AFM®

ACTIVATED FILTER MEDIA

Water Treatment Instructions for Use

- Surface water and ground water treatment
- Drinking water treatment
- Pre-treatment prior to reverse osmosis
- Industrial process water & waste water treatment
- Municipal waste water treatment

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Activated Filter Media AFM® Benefits

- Direct replacement for sand in any type of sand filter
- Doubles the filtration performance of a sand filter by way of a simple media change
- AFM®-ng removes particles up to 1µm as well as dissolved organic components, hydrocarbons and micro-plastics
- Effective removal of most protozoa, fungae, *Cryptosporidium* and bacterial flocs
- Highly improved SDI when used in the pre-treatment to reverse osmosis desalination process
- Bio-resistant, will not support bacterial growth => no biofilm formation on AFM® surface
- Upt to 50% reduction in backwash water consumption
- Manufactured to a precise specification under ISO-9001-2015
- NSF-61 certified for use in drinking water treatment
- HACCP certified for food & beverage production
- AFM® market proven performance >15 years without media replacement

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1. AFM® Introduction

Research & Development

AFM® is the product of more than 30 years of research and development by Dr. Howard T Dryden. AFM® activated filter media was developed as a means of resolving the deficiencies incumbent with conventional filter media such as quartz sand.

The technology is perfectly adapted to any type of media filter 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.

AFM® is a highly engineered product manufactured from a specific glass type, processed to obtain the optimum particle size and shape. It is then exposed to a unique 3-step activation process to become self-sterilising and to acquire superior filtration properties. During activation, the structure and the chemistry of the glass are modified.

Guarantee statement

The performance of AFM® has been independently tested and verified. Test reports are available on our website www.drydenaqua.com. 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 in 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.

Sustainability

- AFM is manufactured from 100% recycled bottle glass from the region.
- The production process is 100% energy and water self-sufficient, using rainwater in a closed-loop filtration system and up to 1,200,000 kWh self-generated solar power per year.
- Waste (metal, paper, plastic) and non-target product (flint glass, CSP, fines) are separated and recycled or used in other industries. Sludge is responsibly disposed of.
- The life cycle of AFM is many times longer than quartz sand. Many AFM installations will last 20 years and longer.
- When the end of the life cycle of AFM has been reached, we encourage customers to use our simple and cost-effective take-back process, by returning the used AFM in re-useable packaging back to our factories.
- Like recycled bottle glass, the returned AFM will undergo the same process of cleaning and decontamination and will be either re-manufactured into new AFM or -if undersized – it will be recycled or used in other industries.

AFM is manufactured from 100% recycled bottle glass from the region

The production process is 100% energy and water self-sufficient, using rainwater in a closed-loop filtration system and up to 1,200,000 kWh self-generated solar power per year

Waste (metal, paper, plastic) and non-target product (flint glass, CSP, fines) are separated and recycled or used in other industries. Sludge is responsibly disposed of (incinerator)

Once AFM has reached its end of life, it can be returned to the Dryden Aqua factory where it will undergo the same process of cleaning and decontamination and is re-manufactured into new AFM

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Manufacturing process

Dryden Aqua owns and operates the 2 most sophisticated glass reprocessing facilities in the world; in Scotland and Switzerland. We optimise every part of the process to make the best material available, with the best shape and size for use in the applications. We ensure that our product has no sharp edges that can injure you or damage the filter. View a video of our production facilities via our website at www.drydenaqua.com

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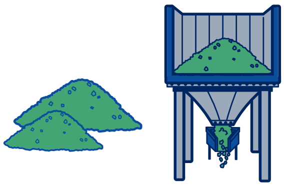

MADE FROM RECYCLED GLASS

When mining sand, landscapes are destroyed and entire ecosystems disappear. Processing and transport are energy inefficient. AFM® is manufactured from recycled glass, a raw material that already exists and needs to be reused.

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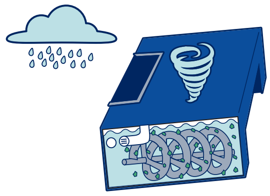

THE PUREST GLASS

AFM® is cleaned, washed and sterilized to become the purest glass filter media on the market with a maximum loose organic contamination of less than 10g/ton. Normal glass sand has up to 20,000g/ton.

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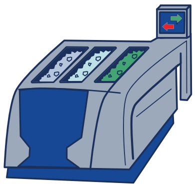

CAREFULLY SELECTED

We only use green and brown glass in the manufacture of AFM® because white (clear) glass does not contain the metal oxides needed to make the media self-sterilizing. AFM® contains more than 98% green and brown glass.

4

OPTIMUM SIZE & SHAPE

The grading process of AFM® has been engineered to obtain a precise consistent particle size and shape. The sphericity and uniformity coefficient are crucial for the outstanding hydraulic properties of AFM®.

