pressure

AFM® is a mechanical filter media whose primary function is to remove solid particles from the water.

If AFM® is exposed to high concentrations of solids, its limitations are related to the rate of change of pressure and acceptable backwash frequency. Depending on the application, AFM® should be backwashed when the pressure differential reaches a maximum of 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 AFM®. The loadings were generated using engineered (ISO CTD) particles; in practical applications, the loading rate may be greater than 2 kg/m^2 and 1.3kg/m^2 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 injected mass at 20m/hr



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

m/hr	AFM® Grade 1	AFM® Grade 0
	mbars	mbars
5	110	40
10	150	120
15	180	220
20	210	n/a
30	310	n/a
40	410	n/a

Suspended solids loading capacity

In practical terms, the shortest backwash 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 backwash frequency the maximum solids load capacity is given in the following table.

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

Water flow velocity m/h	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

The above tests are based on laboratory trials using ISO CTD particles at a 20m/hr filtration velocity. All other figures are estimates only. In practise, depending on the nature of the filtrate, these figures have been found to be very conservative and can be as much as 50% too low at lower filtration velocities.

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 µ particles. For heavy loads of solids above 20 µ, 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 always be backwashed, then sterilised with Chlorine Dioxide (for example Dryden Aqua DryOx product 2 tablets per 5m³ filter volume dosed via the top hatch), then given a standard backwash with clean water. After the backwash, as much water should be drained off from the filter as possible and the drain should be left open.

Prior to going back-online the filter should ideally be sterilised again, then backwashed 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 filter is inversely proportional to the velocity of water passed through it. 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.

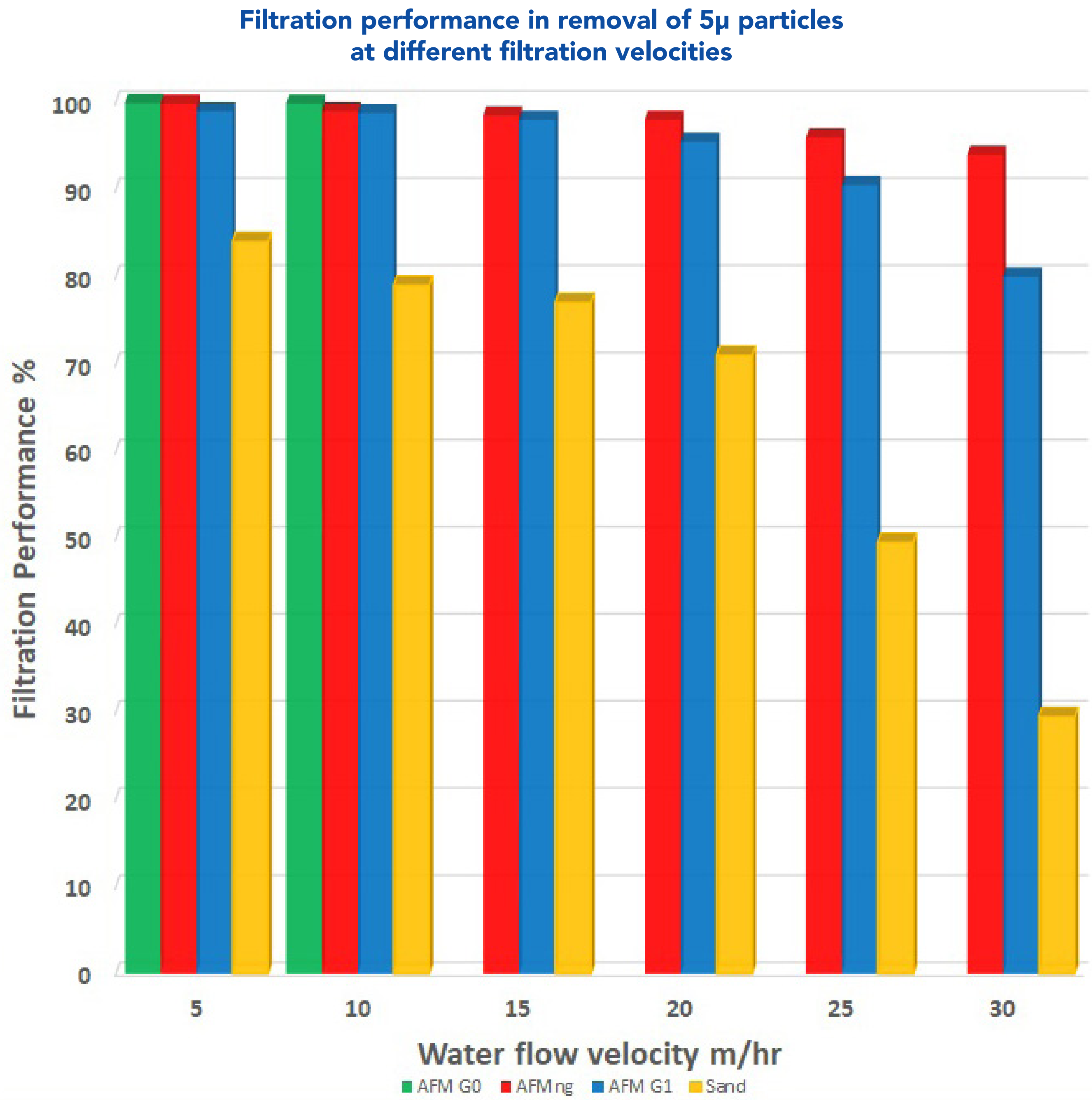
Different filtration media and sand from different countries / deposits will have a different performance. This is a function of particle size distribution, sphericity, chemical composition and uniformity coefficient. Typically, RGF sand filters operate at 6m/hr and pressure filters at 12m/hr. RGF AFM® filters should be operated under the same conditions and will always give better performance than sand. 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. e,g. for drinking water applications, for most 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 5µ. 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 flow rate 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.



Sand tested was Leighton Buzzard 16/30 (0.5 - 1mm) sand.

Recommended, typical maximum run phase water flow for different applications using AFM®.

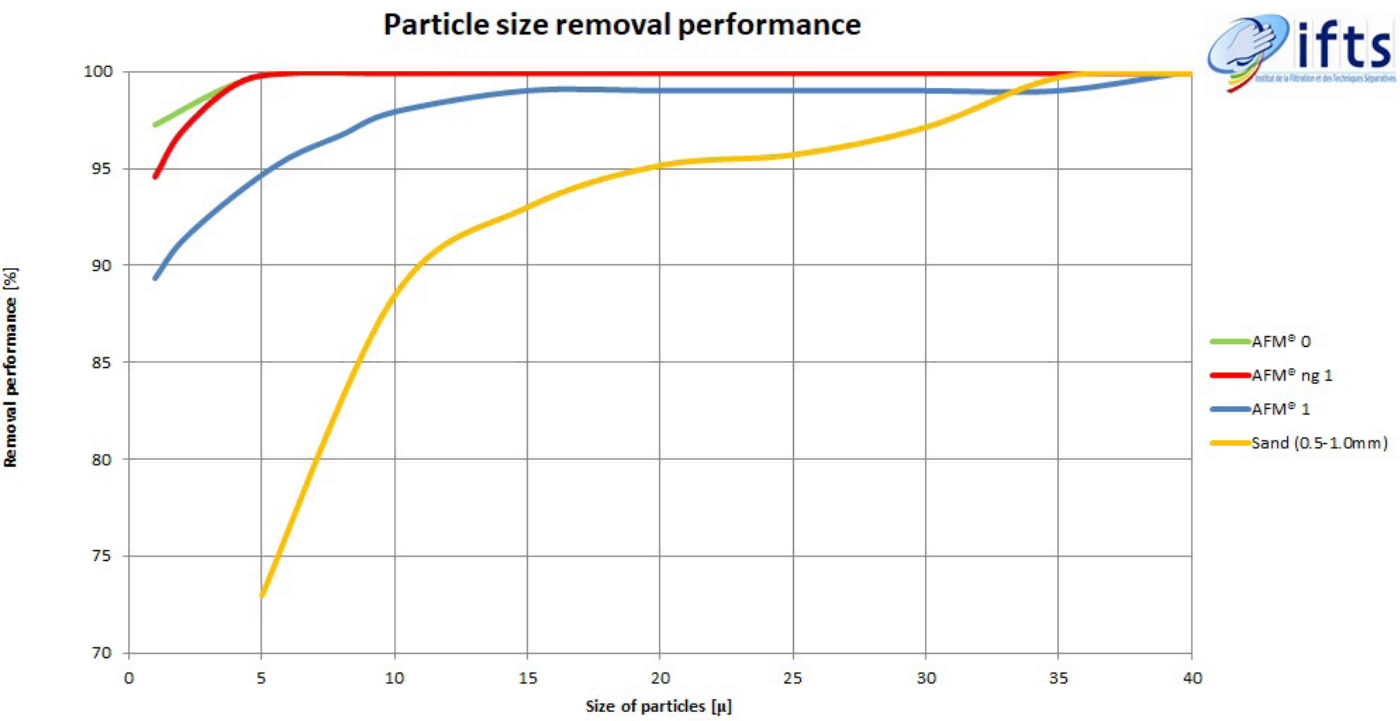
Table 3: Run phase water flows for different applications	Recommended Run phase water flow m/hr	
	Pressure	Gravity flow & Moving bed
Drinking water		
Recommended water flow	<10	<5
Maximum water flow	<20	<15
Municipal wastewater		
Recommended water flow	<5	<5
Maximum water flow	<15	<10
Aquaculture and Aquaria		
Recommended water flow	<20	<5
Maximum water flow	<30	<10
Swimming pools		
Recommended water flow	<30	
Maximum water flow	<30	
Aquaculture		
Incoming Hatchery Water Treatment	<10	
Incoming Ongrowing Farm Water Treatment	<15	
Hatchery RAS	<15	
Ongrowing Farm RAS	<20	
Industrial Water Treatment		
Borehole water treatment for ferric, manganese and arsenic	<10	<5
Treatment prior to membranes	<15	<10
Cooling towers	<20	<10

Filtration performance and grade of filter media

The standard grade of filter media used in most pressure and RGF filter is a sand of 20 x 35 mesh size, AFM® standard Grade 1 is equivalent to this grade of sand. Because AFM® does not biofoul, this will give superior performance even with standard grade 1 or, to use a much finer grade of media. There is also an opportunity to tailor the choice of AFM specification to suit the application:

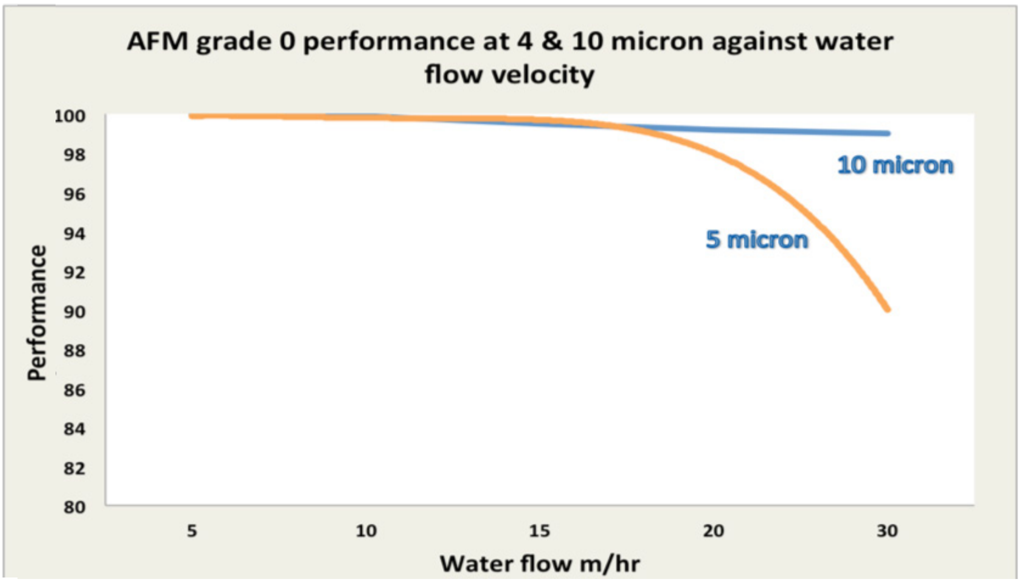
- AFM® Grade 0, which has a particle size distribution of 0.25 to 0.50mm. This is slightly more than half the size of 20 x 35 sand and AFM® Grade 1 and will filter to 1 micron without flocculation. Slower filtration velocities of <10m/hr are advised
- AFM® standard Grade 1, which has a particle size distribution of 0.4 to 0.8mm should be used in any application where water is contaminated with metals. It is better at removing positively charged contaminants.
- AFM®ng Grade 1, which also has a particle size distribution of 0.4 to 0.8mm is better for removing organic contaminants, oils/fats, pharmaceuticals and microplastics in both hard and soft water. AFM®ng is particularly well adapted for use in all applications where water hardness and alkalinity are less than 50mg/l.

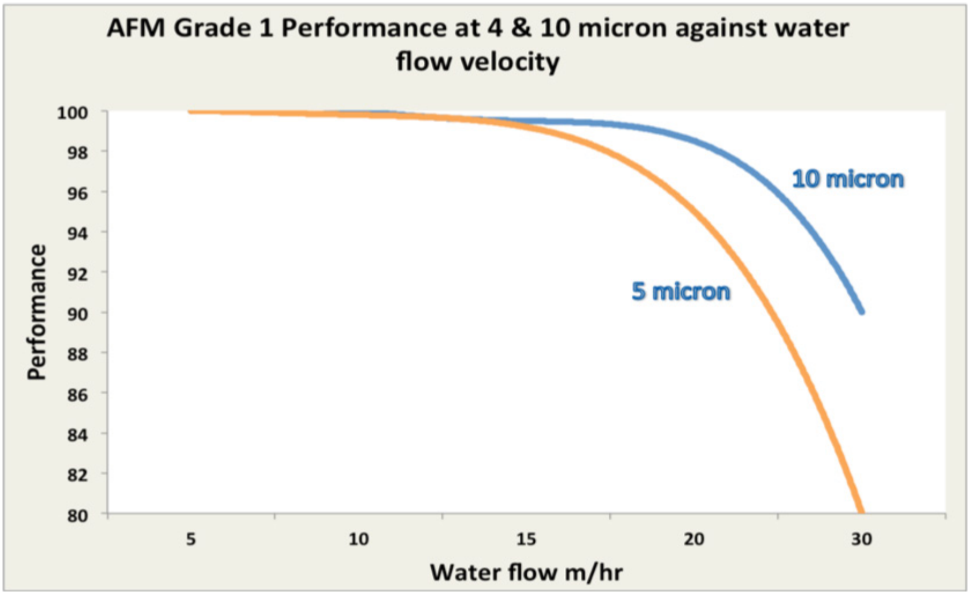
Particle size removal performance of AFM® vs sand at 20m/hr

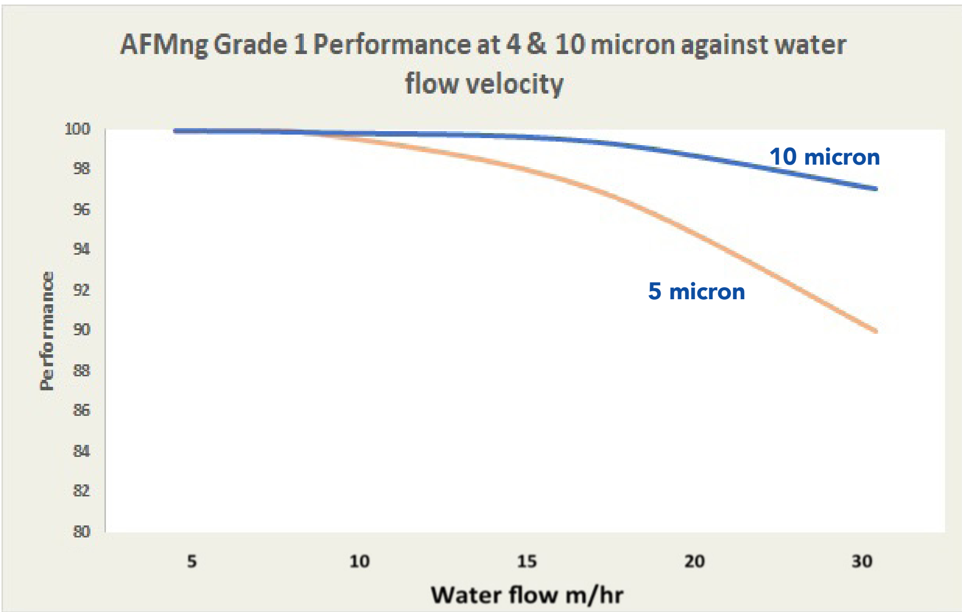


AFM® Grade 0, AFM®ng Grade 1 and AFM® Grade 1 performance at different flowrates

The following graphs show the influence of water flow rate on performance of Grade 0, Grade 1 AFM®ng and standard AFM® over a filtration velocity range of 5 to 40m/hr.

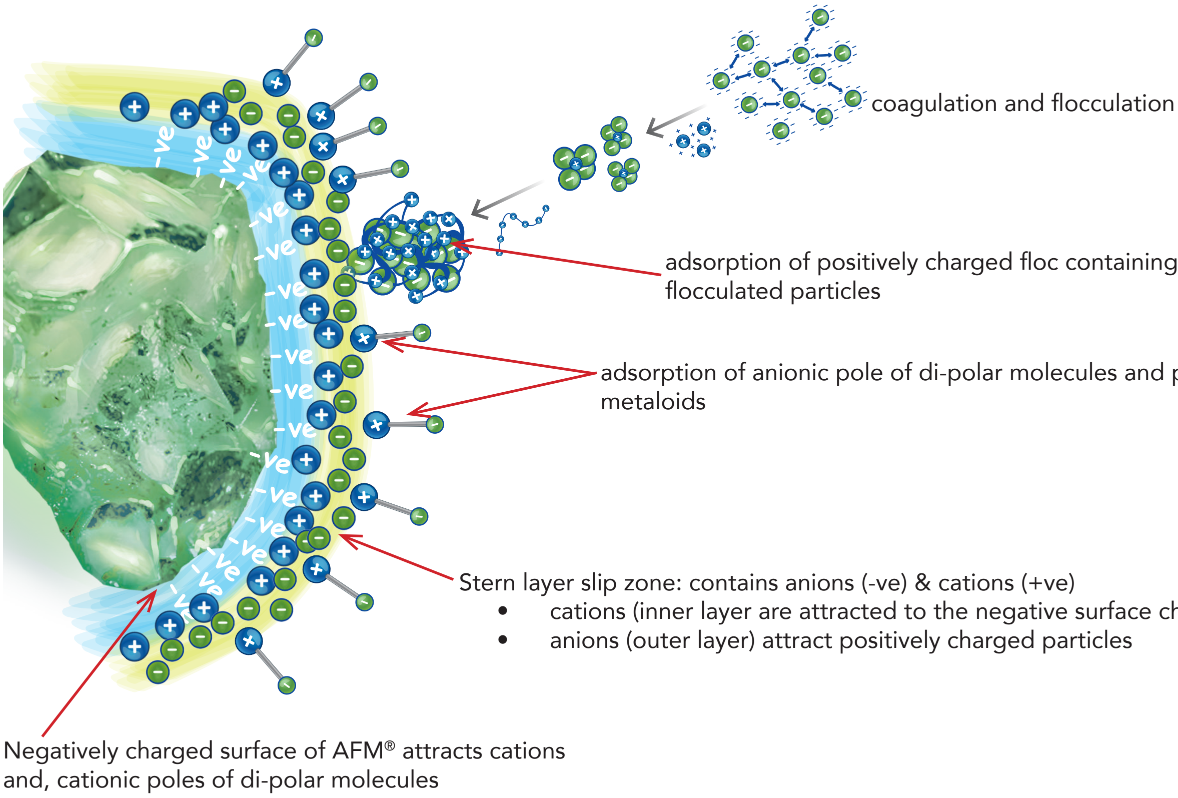






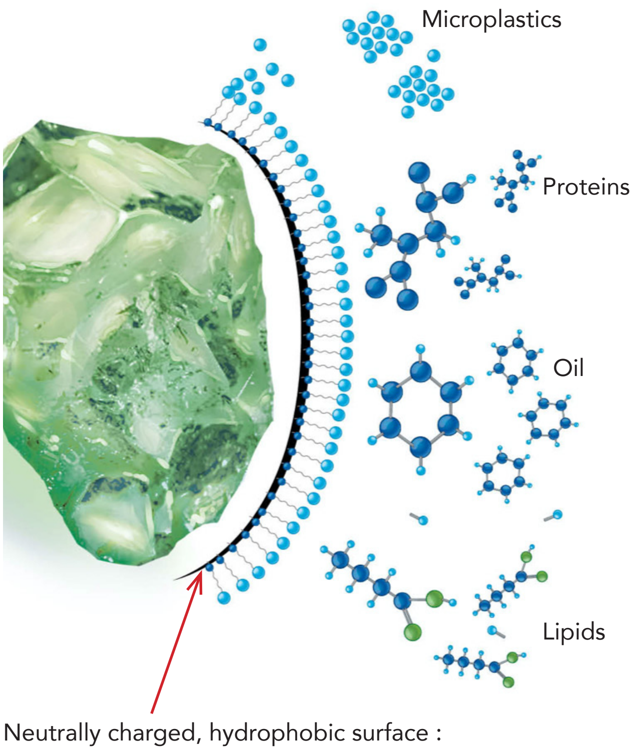
Standard AFM® :

Chemically activated and thermally treated to carry a negative surface charge.



AFM®ng :

- Chemically activated and thermally treated to have hydrophobic, neutrally charged surface properties



Advanced adsorption of organics

Most organic substances are non polar and tend to float like oil or be adsorbed onto a non polar hydrophobic surface.

AFM® Grade 0 performance

All performance data for AFM® has been established without the application of coagulants or flocculants.

AFM® Grade 0 can remove 99.93% of all particles down to 3 μ at 2m/hr filtration velocity (IFTS verified). AFM® Grade 0 can be used as an effective Cryptosporidium oocysts barrier (log 3 reduction) at water flows of <5m/hr with a 900mm bed depth.

We would not generally advise the use of AFM® Grade 0 with chemical flocculants other than ozone. The performance data presented below, from Dryden Aqua's own test labs, is without the application of flocculants.