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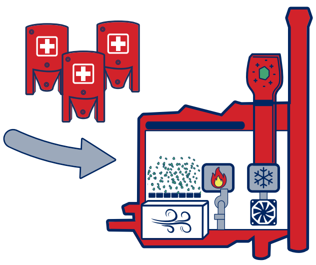

UNIQUE ACTIVATION PROCESS

The raw AFM® goes through a unique three-step chemical and thermal activation process. The Activation is the reason for its bio-resistance and superior filtration properties. The surface of AFM®ng becomes hydrophobic.

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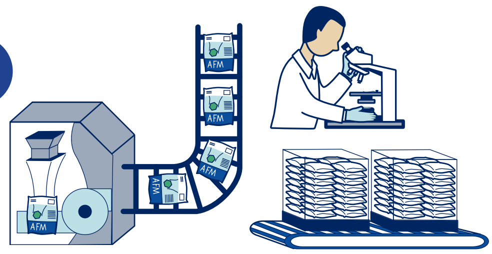

PACKAGING & QUALITY CONTROL

AFM® fully automated packaging system delivers 25 pallets/hour (40 bags/pallete or 1 big bag/palette). An integrated quality control and ISO management system guarantees a consistent and high quality product..

Learn how AFM® is produced - Take a virtual tour through our factory

Quality and Certification

AFM® is manufactured to a precise specification and ISO certified management control system

AFM is tested and Certified by WQA to NSF/ANSI/CAN 61 and NSF/ANSI/CAN 372 for material requirement(s) only. Drinking Water Systems Components

UK Drinking Water Inspectorate

Approved for use in Food production

ISO Quality & Environmental Management System

Global leading French Institute for Filtration & Separation Technology testing

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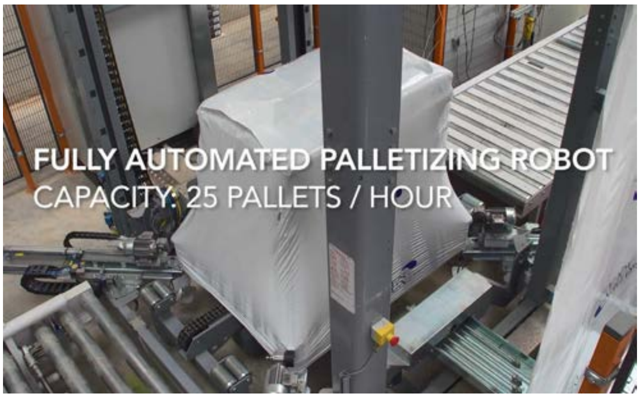
Fully Automated Filling and Packaging Plant



AFM® Factory in Bonnyrigg, Scotland

AFM® Factory in Büsserach, Switzerland

Learn how AFM is produced, take a virtual tour in our Swiss factory.

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2. AFM® Properties and Specification

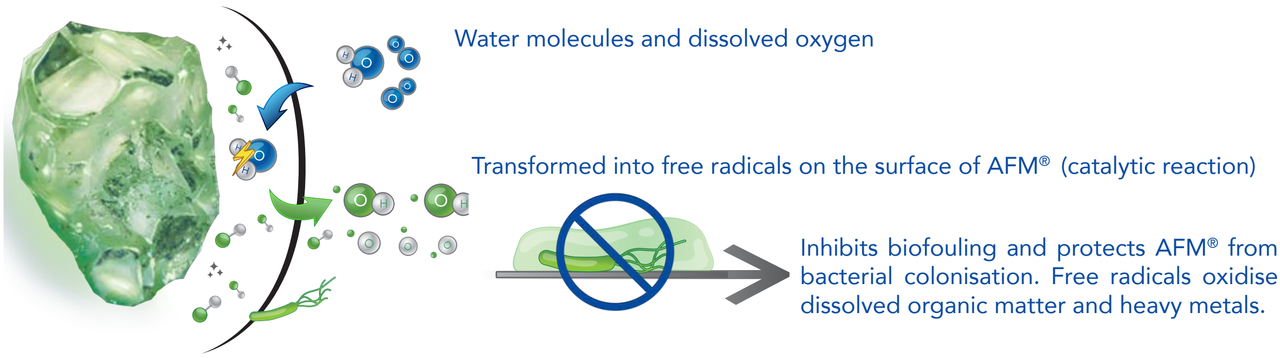
AFM® is an inert, amorphous aluminosilicate (glass) manufactured by up-cycling post-consumer green and brown glass bottles in dedicated, state-of-the-art factories designed and operated specifically for the production of activated glass water filtration media. AFM® is used as filter media in single or dual media filtration in both open (RGF) and closed (pressure) filters for treatment of various sources of water such as ground water, surface water, seawater and waste water treatment.

Description

AFM® particle shape and size distribution are optimised for filtration. AFM® is not a passive filter media, the surface is activated by using a secret formula of chemicals and heat in a SolGel-like process, where the surface structure of each grain of media is altered to control the surface properties:

AFM Type & Surface Properties

Self-sterilizing surface resistant to bacterial growth

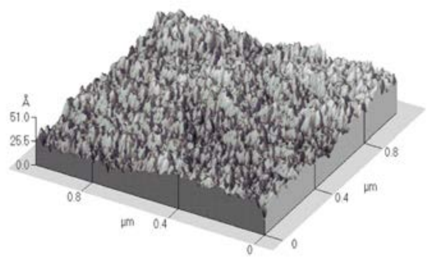


Increased surface area for superior filtration

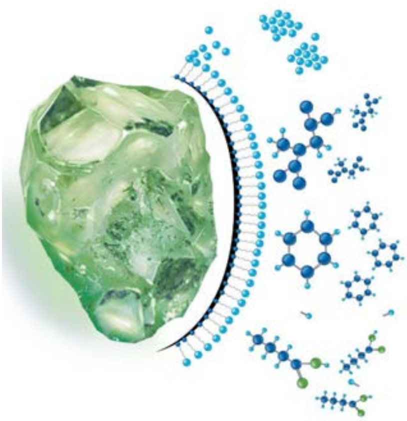
Large surface area provides for superior mechanical filtration

Optimal sphericity, uniformity coefficient, particle size and shape of grain for best hydraulic performance (not round, not flat, no broken bits of glass)

Surface Area by Langmuir Isotherm Method
1’000kg: AFM = 50.000 m² / Sand 3.000 m²



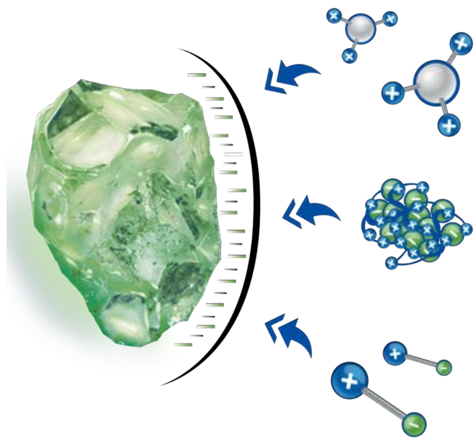
AFM®ng
Hydrophobic, neutral surface charge



Superior mechanical filtration up to 1µm particles (95% removal)

Adsorption of organic substances including Hydrocarbon and Microplastic

AFM®s (Standard)
Negative surface charge



Superior mechanical filtration up to 4µm particles (98% removal)

Adsorption of positively charged particles, flocs and metals (Fe, Mn, As)

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AFM® Grades & Specification

AFM Grades

AFM®s (Standard) negative surface charge
- AFM®s Grade 0
- AFM®s Grade 1
- AFM®s Grade 2
- AFM®s Grade 3

AFM®ng hydrophobic surface property
- AFM®ng Grade 1
- AFM®ng Grade 2
- AFM®ng DIN

The particle shape of AFM® is controlled to maximise surface area, suspended solids removal and to minimise pressure differential and filter 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. Through an innovative and proprietary activation process, AFM® obtains unique surface properties including negative or neutral surface charge and hydrophobicity.

While a high sphericity can be 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 which is frequently the case with conventional quarried filter media such as silica/quartz sand.

AFM® is an advanced, unique manufactured product allowing an optimized particle size distribution and shape which improves filtration performance especially related to superior particle removal efficiency and high filtration velocity.

AFM Specification

Specification	Grade 0	Grade 1	Grade 2	Grade 3	DIN	Standard
Particle size	0.25 - 0.5 mm	0.4 - 0.8 mm	0.7 - 2.0 mm	2.0 - 4.0 mm	0.7-1.2mm	ISO 13322-2
Undersized	≤ 5 %	≤ 5%	≤ 10%	≤ 10%	≤ 10%	ISO 13322-2
Oversized	≤ 5 %	≤ 5%	≤ 10%	≤ 10%	≤ 10%	ISO 13322-2
Effective size (expressed as d10)	0.26 mm	0.41 mm	0.78 mm	2.3 mm	0.79 mm	ISO 13322-2
Hardness	5.5 - 7.0 mohs					ASTM C-730
Sphericity x (average) : 1	0.77	0.79	0.80	0.81	0.80	ISO 13322-2
Uniformity coefficient (d60/d10)	1.4 - 1.8					ISO 13322-2
Roundness	0.65 - 0.68					ISO 13322-2
Aspect ratio	2.25					
Organic contamination	< 50 g/mt					
Coloured glass (green/amber)	> 98 %					
Specific gravity (grain)	2.4 - 2.52 kg/l					GTS QP9*
Embodied energy kW/1000kg	< 72	< 65	< 50	< 50	< 50	
Porosity** (%) (calculated, uncompacted)	50 ± 2	46 ± 2	43 ± 2	42 ± 2	45 ± 2	ASTM D-7263
Porosity** (%) (calculated, compacted)	40 ± 2	38 ± 2	37 ± 2	37 ± 2	37 ± 2	ASTM D-7263
Uncompacted Bulk bed density	1.24 kg/l	1.33 kg/l	1.40 kg/l	1.43 kg/l	1.36 kg/l	EN 12902:1999
Attrition	< 1 % (50 % bed expansion, 100h backwash).					
Product Picture						