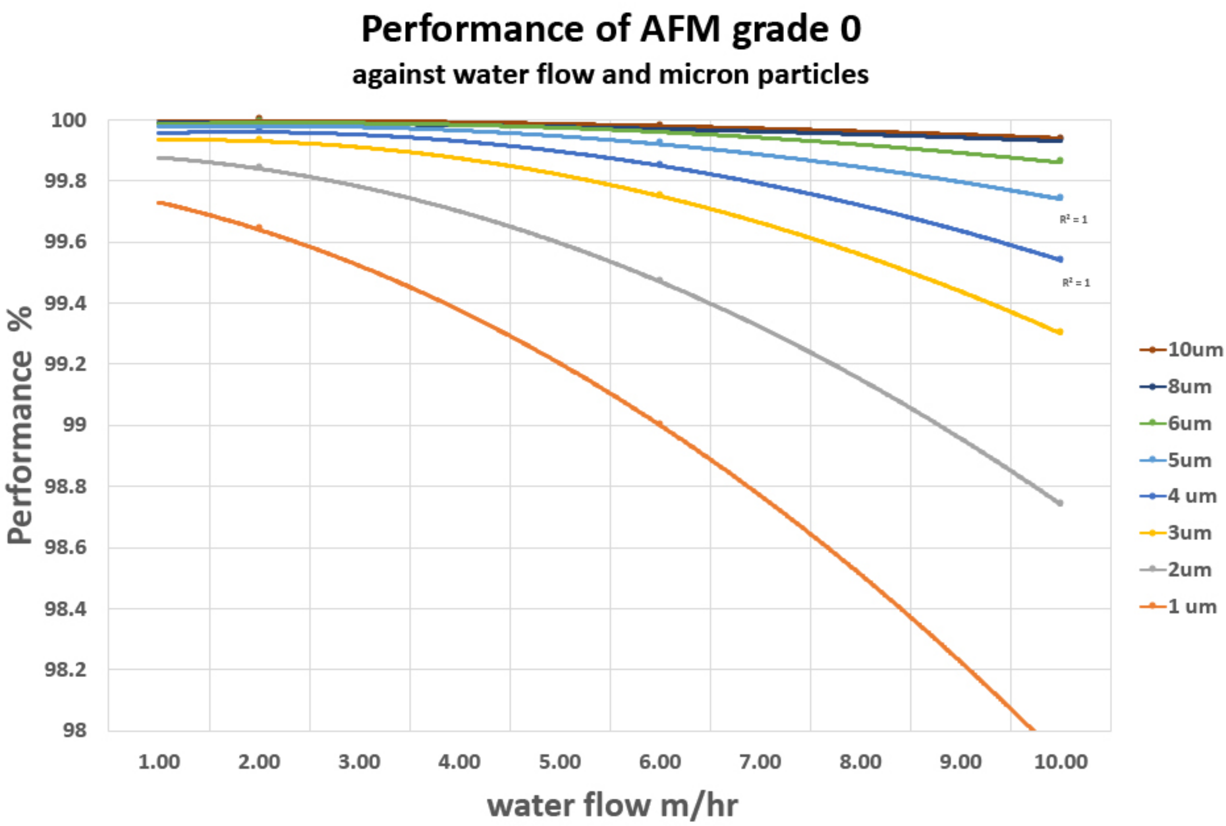
>4μ particle filtration performance	
Filtration performance %	**Water flow**
99.96%	2m/hr
99.89%	5m/hr
99.85%	6m/hr
99.75%	7m/hr
99.54%	10m/hr

>3μ 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 %	**μ rating**
99.96%	4um
99.93%	3um
99.80%	2um
99.60%	1um

Use of AFM® Grade 0

Water filtration without the requirement to use coagulation or flocculation chemicals.



AFM® grade 0 is preferably used between water flow velocities from 1 to 10m/hr,.Filtration performance is related to filtration velocity, the slower the water flow velocity the better the performance. The above data is without any pre-coagulation of flocculation and is using IS0 A4 grade silica particles.

Smaller particles tend to be more sensitive to water flow, so if the objective is to remove small particles such as Cryptosporidium oocysts, algae, colloidal particles or even some bacteria, then the filter should be operated at a slow flow rate.

The independent IFTS data above confirms >99.9% 3μ particle removal at a water flow velocity <2m/hr. Given this performance AFM® grade 0 could be an effective barrier for Cryptosporidium oocycts without the requirement to use flocculants. The performance of AFM® then provides a perfect solution for applications such as sustainable rural community drinking water systems for developing countries as well as Europe and North America.

The CAFÉ filter (Clean Aqua For Everyone) has been developed specifically for grade 0 AFM®. The filter has automatic backwash working on the basis of a siphon system with no requirement for a control system or automatic valves.

Standard AFM® Grade 1 performance

All performance data for standard AFM® has been established without the application of coagulants or flocculants.

AFM® Grade 1 can remove >95% of all particles down to 5µ at 20m/hr filtration velocity (IFTS verified).

When standard AFM® Grade 1 is combined with coagulation and flocculation using PAC (Poly-Aluminium Chloride) or Polyamide cationic flocculants, the performance and ability to remove Cryptosporidium oocysts at 5µ and sub 1µ is greatly enhanced. In recirculation (e.g. chlorinated swimming pool) systems AFM® Grade 1 can therefore be used to provide an effective Cryptosporidium oocysts barrier at 20m/hr, with a 900mm bed depth and with coagulation and flocculation.

The performance data presented below, from Dryden Aqua's own test labs is without the application of flocculants.

>10 µ particle filtration performance	
Filtration performance %	Water flow
98.81%	5m/hr
98.20%	10m/hr
97.5%	15m/hr
97.23%	20m/hr
90%	30 m/hr

>5 µ particle filtration performance	
Filtration performance %	Water flow
99.24%	5m/hr
98.00%	10m/hr
96.58%	15m/hr
95.02%	20m/hr
90.06%	25m/hr
79.00%	30m/hr

filtration performance at a water flow of 5m/hr	
Filtration performance %	µ rating
99.24%	5um
97.66%	3um

Use of standard AFM® Grade 1

AFM®s is a robust and stable, bio-resistant general purpose media with a 20 year performance track record. It is best suited to water filtration for the removal of positively charged contaminants such as heavy metals and, in conjunction with coagulation and flocculation for removal of organics and negatively charged contaminants etc. .

AFM®ng Grade 1 performance

All performance data for AFM®ng has been established without the application of coagulants or flocculants. I

AFM®ng Grade 1 can remove >94% of all particles down to 2μ at 20m/hr filtration velocity (IFTS verified).

When AFM®ng Grade 1 is combined with coagulation and flocculation using different flocculants, its performance can be further enhanced. Depending on water quality its performance can equate to that of AFM®s Grade 1 + flocculants.

The performance data presented below, from Dryden Aqua's own test labs is without the application of flocculants.

>10 μ particle filtration performance	
Filtration performance %	**Water flow**
99.86%	5m/hr
99.34%	10m/hr
99.30%	15m/hr
99.22%	20m/hr
97.10%	30 m/hr

>5 μ particle filtration performance	
Filtration performance %	**Water flow**
99.35%	5m/hr
99.02%	10m/hr
97.00%	15m/hr
96.18%	20m/hr
88.67%	30m/hr

filtration performance at a water flow of 5m/hr	
Filtration performance %	**μ rating**
99.35%	5um
99.04%	3um

Use of AFM®ng Grade 1

AFM®ng's hydrophobic surface is suitable for filtration/removal of all hydrophobic non-polar contaminants such as organics, lipids/fats/oils, pharmaceuticals and microplastics with or without the use of flocculants. Good coagulation and flocculation will always further enhance performance.

Filtration in water with low electrolyte content (TDS <50mg/l), low Calcium hardness (<20mg/l) and low alkalinity (<50mg/l) is always challenging. AFM®ng offers a significant performance advantage in soft water where even AFM® Grade 0 may be compromised. When used in conjunction with good coagulation and flocculation it offers exceptional performance in soft water when sand or, any other known media would simply fail.

AFM®ng is particularly well suited to water filtration in soft water areas such as Scotland and Scandinavia.

6. How to backwash a filter

Backwashing an RGF (rapid gravity filter) or a pressure filter is a very simple procedure, however it must be conducted properly to ensure optimal filter performance during the run phase. This applies to all media bed filters, irrespective of the media contained within the filter vessel.

The normal AFM® backwash process has 5 stages.

1. Initiate and slowly accelerate backwash flow to 100% over a period of 15 to 45 seconds. Backwash water flow to achieve >15% bed expansion
2. Backwash duration to ensure completion of the backwash process
3. At the end of backwash, slow down the water flow over a period of >30 seconds to allow the bed to properly re-classify
4. Rinse phase to prevent solids entering the product water
5. Run phase

Air purge (not normally required with AFM®)

Air purging a filter bed will help to scrub and clean 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 backwash water consumption. 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 m^2 of filter bed surface area for a period of 5 to 10 minutes. The filter will then be backwashed 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 backwash water flow does not expand the bed, the grades will not re-classify. The nett result, is that all the grades get mixed together in a filter bed that is not backwashed 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 requires 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, then water-hammer could damage the pipework or the filter internals. The fluid hydraulics are never perfect, especially with filters using laterals in radial" configuration, or in the case of most horizontal filters.

In horizontal filters; at the start of a backwash, water will rush towards the back-end of the filters and proportionally there will be a slightly greater flow velocity at the end of the laterals. The water will therefore kick up the media at the end of the filter and at the edges. Pressure drop will be reduced locally 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 backwashed 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 backwashed, 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 backwashed 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 backwash water flow
German DIN standard vertical filter with nozzle plate	15
Vertical filter with standard lateral arrangement	30
Horizontal filters with nozzle plates or laterals	45

Backwash water flow to achieve the correct bed expansion

The minimum backwash velocity should expand the bed by 15%. 15 - 20% bed expansion is therefore recommended, especially for multimedia beds. If activated carbon is used, because it has a lower density than sand, expansion of the carbon layer may be as much as 50%. The total bed depth should be adjusted to accommodate this.

The backwash velocity depends on several factors, including;

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

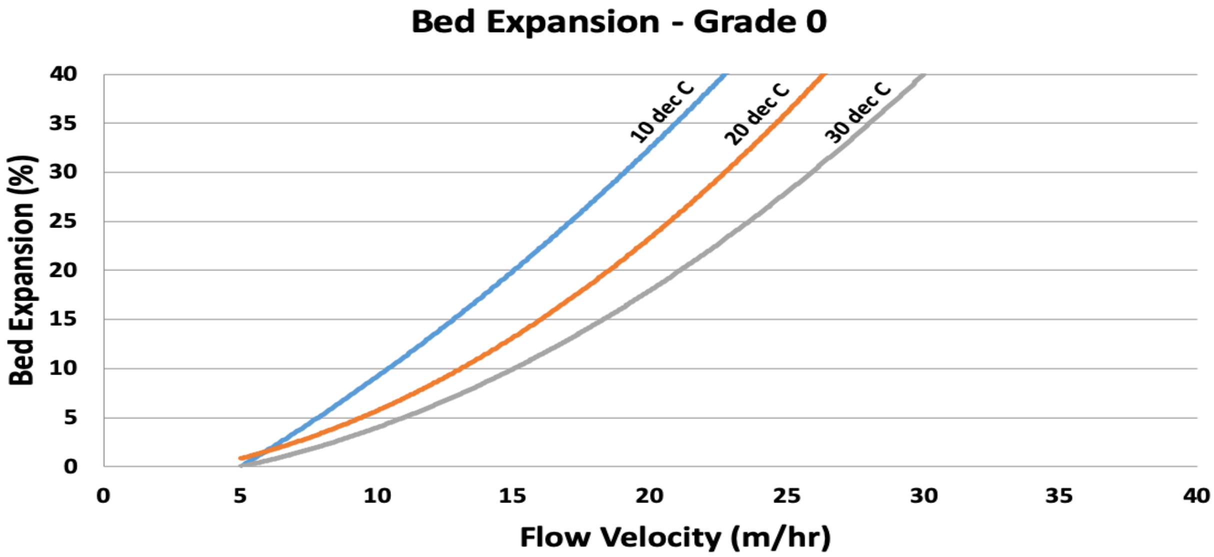
Recommended backwash water flow velocities

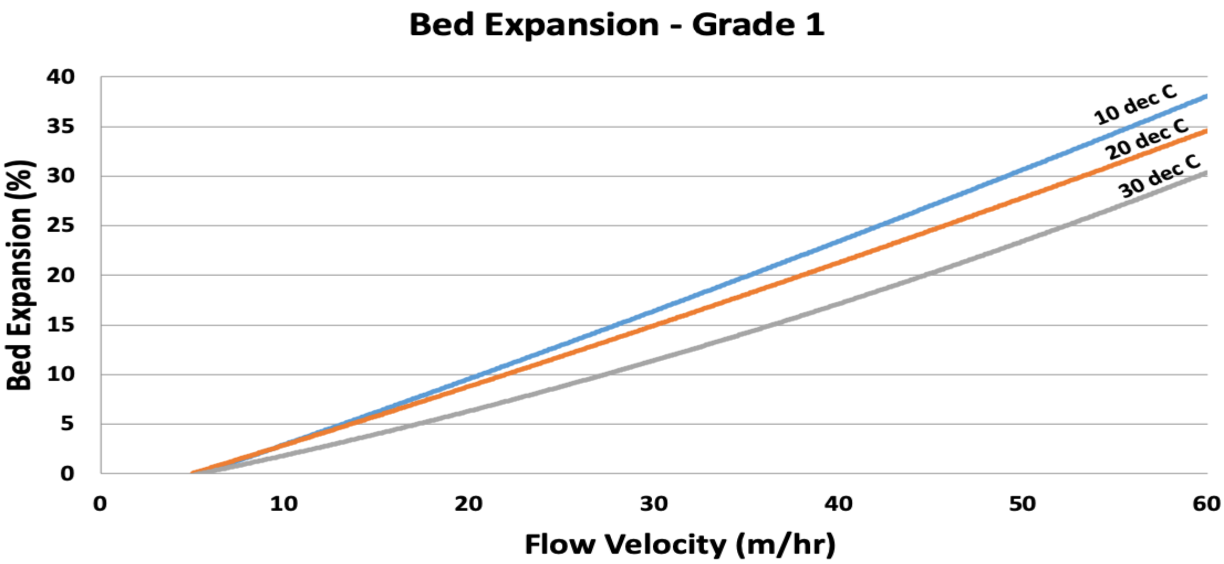
AFM® grade	Backwash water flow velocity
Backwash water flow for grade 0 AFM®.	>25 m/hr
Backwash water flow for grade 1 AFM®	40 - 50m/hr (see notes below)
Backwash water flow for 60% grade 1 and 20% grade 0 bed	30 - 40m/hr

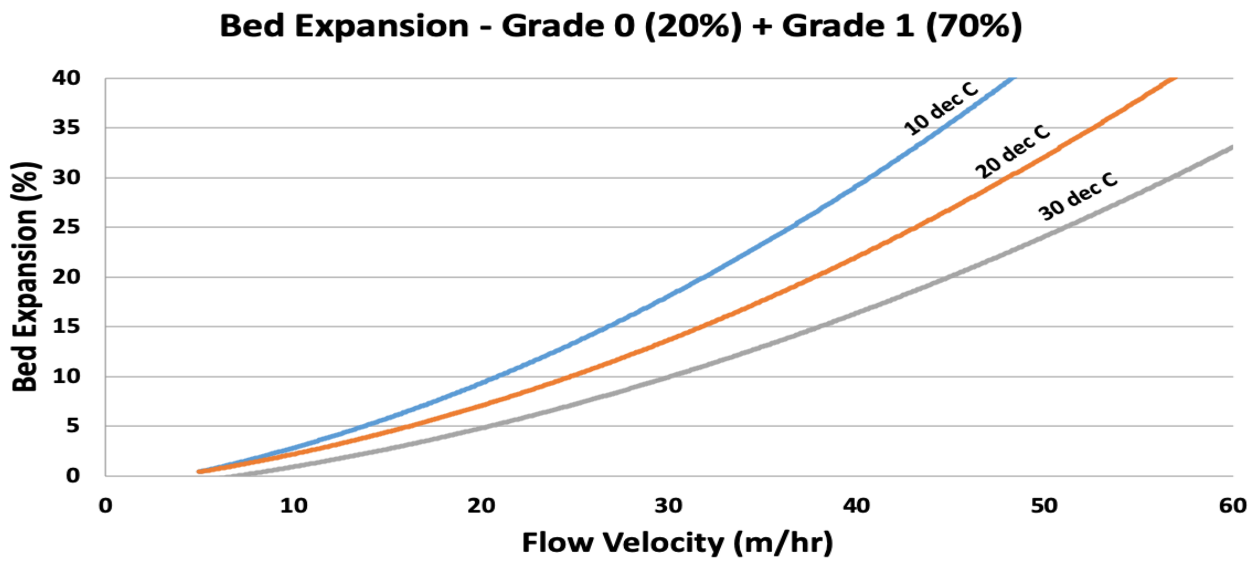
Please note that the figures in the above table, and, in general throughout this document, have been updated to reflect changes in size banding of all specifications of AFM grade 1. The latest standard AFM® and AFM®ng can be fluidised at velocities from 30m/hr. This will be sufficient to fluidise the bed but, will not always be enough to suspend heavier particles in the water column and, to evacuate them from the filter. For this reason Dryden Aqua advise that backwash rates should preferably be at least 40m/h.

For applications where very heavy particles such as iron and manganese need to be evacuated from the filter, a minimum backwash velocity of 50m/hr is required.

Bed Expansion in Freshwater

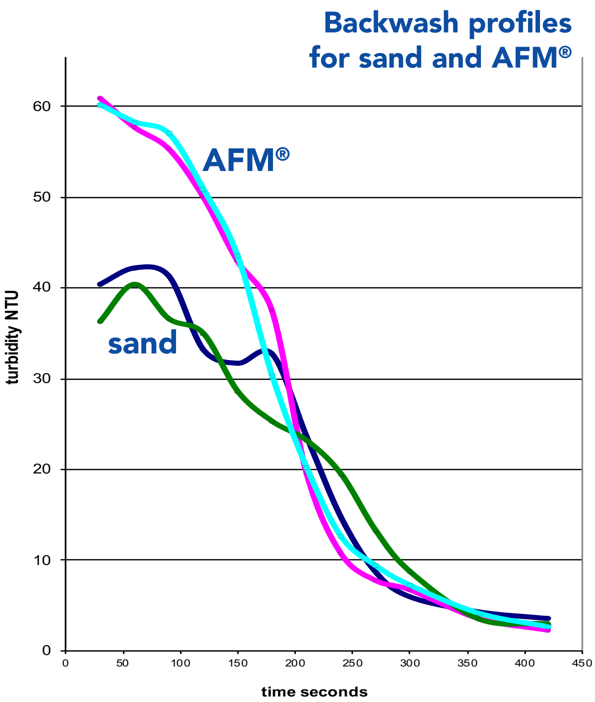






Bed Expansion is influenced by both temperature and by water density (TDS). In practise the influence of temperature is far greater than TDS. Expansion curves for seawater are therefore not significantly different from the above.

Backwash duration



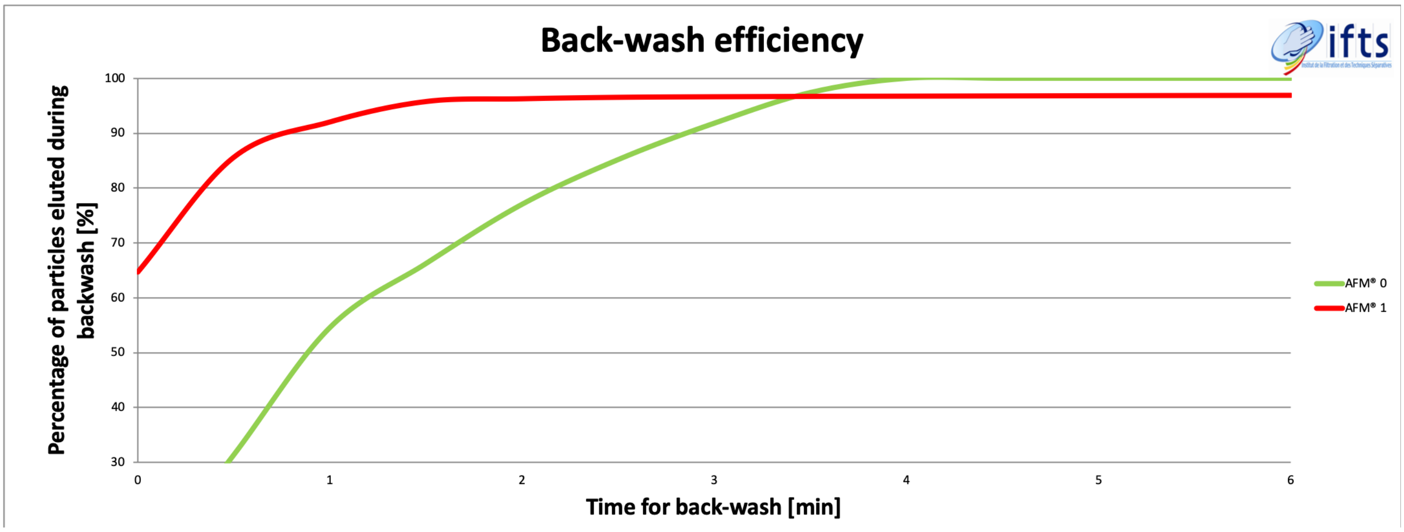
The backwash must progress until the solids are removed from the filter bed, and evacuated from the water above the filter bed. To achieve this task, the bed must be expanded by at least 15% to release the solids, if this is not achieved, the filter bed will never be cleaned, irrespective of how long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

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

If the filter media is stable and not subjected to compaction, or coagulation by bacteria or chemicals in the water, the backwash 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 backwash profile that can be attributed to coagulated lumps of media breaking up during the backwash 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 backwash 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 backwash will be required, not only to clean the media but also to evacuate all the water above the bed.

A sightglass should be installed in all filters for evaluation of bed condition, bed expansion and backwash efficiency.



Backwash wind down

Once the backwash has completed it is important to slowly wind down the backwash water flow back to zero over a period of 10 - 15 seconds, this is to allow the AFM® filter bed to properly classify the bed back to the perfect filtration configuration.