The values given in the table above express the typical range. If required for hydraulic calculations specific values must be stated by the purchaser or must be determined.

* Glass Technology Services, Sheffield, UK procedure QP9 - 'X-ray fluorescence analysis - predictive density measurement'

** Porosity - calculated using average bulk density and average particle density

AFM Chemical composition

Chemical composition of all AFM® types and 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:

Free Chlorine	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
Alkali resistance	A1 (ISO 695)
Acid resistance	S2 (DIN 12116)
Hydrolytic resistance	Class 2 (ISO 720)

Salinity & TDS
Salinity and high TDS concentrations have no phyiscal or chemical effect on AFM®. AFM® is used for marine applications with up to 40g/l and for some systems up to 165g/l

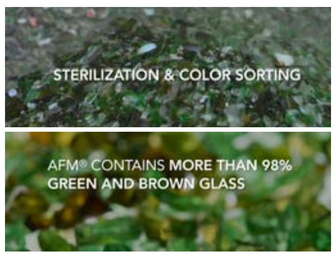
Temperature
AFM® is not affected by temperature, as long as the water is liquid then AFM® may be used.

Temperature range	0 to 100°C

Chemical resistance
AFM® is chemically resistant to all solvents and hydrocarbons.

Purity

During the manufacturing process, AFM® is exposed on two locations to temperatures over 500°C. The product is cleaned and sterilised, with organics are reduced to less than 50 g/mt.



3. AFM® 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:

- 1000 kg big bag with bottom discharge on one CP1 pallet 1200 x 1000mm delivered in full truck loads of 24 pallets or in 40ft container loads of 20 pallets
- 25 kg plastic bag - 40 bags 1000kg on one CP1 pallet 1200 x 1000mm
- 21 kg plastic bag - 40 bags on one EUR-1 pallet 1200 x 800mm
- AFM® or 21 kg are delivered in full truck loads of 24 x CP1 pallets (25 kg bags) or 28 x EUR-1 (21 kg bags) and in 20ft container loads of 20 pallets CP1 or EUR-1 pallets.

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

1 tonne big bag label is attached to each bag providing the same information as the plastic bags

Product codes

	Product order codes				
	Grade 0 0.25 - 0.50mm	Grade 1 0.40 - 0.8mm	Grade 2 0.7 - 2.0mm	Grade 3 2.0 - 4.0mm	DIN 0.7 - 1.2mm
AFM®s 21 kg (46 lbs) bag	10030	10031	10032	10033	n/a
AFM®ng 21 kg (46 lbs) bag	n/a	10021	10022	n/a	n/a
AFM®s 25 kg (55 lbs) bag	10000	10001	10002	10003	n/a
AFM®ng 25 kg (55 lbs) bag	n/a	10005	10006	n/a	10007
AFM®s 1 mt (2,200 lbs) big bag	10010	10011	10012	10013	n/a
AFM®ng 1 mt (2,200 lbs) big bag	n/a	10015	10016	n/a	10017

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 dry place. AFM® may be stored outside. If stored outside it should be protected from the elements by covering with a tarpaulin. 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. AFM® is a circular economy product and should ideally not be sent to landfill.

4. AFM® Filter loading, commissioning and decommissioning

Dust handling

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 of AFM® is considered safe, however, precaution should be taken when handling the material, especially in confined spaces. Please consult the AFM safety data sheet for detailed product and handling information.

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 standard but AFM® may be used in any type of sand filter.

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

Filter bed depth may range from 500mm to 1500mm (20" - 60"). If the filter complies to German DIN, it will have a bed depth from 1200mm to 1500mm (48" - 60").

There will be a variation in quality and performance of different types and manufacturers of filters. Regarding filtration and backwash performance, vertical filters are always better than horizontal filters, and filters with a nozzle distribution plate are preferred over laterals.

Transferring AFM® to the filter

AFM® may be transferred manually to the filters by emptying the plastic bags, or 1 tonne (2200 lbs) big bags directly into the filter in accordance with the filter manufacturer's filling instructions or the procedure below.

Water can be used to transfer the AFM® from bulk tanker into the filter. Alternatively, compressed air combined with water may be used to transfer the AFM®. Do not use compressed air to transfer the AFM® without water. There may be attrition of AFM® if air is used for transfer.

How to fill and commissioning your filter

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.

The larger grades are added first. See following pages for AFM layering details in horizontal, vertical and rapid gravity filters (Tables 1 - 3). For filters with laterals, we recommend covering the laterals with Grade 3 to allow an equal water distribution.

After the addition of each layer, it is important to make sure that the AFM® is evenly distributed and the bed is flat. Once all the AFM® layers are in place, perform a backwash at the recommended backwash flow rate (see table 5, page 18). Continue to backwash(s) until the water runs clear out of the filter.

If AFM®-ng is used it is required to wet the hydrophobic surface. This requires AFM®-ng to be fully submerged in water and soaked overnight (>12h) prior to first backwash (see table 5, page 18). Optionally the AFM®-ng can be rinsed to drain for >10min at >15m/h or >30min at 5m/h linear flow velocity. After the wetting proceed continue to backwash(s) until the backwash water runs clear out of the filter.

After the backwashing is completed, the AFM® should be rinsed to drain until the required water quality is achieved. The filter may be switched to filtration mode once the rinsing is completed.

The bed is now ready for service, however before going online with a drinking water network, it is good practice to conduct a water analysis to verify quality is in line with corresponding drinking water regulation.

Decommissioning / Mothballing and recommissioning a filter

AFM® filters should be operated continuously. They should not be stopped for a long time or allowed to go anaerobic. If the filters must be turned off for a long period (mothballing), the following procedure should be used.

Prior to turning off (mothballing) an AFM® filter must be thoroughly backwashed, and then disinfected soaking with Chlorine Dioxide or similar chemical for 30--60min, followed by another backwash. After the backwash, the water should be drained from the filter and the drain left open.

Prior to recommissioning the filter must be disinfected again, then backwashed for a period of 5 minutes followed by a rinse phase

For questions related to extended period of shut-down contact Dryden Aqua technical support at info@drydenaqua.com

5. AFM® Filter media layering

The following table is for guidance only, as percentages will differ depending on filter type and manufacturer. It is recommended to use filter manufacturer's dimensions (drawings) to determine AFM® media volumes and apply recommended ratios of AFM® support media and filtration grades. It is not recommended to use other media as the supporting layer as these will allow for bacterial growth on it and compromise the anti-bacterial benefits of using the AFM® above it.

Anthracite may be used on top of the AFM® to extend the filtration period between backwashs and allow the AFM® to cope with high loadings of solids (>30ppm TSS). A layer of ca. 200mm Granulated Activated Carbon (GAC) may be used on top of the AFM® for de-chlorination, de-colourisation and dissolved organics removal. GAC is not used for suspended solids removal.

Vertical Pressure Filter

Vertical filters manufactured to DIN standards with nozzles provide best filtration efficiency and deliver the best result AFM® can achieve. However, filters with well designed lateral system (close together and as close to the filter walls as possible), can achieve near nozzle quality filtration performance

Horizontal Pressure Filter

Horizontal pressure filters provide more filter bed surface 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. Horizontal sand filters have the advantage of lower cost per m^2 of filter surface area, but filtration and backwash performance is compromised, in comparison to vertical pressure filters.

Rapid Gravity Filters (RGF)

RGF's are often used in municipal ground and surface water and industrial process water treatment as well as in desalination pre-treatment where RGF is often combined with pressure (media) filtration followed cartridge filter and reverse osmosis membrane (desalination) process. At the slower filtration velocity that RGF usually operate (ca. 5-8m/h), they can often out perform vertical and horizontal pressure filters from a particulate and fine particle retention perspective.

Table 1: AFM® media ratio

- AFM® filter bed depths as a guidance for layer height in percentage for the different AFM® grades to be adjusted in function of the total filtration bed depth, filter dimensions and as required for the intended application. AFM®s Grade 3 must always cover the laterals.
- Depending on application (table 5, page 18) the filtration bed depth (layers above lateral or nozzle plate) typically ranges from 500 mm to 1500 mm. AFMng/s Grade 1 minimum bed depth must be 500mm. See annexes for instruction on AFM® use in different applications.