Rinse phase

After the backwash, 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. In drinking water systems this serves to reduce the risk of solids such as Cryptosporidium parasites passing into the product water. It also reduces discharge of solids that otherwise might foul or block a membrane.

Rinse water from often unstable sand filters needs to be sent to waste for at least 30 minutes before filters can be put back online. With AFM® the rinse phase duration can be reduced to only 5 minutes.

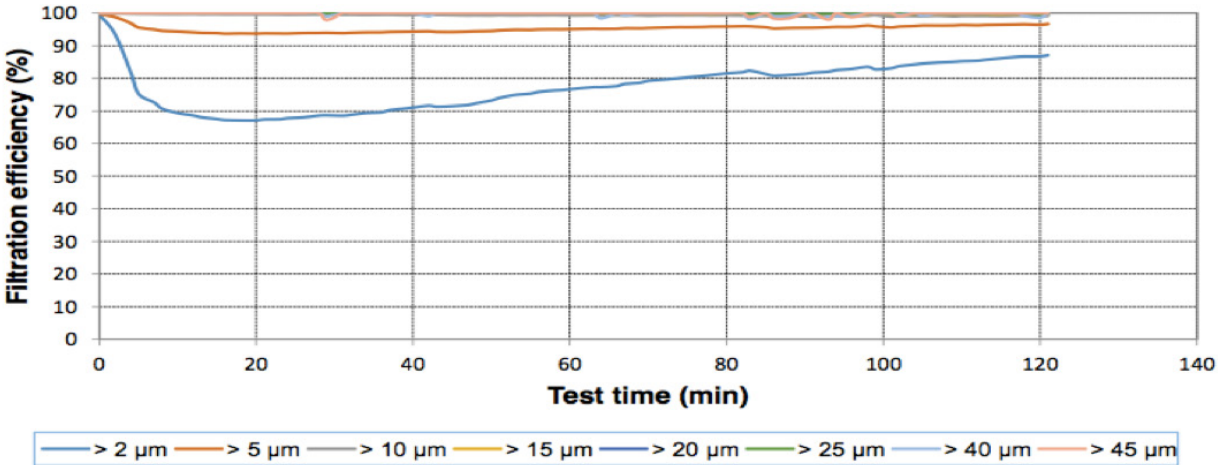
If the backwash profile defines the bed as unstable, then the rinse phase will require at least 30 minutes. The following data from IFTS (Institute of Filtration and Techniques of Separation in France), presents measurements for AFM® Grades running at 20m/hr and sand at 20m/hr.

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

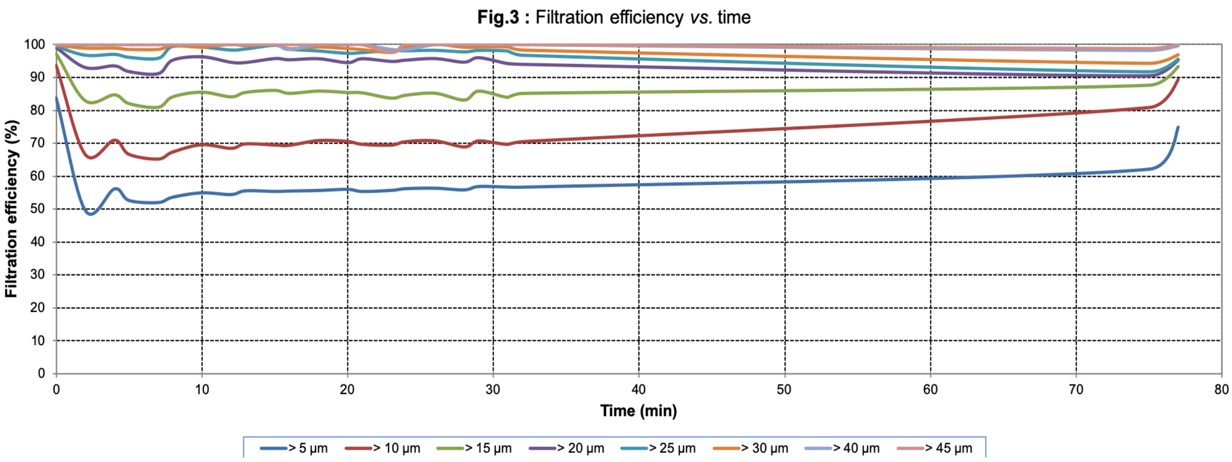
Instantaneous filtration performance after a backwash

After any backwash the media has to be compacted again before it will deliver its design performance. The graphs below illustrate the time required for this compaction *(referred to as ripening by drinking water technicians)* to take place.

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



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 5µ



Taking 5u 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 stabilised at approx 55%.

At 5u and a water flow of 20m/hr. In relation to a water treatment risk analysis, the results confirm the greater security afforded by AFM® over sand.

7. Annex Index

Annex 1: Applications overview for AFM®

Annex 2: AFM® for pre-filtration to membranes

Annex 3: AFM® for the tertiary treatment of waste water

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

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

Annex 6: AFM® for parasitic nematode egg removal from waste water and second use of water for irrigation

Annex 7: Calculation of bed depth for sigle media and multimedia filters allowing for expansion

Annex 8: Analysis of product water prior to connection of drinking water filtration system to a network

Annex 9: Water quality standards…Standards European and WHO drinking water quality

Annex 10: Pressure system filter schematic

Annex 11 : Description of Media Specification Terms

Annex 12 : Glossary of Technical Terms

Annex 1: Applications overview for AFM®

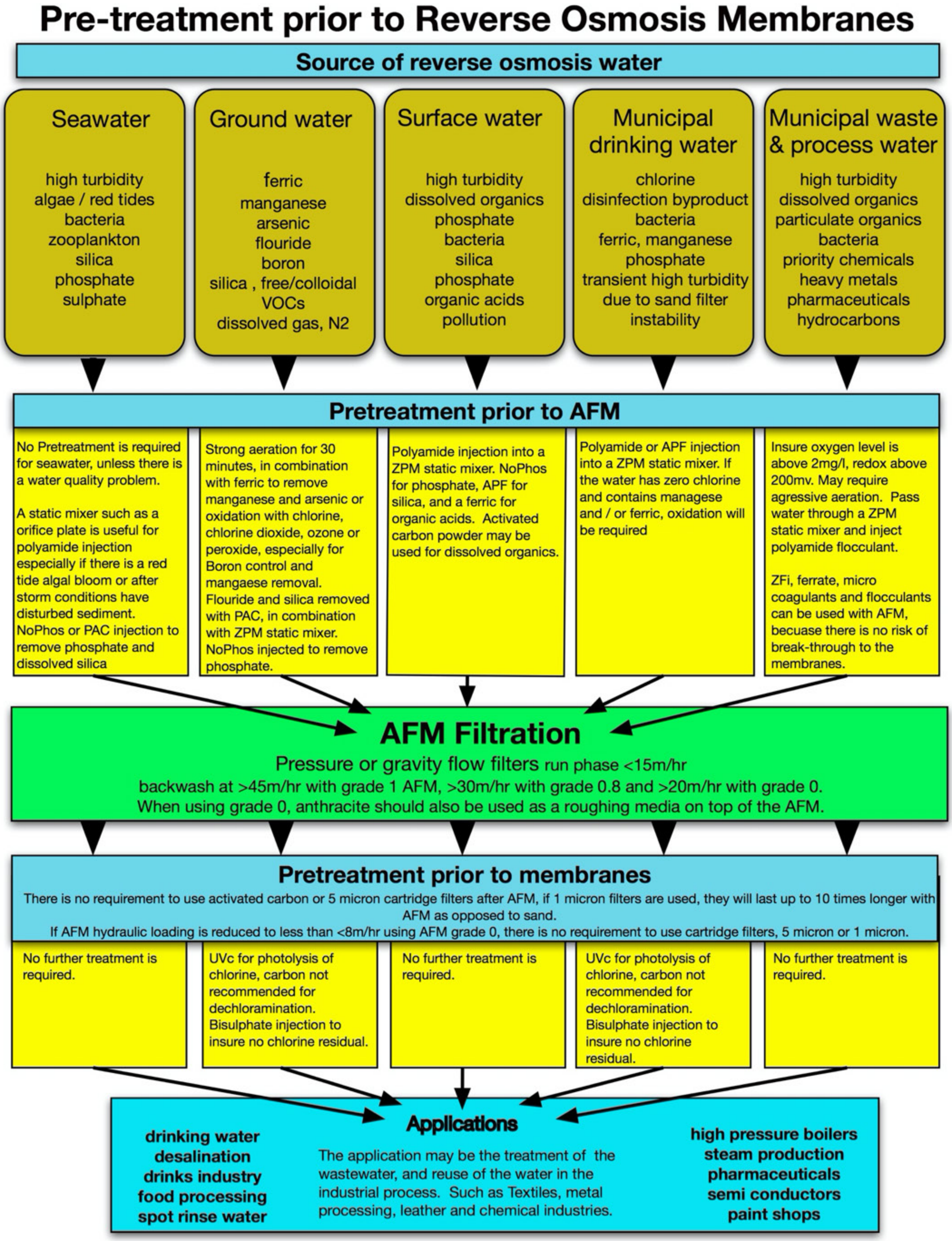
Application	Water source	Advantages
Municipal Wastewater • Municipal wastewater	Tertiary treatment after activated sludge.	• Will more easily comply with discharge legislation • Product water of a higher quality more suitable for second use applications • No chlorine or less required when the water is used for class 1 irrigation • Return in capital from revenue is always under 2 years and often under 1 year.
Process Wastewater • Textiles • Leather • Oil in water • Food washing • Cooling towers • Steel process water	The wastewater will be from a variety of sources. AFM® is usually used as part of the water treatment process located after activated sludge or MBR membrane bio-reactors.	Textiles: AFM® applied after the fluidised bed bio-filtration or MBBR. Advanced coagulation and flocculation systems have been developed and optimised for AFM® to remove dyes and facilitate recirculation of the water. Leather: The industry generation a hexavalent chromium wastewater, with pre-reduction of the water and conversion of Cr^{5+} to Cr^{3+} 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 flocculant. Permits AFM® to be used up to 2000mg/l and achieve >99% removal.
Drinking water & Clean Water • Drinking water • Ground water • Surface water • Process feed water • Drinks industries • Food processing • Pharmaceuticals • Hospitals feed water & dialysis recycle • 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 100 times more sub 5μ solids from the water than sand. Not 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®
	Ultrapure water, pre-treatment. Water from a variety of sources	Ultrapure 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
Pre-treatment prior to membrane desalination 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 μ and will remove chemicals from solution such as soluble reactive silica, phosphate and dissolved organics that would otherwise foul the membranes
Aquaculture & Aquaria • Aquaculture • Aquaria	Incoming seawater, surface water or borehole sources. Mechanical filtration in LSS/RAS systems	Aquaculture and Aquaria, require the best possible water quality. AFM® provides at least double the performance of sand and reduces the viral parasitic and bacteria risk. AFM® will physical remove all parasites from the influent water, such as Cryptocaryon, amoebae and even fungal spores
Swimming pools & Water features • Swimming pools • Fountains • Water features	Recycled water around a process. This is one of the main applications for AFM® with over 200,000 systems currently running in Europe.	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 more than 25m and turbidity usually less than 0.1NTU. Water features, 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.

Summary of application protocols for Dryden Aqua AFM®.

Application Type	Associated Processes		PSF Typical flow m/hr		%-age reduction
Municipal & Industrial 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 H_2O_2 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	typically SDI <3
Seawater Intake Filtration	Pre-screening of macro-algae by mesh or wedgewire screens	AFM® filtration	>10	<20	
Industrial Process Water					
Organic pollutants & oils,	Oxidation 30 mins by aeration	Alginate flocculant + 5 - 10m/hr filtration for concentrations 100 - 2000mg/l	>10	<15	95% reduction
TSS, VSS & particles >1µ	Oxidation 30 mins by aeration	>5 <10m/hr if high loads of 1 - 5µ particles	>10	<15	
Cooling tower sidestream filtration	Coagulation with LaCl (NoPhos) + ZPM for PO_4^{2-} removal		>15	<20	
Municipal Wastewater					
Phosphorous & Bacteria, BOD, COD & TOC	DAFs or MBBR filtration or Aggressive aeration + Flocculation via ZPM	Coagulation with LaCl (NoPhos) +ZPM for PO_4^{2-} removal	>5	<15	90% reduction
Tertiary Treatment	Pre-filtration to <100 µ + FeCl coagulation then AFM®	Oxidation 30mins with NaHOCl after AFM® filters	>5	<15	-95% COD
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

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..

Annex 2: AFM® for pre-filtration to membranes



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 5µ and 1µ 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 0.03µ

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 0.03µ 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 channelling 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 aluminium in the water or if aluminium is used as a flocculant.

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 developed surface area that is much greater than sand. The very large surface area of standard AFM® has a negative –ve charge for the adsorption of positive +ve charged particles or metals that are too small to be mechanically removed from the water. In seawater applications AFM®ng may give better performance in removal of organics. AFM® will also give excellent performance in removal of hydrocarbons.

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 0.1µ. 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.

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 stabilise 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 Fe^{2+} to Fe^{3+}, arsenic changes from AS^{3+} to AS^{5+}.

During the oxidation stage with Fe^{2+} to Fe^{3+}, 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

- 95% removal of 4µ particles with standard AFM® Grade 1 and, 97% of 1µ particles with Grade 0, independently verified.
- When combined with coagulation and flocculation, nominal filtration performance is better than 0.1µ.
- 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 hypobromous acid production.
- Regenerated by backwashing with water, air purge not required.
- 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
- Standard AFM® will remove 95% of all particles down to 4µ.
- Many priority chemicals such as herbicides are hydrophobic. AFM®ng is specifically adapted to removal of hydrophobic particles and will remove 94.6% of 1µ particles.

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
Backwash water flow	>50m/hr	60m/hr	Backwash 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 stabilise after a backwash
Backwash 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 $m^3/m^2/h$
	inlet	outlet		inlet	outlet		inlet	outlet		
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 10µ	14.66	7.33	50	7.16	3.88	45	56712	38460	32	3.23
Disc Filter 10µ	5.6	3.1	44	2.22	2.06	7	30450	21138	30	2.12
Ring Filter 10µ	7.41	3.98	46	3.01	3.17		9447	7761	17	2.5
AFM®s Pressure filter	10.60	0.89	96	2.98	0.24	92	23000	10000	58	3.59

Municipal wastewater

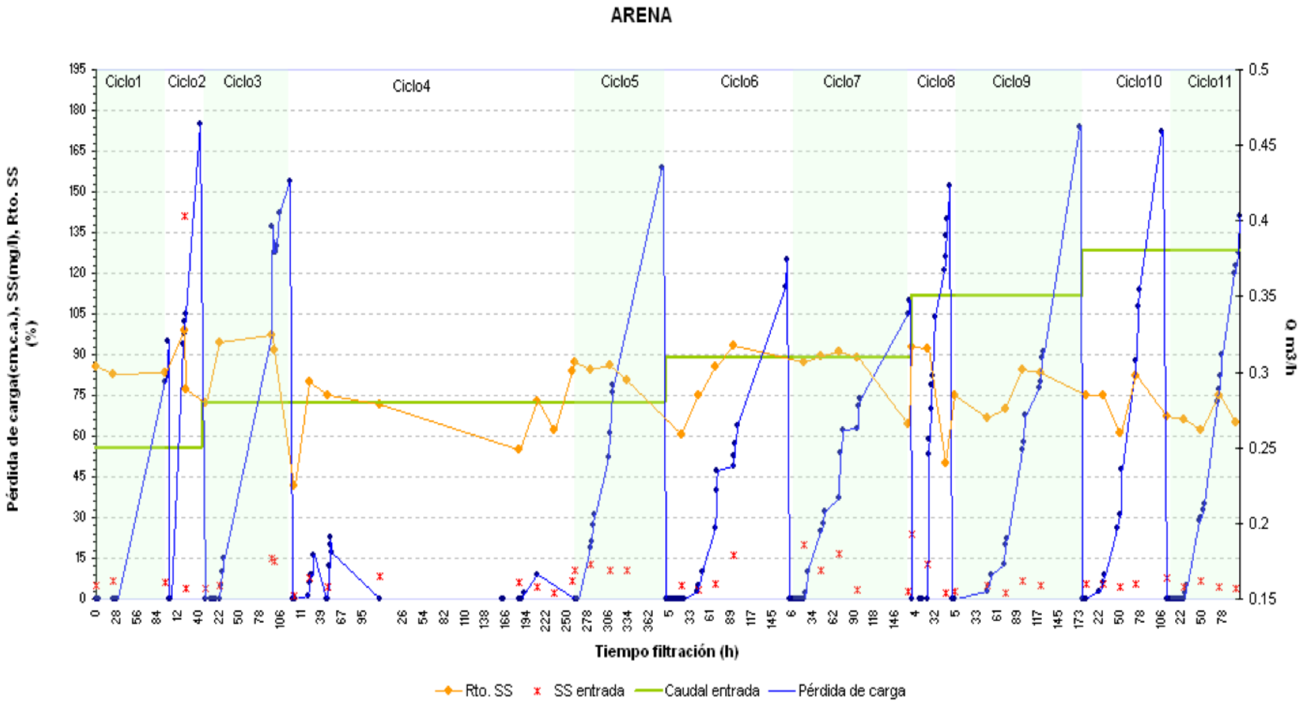
The following is published data by a Spanish Water Utility on the treatment of wastewater for second use. The data shows the backwash profile from the gravity flow sand filter and then the AFM® Grade 1 filter media. The data confirms the stability and high performance of AFM®s in comparison to sand.

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

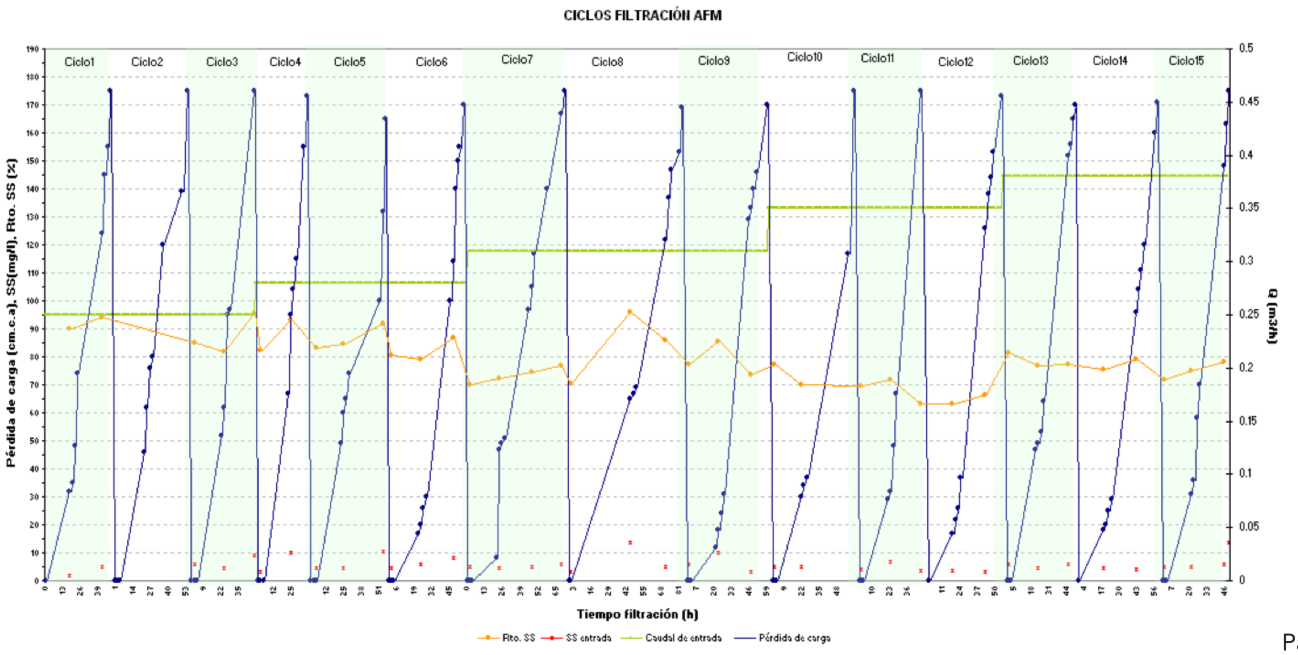
The AFM®s filter was like clock-work, each run phase and every backwash was the same. The data confirms the stability of AFM®s and the high quality of product water that may be achieved.

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
Backwash profile	Used to check performance

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

Annex 4: AFM® for 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 on local geology. The process used by Dryden Aqua to remove the chemicals is as follows;

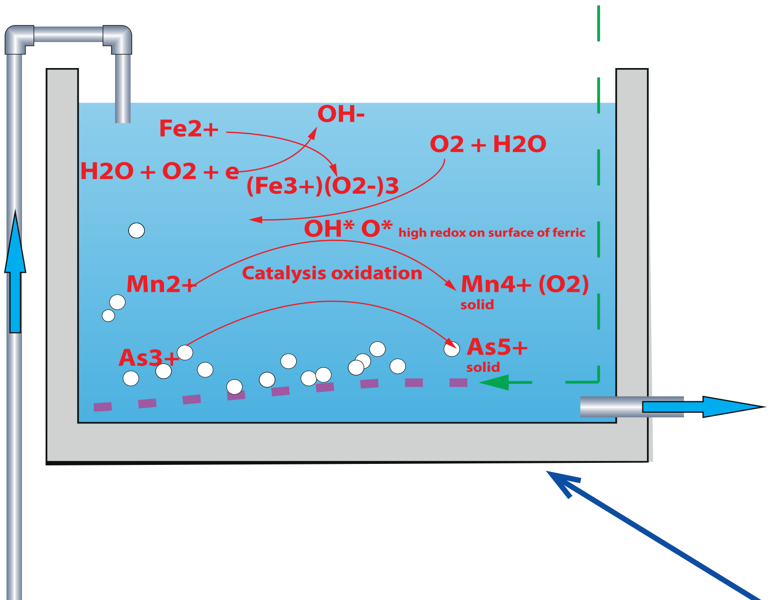
1. Oxidation reactions by aeration to convert metals from soluble ionic form to insoluble oxidised precipitate.
2. pH correction by aeration/oxidation
3. Decantation may be required if the concentrations are above 5 mg/l, if not proceed to AFM® filtration
4. Enhanced coagulation by ZPM cavitating mixer.
5. 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 will co-precipitate the arsenic and manganese and, the AFM® will remove them from solution.