AFM®ng and AFM®s Media Ratio	Support(1)	Filtration(3)			
	AFM®s Grade 3 2 - 4 mm	AFM®ng / s Grade 2 0.7 - 2.0 mm	AFM®ng / s Grade 1 0.4 - 0.8 mm	AFM®s Grade 0 0.25 - 0.5 mm	Anthracite(2)
With and without flocculation					
Pressure filters, with laterals	Up to/above lateral*	30-40%	60-70%	20-30%	-
Pressure filters, with nozzle plate	-	30-40%	60-70%	-	-
Multi-layer with Anthracite – with & without flocculation					
Pressure filters, with laterals	Required*	30-40%	50-60%	-	100 - 250mm
Pressure filters,	-	30-40%	50-60%	-	100 - 250mm
Fine particle removal with AFM®s Grade 0 – without flocculation					
Pressure filters, with laterals	Required*	20-30%	40-50%	20-30%	-
Pressure filters, with nozzle plate	-	20-30%	40-50%	20-30%	-
Fine particles removal with AFM®s Grade 0 and Anthracite – with & without flocculation					
Pressure filters laterals	Required*	20-30%	30-40%	20-30%	100 - 250mm
Pressure filter with nozzle plate	-	20-30%	30-40%	20-30%	100 - 250mm

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Notes.

(1) Pressure filter with laterals: AFM® Grade 3 is the recommended support layer to fill the space below and to cover the laterals. Use the filter dimensions (ask the filter manufacturer) to calculate the required AFM® Grade 3 support volume or ask Dryden Aqua for advice.

Filters from different manufacturers will have different dimensions and may require different proportions of each grade. The above layering relates to commercial filters that respect the Klopper standard for steel and, the Korboggen standard for (GRP) filter housing design, as well as for rapid gravity filters.

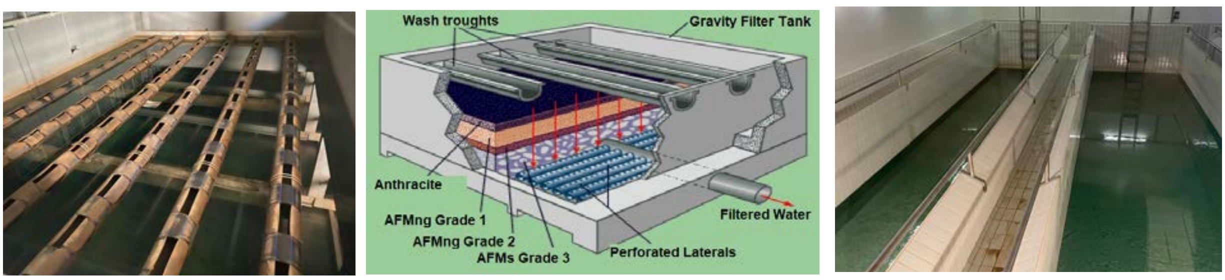
(2) For heavy loads of solids above 30mg/l, a 100 to 250mm layer of anthracite with 0.6 to 1.6mm is recommended on top of AFM® Grade 1 or AFM® Grade 0.

(3) For filter bed design, consider application specific filtration and backwash velocity (Table 5, page 16), recommended backwash velocities to achieve the correct bed expansion (Table 6, page 22) and filtration suspended solids loading capacity (Table 4 page 15)

Vertical Pressure Filters

Horizontal Pressure Filters

Rapid Gravity Filters (RGF)



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Standard mixed bed layering with AFM®ng Grade 1 and Grade 2

The best overall AFM® filtration performance is achieved when AFM®ng Grade 1 and AFM®ng Grade 2 is combined in a mixed bed layering. This allows to reach a high particle retention capacity at lowest differential pressure (energy saving) and optimized backwash performance due to improved filter bed expansion at lower backwash velocity (energy and water savings).

Depending on total filter media height the below AFM®ng or AFM®s layering is recommended.

Filters < 800mm

- 60% — **GRADE 1** (ng) 0.4 – 0.8 mm
- 40% — **GRADE 2** (ng) 0.7 – 2.0 mm

Filters > 800mm

- (ng) **GRADE 1** 0.4 – 0.8 mm — 60%
- (ng) **GRADE 2** 0.7 – 2.0 mm — 20%
- **GRADE 3** 2.0 – 4.0 mm — 20%

AFM®s Grade 3 is only used in pressure filters with laterals

AFM® Pressure Filter, Calculation of bed depth allowing for expansion

Filters must allow sufficient height above the filter bed to allow for media expansion during backwash plus some (ca. 200mm) free-board to avoid loss of media. Manufacturer's data on expansion of anthracite, GAC or, any other media on top of AFM® in a mixed media bed should be consulted to determine bulk bed density (must be lighter than AFM) and the applicable expansion coefficient.