The process is very simple and it is easy to reduce the arsenic concentration to less than 10ppb in a sustainable system. If the water is deficient in ferric, it can 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

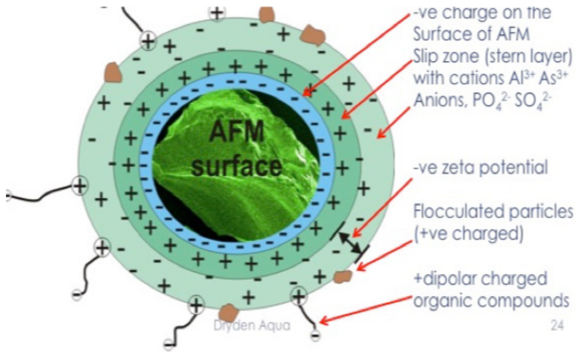
This is achieved through aeration of the water. The water is aerated for a period of no less than 30 minutes. If water flow is 50 m^3/hr the aeration level is 50m^3/hr of air and tank volume is 25m^3 of water. Dryden Aqua manufacture fine bubble drop in air diffusers for this application.

	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
Backwash water flow	>45m/hr	60m/hr	Backwash 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 stabilise after a backwash
Backwash frequency / per wk	1	7	Reduce backwashing to a minimum.

Annex 5: AFM® for 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 1μ when coupled with pre-coagulation and flocculation. The removal rate of organic and inorganic particulate phosphate will be >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;

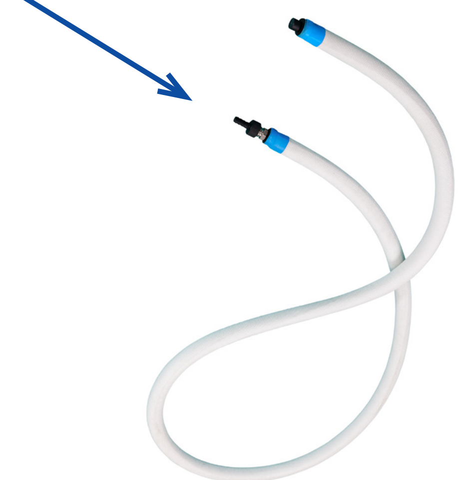
a. ferric to form ferric phosphate
b. magnesium to form struvite.
c. lanthanum to form lanthanum phosphate

At Dryden Aqua we have been using (a) 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, cavitating 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 cavitating 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® when combined with pre-oxidation by air is highly effective for the removal of ferric, arsenic and manganese and a good solution for the removal of the ferric phosphate salt.

Dryden Aqua fine bubble air diffusers



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 PO_4-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 $Co_3(AsO_4)^{2\cdot}8H_2O$ • Amblygonite $LiAlPO_4F$ • Lazulite $(Mg,FeAl_2(PO_4)2(OH)_2$	• Wavellite $Al_3(PO_4)_2(OH)_3\cdot 5H_2O$ • Turquoise $CuAl_6(PO_4)_4(OH)_8\cdot 5H_2O$ • Autunite $Ca(UO_2)_2(PO_4)_2\cdot 10\text{-}12H_2O$ • Carnotite $K_2(UO_2)_2(VO_4)_2\cdot 3H_2O$ • Phosphophyllite $Zn_2(Fe,Mn)(PO_4)_2\cdot 4H_2O$ • 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.

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 ratio 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 NH^3:Mg:PO_4 equates to 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 de-scaling.
6. Decantation may be required if the concentration of phosphate is above 5 mg/l as PO_4-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 ortho-phosphate is in development.)

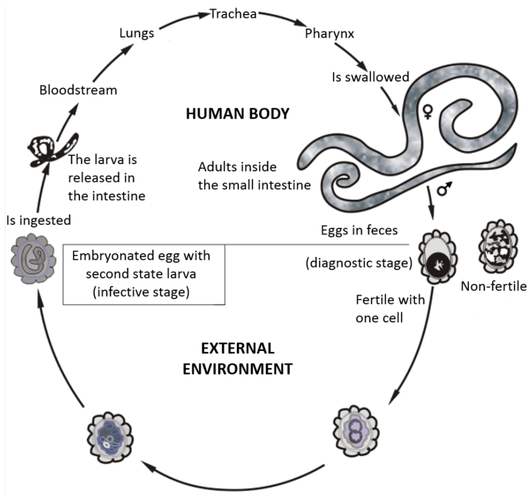
Annex 6: AFM® for parasitic nematode egg removal from waste water, and second use of water for irrigation

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 µ 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 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.



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

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 be 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.

DRYDEN AQUA

Annex 7: Calculation of bed depth for single media and multimedia filters allowing for expansion

Vertical Pressure Filter, Calculation of bed depth allowing for expansion

Good quality commercial filters must allow sufficient height above the filter bed to allow for media expansion during backwash plus some free-board to avoid loss of media. The allowable bed depth in order to avoid media loss can be calculated using the following formula:

Distance from laterals or nozzle plate to top collector (TC) - 17.5% = Bed Depth + expansion

N.B. This does not include media in the bottom of the filter, below the laterals.
For multimedia beds expansion should be calculated for each layer:

e.g. A DIN filter with 1.2m bed depth measures 1.7m from nozzle plate to top collector
With AFM grade 1 only we would normally design for 20% bed expansion

Therefore the calculation shows that, with a Bed Depth (BD) of 1.2m we need:

(Distance to Top Collector x 0.825) / 1.2 = Bed Depth

For a filter with a 1m bed depth then:

BD x 1.2 / 0.825 = TC

(1m x 1.2) / 0.825 = 1.45m

If you have a filter with 1.2m height from laterals to top collector then ::

$$\text{Bed Depth (BD)} = \frac{\text{TC x 0.825}}{1.2} = \frac{\text{1.2m x 0.825}}{1.2} = \text{0.825m}$$

Multimedia Beds

If we have a multimedia bed with 0.1m of Granulated Active Carbon (GAC) on top of AFM® Grade 1 then, we need to allow for 50% expansion of the Carbon layer and 20% of the AFM® layer. For a DIN standard filter with 1.7m from nozzle plate to top collector we therefore need:

TC x 0.825 = [(BD,AFM® x 1.2) + (BD, GAC x 1.2)]

So,

$$\text{BD AFM®} = \frac{\text{TC x 0.825}}{\text{1.2 + (BD, GAC x 1.5)}} = \frac{\text{1.7m x 0.825}}{\text{1.2 + (0.1 x 1.5)}} = \text{1.038m}$$

In reverse,

$$\frac{\text{[(BD AFM® x 1.2) + (BD, GAC x 1.5)]}}{0.825} = \text{1.69m}$$

Mixed AFM® Grade 1 and Grade 0 beds

If we have a multimedia bed with 0.20m of AFM® grade 0 on top of AFM Grade 1 then, we need to allow for 40% expansion of the AFM® grade 0 and 20% of the AFM layer. For a DIN standard filter with 1.7m from nozzle plate to top collector then:

TC x 0.825r = [(BD,AFM® Grade 1 x 1.2) + (BD, AFM® Grade 0 x 1.4)]

So,

$$\text{BD AFM® Grade 1} = \frac{\text{TC x 0.825}}{\text{1.2 + (BD, AFM® Grade 0 x 1.4}} = \frac{\text{1.7m x 0.825}}{\text{1.2 + (0.2 x 1.4)}} = \text{0.947m}$$

For practical purposes the difference between Grade 1 and Grade 2 expansions can be ignored. Otherwise, expansion ratios for each grade of AFM® at different temperatures can be determined by reference to the graphs on pages XX and YY

Manufacturer's data on expansion of GAC, anthracite or, any other media to be used in a mixed media bed should be consulted to determine bulk bed density (must be lighter than AFM) and, the applicable expansion coefficient.

Annex 8: 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	Required	Method of water analysis
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)

Metals	Required	Method of water analysis
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	Required	Method of water analysis
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	Required	Method of water analysis
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	Required	Method of water analysis
Gross Alpha and Beta	Optional	Proportional counting
Tritium	Optional	Distillation and scintillation counting

Annex 9: Water quality standards…Standards European and WHO drinking water quality

General Chemistry	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 $CaCO_3$	***	150 – 500
TDS	***	***

Cations (positive ions)	WHO standards	EU standards
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
Molybdenum (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)	WHO standards	EU standards
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
Sulphate (SO_4)	500 mg/l	250 mg/l
Nitrate (NO_3)	(See Nitrogen)	50 mg/l
Nitrite (NO_2)	(See Nitrogen)	0.50 mg/l

Microbiological parameters	WHO standards	EU standards
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 22°C	***	<100 in 1 ml
Colony count 37°C	***	<20 in 1ml

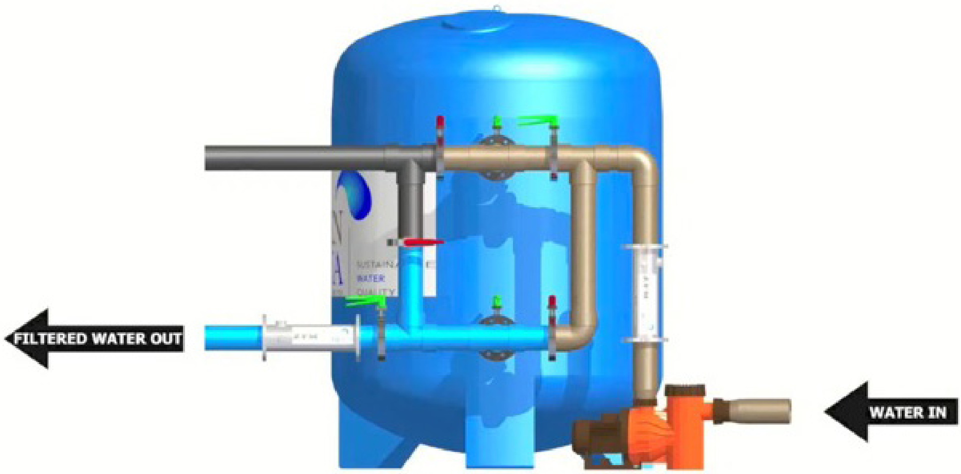
Other parameters	WHO standards	EU standards
Acrylamide	***	0.0001 mg/l
Benzene (C6H6)	***	0.001 mg/l
Benzo(a)pyrene	***	0.00001 mg/l
Chlorine dioxide (ClO_2)	0.4 mg/l	
1,2-dichloroethane	***	0.003 mg/l
Epichlorohydrin	***	0.0001 mg/l
Pesticides	***	0.0001 mg/l
Pesticides – Total	***	0.0005 mg/l
PAHs	***	0.0001 mg/l
Tetrachloroethene	***	0.01 mg/l
Trichloroethene	***	0.01 mg/l
Trihalomethanes	***	0.1 mg/l
Tritium (H_3)	***	100 Bq/l
Vinyl chloride	***	0.0005 mg/l