The following formula can be used to calculate the allowable AFM bed depth in order to avoid media loss. Expansion ratios for each AFM® Type and Grade of at different backwash velocities and temperatures can be determined by using the backwash bed expansion graphs as shown on pages 23

To calculate the filter bed depth and consider the bed expansion during backwash, measure the distance from laterals or nozzle plate to top collector (TC) and deduct 17.5% required free-board from the measured distance. This is to prevent the loss of media during backwash. The free-board is the free space of the expanded filter bed to the top collector (TC) during backwash

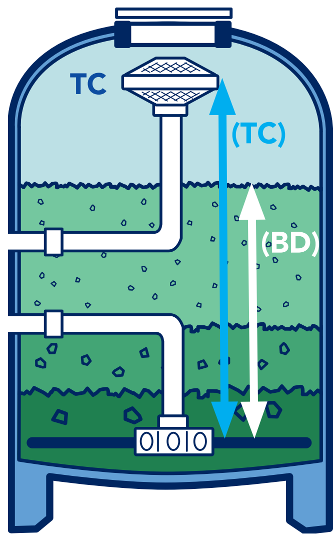
Bed depth does not include media in the bottom of the filter, below the laterals.

Filter bed calculation example:

- TC of 1.6m from nozzle plate to top collector
- 20% backwash bed expansion for AFM®

TC x 0.825 (17.5% freeboard) / 1.2 (20% bed expansion) = Bed Depth (BD)

$$\text{Bed Depth (BD)} = \frac{1.6\text{m} \times 0.825}{1.2} = 1.1\text{m}$$



Simple rule to calculate TC by expanded media bed height and free board
Calculate bed depth (BD) + 20% bed expansion and add a 200mm free-board to avoid loss of media during backwash.

Using multiple AFM® grade layers in your filter, bed expansion should be calculated for each layer using the AFM® backwash bed expansion graphs on page 23.

For multimedia bed using Anthracite or Granular Activated Carbon (GAC) read Annex 2, "AFM® dual-media beds - Anthracite & Activated Carbon" on page 28.

Filtration suspended solids loading capacity

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 differential pressure has increased by 500mbar. For a stable and long term AFM® performance, a backwash is recommended after a period of 1 week operation.

Taking 8 hours as the shortest backwash frequency the maximum solids load capacity in mg/l suspended solids (SS) is given in table 4a and 4b each using a different test dust having a different particles size distribution and which are ues to to simulate the particle "contaminants" to be removed during filtration.

Table 4a - Filtration suspended solids loading capacity using ISO A4 test dust (2)

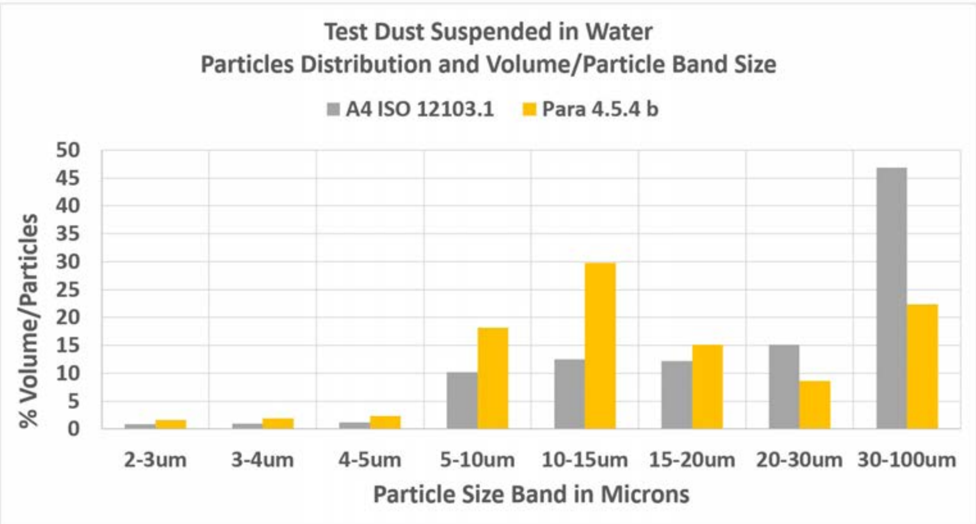
Filtration Velocity m/h	AFM-s Grade 0			AFM-s / AFM-ng G1			AFM DIN	
	mbar (1)	mg/l ss (2)	mg/l ss (2) Anthracite 0.6-1.6mm 250mm	mbar (1)	mg/l ss (2)	mg/l ss (2) Anthracite 0.6-1.6mm 250mm	mbar (1)	mg/l ss (2)
5	70	33	131	30	68	272	20	158
10	130	16	65	65	34	136	30	79
15	210	11	44	75	23	90	40	53
20	310	8	33	110	17	66	55	40
25	370	7	26	130	14	54	70	32
30	430	5	22	170	11	45	90	26