Drinking water Standards

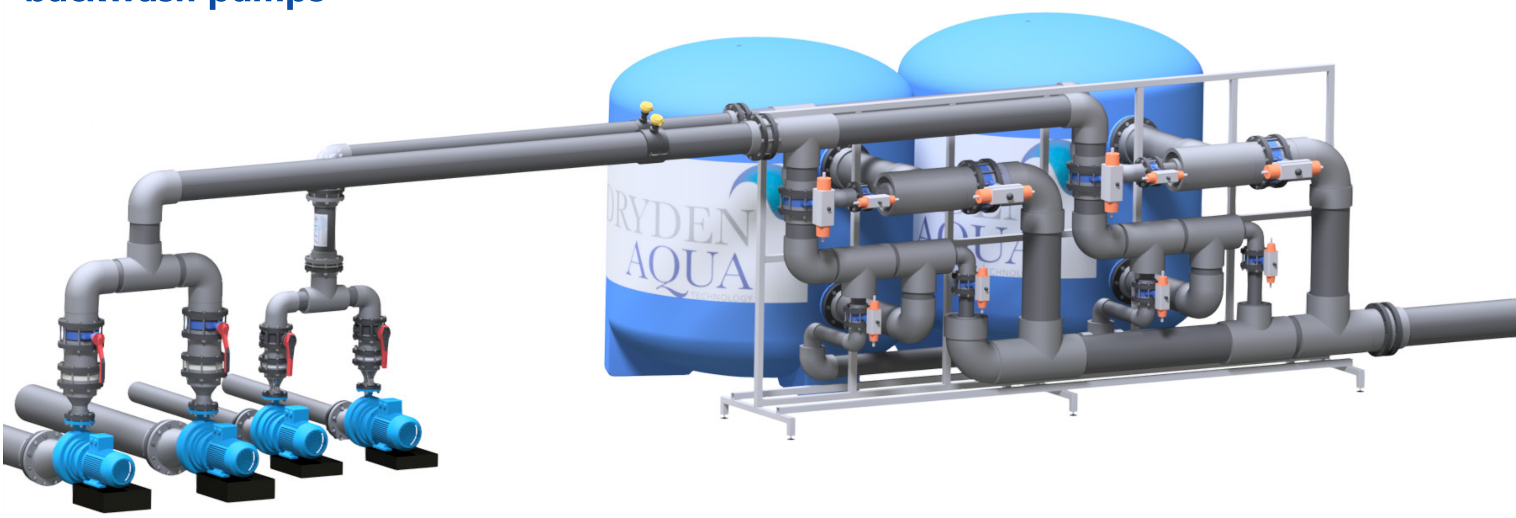
*** required but parameters have not been set

Annex 10: Pressure filter system schematics

5 Valve – Single Filter layout and multi filter configuration



Multi filter configuration with pneumatic actuated valves and separate backwash pumps



Annex 11: Description of Media Specification Terms

Granular filter media:

- A term used to describe particle shape and particle size distribution characteristics.

Particle shape:

- There are 3 ratios that are used. These are expressions of the dimensional (3D) values of the particles – length, width and depth. Being ratios, the values given for these expressions are dimensionless numbers.

Sphericity:

- A measure of the degree to which a particle approximates the shape of a sphere or a cube and is independent of its size. The sphericity of a sphere is 1.0. The adopted standard for the sphericity of glass grains is that the value should be ≥ 0.7.

Roundness:

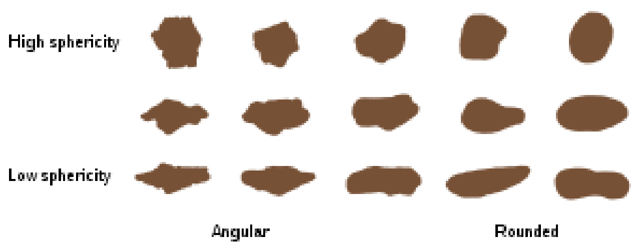
- A measure of the sharpness of a particle's edges and corners. This relates to angularity. Again, this ratio is a measure of the degree to which a particle approximates the shape of a sphere or a cube. The roundness of a sphere or cube is 1.0. The adopted standard for the roundness of glass grains is that the value should be ≥ 0.6.

Aspect ratio:

- A measure of the flatness and elongation of the particle. Therefore, this ratio is an expression of the length and the depth of the particles. Again, this ratio is a measure of the degree to which a particle approximates the shape of a sphere or a cube. The flatness ratio of a sphere or cube is 1.0. The adopted standard for the flatness of glass grains is that the value should be ≤ 5:1. In other words, the average flatness value for the measured sample of particles should indicated that particle length is less than 5 times the particle depth.

- The most simplistic consideration of these ratios is:
  - Sphericity = width / length
  - Roundness = depth / width
  - Aspect = length / depth

- All 3 of these ratios provide an indication of how well the granular material will perform as a filter media. The aspect ratio is particularly important in that very flat and elongated particles can, over prolonged backwashing, build up in the filter bed and create a 'mirror' layer. This 'mirror' layer can detrimentally affect the hydraulic flow performance, and hence the overall filtration performance, of the filter and may lead to hydraulic short-circuiting.

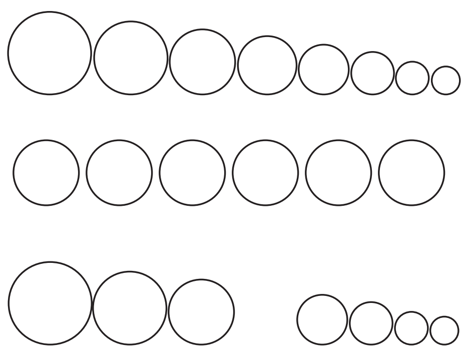


- The diagram right illustrates particle shape characteristics of sphericity in relation to roundness. The more the shape complies with the top right representation then the closer the 2 shape ratios are to 1.0. The more the particle shape complies with the bottom left then the more angular the particles become. This also illustrates the need to consider flatness.

Particle size distribution.

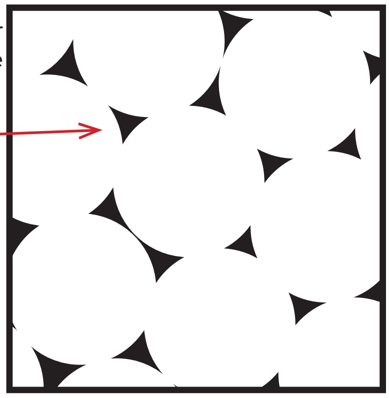
- An expression of how uniformly or non-uniformly a granular material is graded.

- The 3 main types are:
  - Well graded in terms of the spread of particle sizes.
  - Uniformly graded in terms of the same particle size.
  - Gap graded.



Uniformity Coefficient (UC):

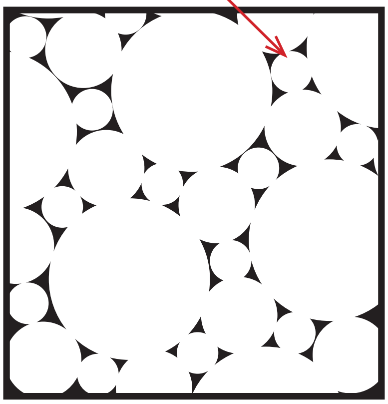
- a value describing the range of grain sizes that are present in a sample. The lower the UC value then the more tightly graded the material is in terms of size. The more uniformly graded the media then the more uniform is the interstitial porosity:



Interstitial pores

- This uniformity means, for example, that it is easier to predict the filtration and hydraulic performance of a filter. So, engineers would tend to use tightly graded media to address specific filtration needs. So, they would specify Uniformity Coefficient and Effective size values.

- Where the media is well graded in terms of size, then the interstitial porosity becomes much more variable. This results in improved filtration performance in terms of the size range of waste particles removed:



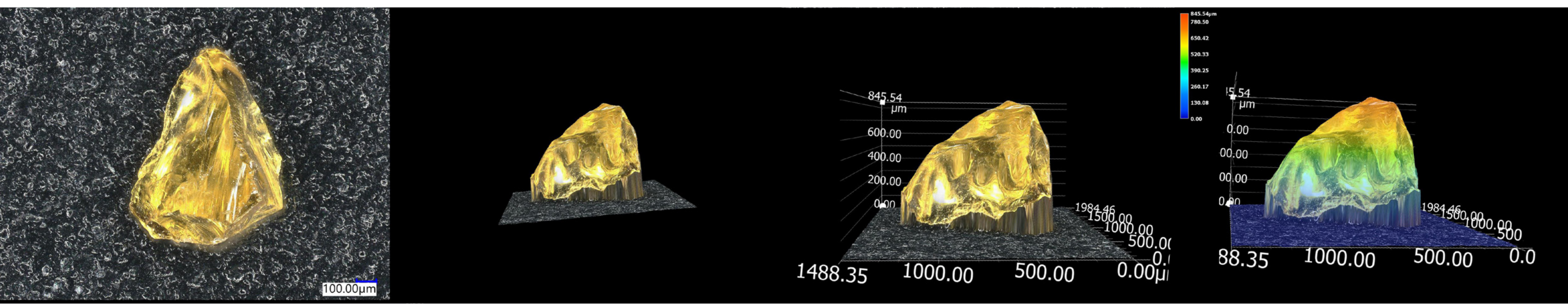
Uniformity Coefficient (UC)

- is calculated by using the following equation:
    - D60/D10 = UC
    - Where D60 = mesh size (mm) at which 60% of the media passes through
    - D10 = mesh size (mm) at which 10% of the media passes through

Effective Size (ES)

- = D10 = mesh size (mm) at which 10% of the media passes through
- Effective size is a value basically describing the average of grain sizes present in a sample. This is not to be confused with D50 which is often considered to be the average particle size in a sample.

Topography of an AFM grain



Annex 12: Glossary of Technical Terms

Nominal Filtration

- Ability to extract (filter out) more than 90% of particles on any given particle size.

Log 2 reduction

- Ability to extract (filter out) more than 99% of particles on any given particle size.

Log 3 reduction

- Ability to extract (filter out) more than 99.9% of particles on any given particle size.

SDI - Silt Density Index

- A measure for the fouling capacity of water in reverse osmosis systems. The test measures the %age drop in flowrate per minute averaged over 15 mins for blockage of a 0.45 micron filter when subjected to a pressure of 30 psi.

BOD - Biochemical (Biological) Oxidation Demand

COD - Chemical Oxidation Demand, same as KMnO4

Turbidity – nephelometric, reflected light, P.BOD = turbidity/2 + 5

TOC - Total Organic Carbon

SOC – Suspended Organic Carbon

SIC - Suspended Inorganic Carbon

NPOC – Non Purge-able, Acidified

VOC – Volatile Organic Carbon (purge-able)

TIC - Total Inorganic Carbon

TDC – Total Dissolved Carbon

DOC – Dissolved Organic Carbon

TSS - Total Suspended Solids

TDS - Total Dissolved Solids

AOX - activated carbon Absorbable Organic Halides, halide organic chemicals e.g. PCB's, ...AFM ng may adsorb.

POPS - Persistent Organic Pollutants

pH - hydrogen ion concentration pH 7 = 10 -7 moles (6.02 x 10 23) of H+

EC - Electro Chemical potential

RedOx – Reduction/Oxidation potential in milli volts

Zeta Potential – electrical charge potential on particle

The new AFM® factory in Switzerland