Table 4b - Filtration suspended solids loading capacity using Para test dust (2)

Filtration Velocity m/h	AFM-s Grade 0			AFM-s / AFM-ng G1			AFM DIN	
	mbar (1)	mg/l ss (2)	mg/l ss (2) Anthracite 0.6-1.6mm 250mm	mbar (1)	mg/l ss (2)	mg/l ss (2) Anthracite 0.6-1.6mm 250mm	mbar (1)	mg/l ss (2)
5	70	66	262	30	113	260	20	368
10	130	33	131	65	56	128	30	184
15	210	22	87	75	38	84	40	123
20	310	16	66	110	28	64	55	92
25	370	13	52	130	23	52	70	74
30	430	11	44	170	19	40	90	61

Notes:
(1) Differential pressure against flow velocity for a clean AFM® bed with 1000mm bed depth.

(2) The above suspended solids removal figures have been established on laboratory trials using ISO A4 SO 12103-1 (Table 4a) and Para 4.5.4 b -Top-3-2-045:2007 (Table 4b) test dust particles. In practise, depending on the nature of the feed water, these SS load rate figures can be up to 50% higher at same or reduced filtration velocities.



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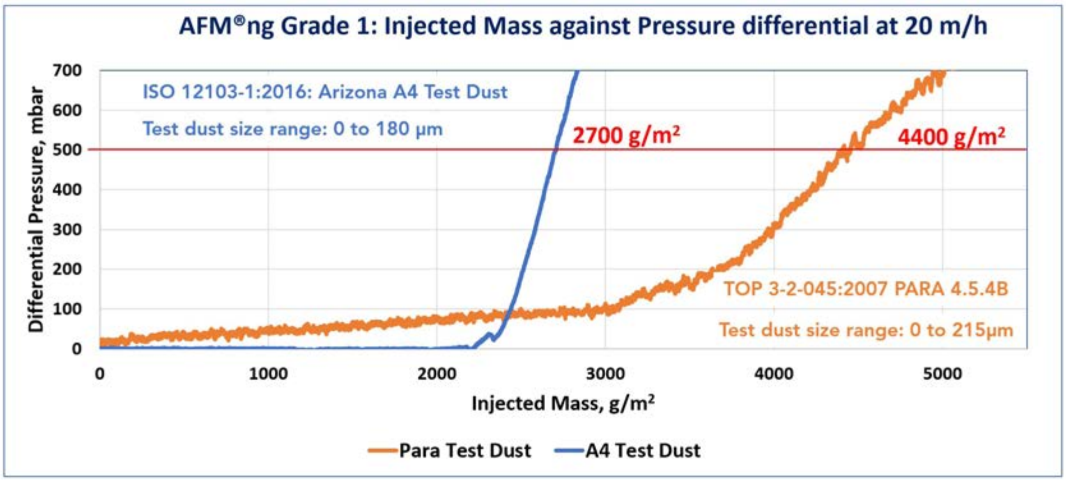
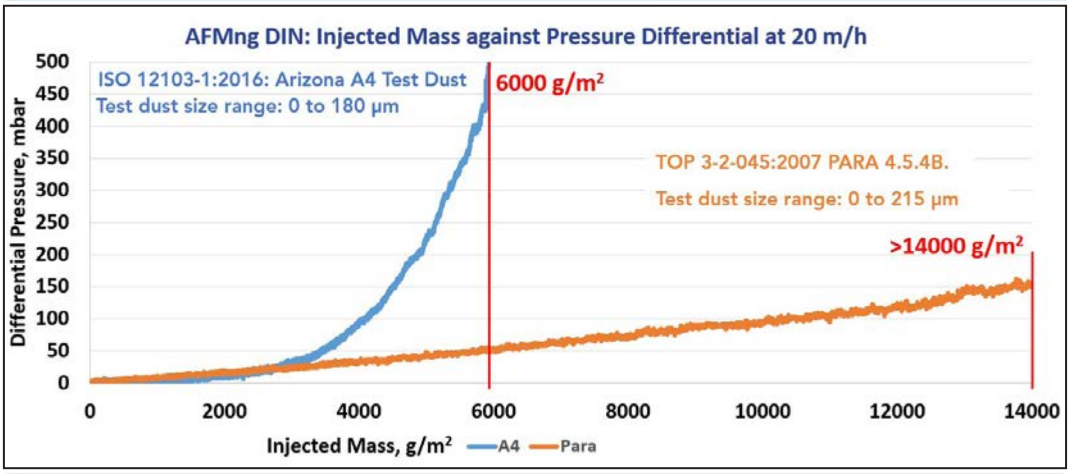
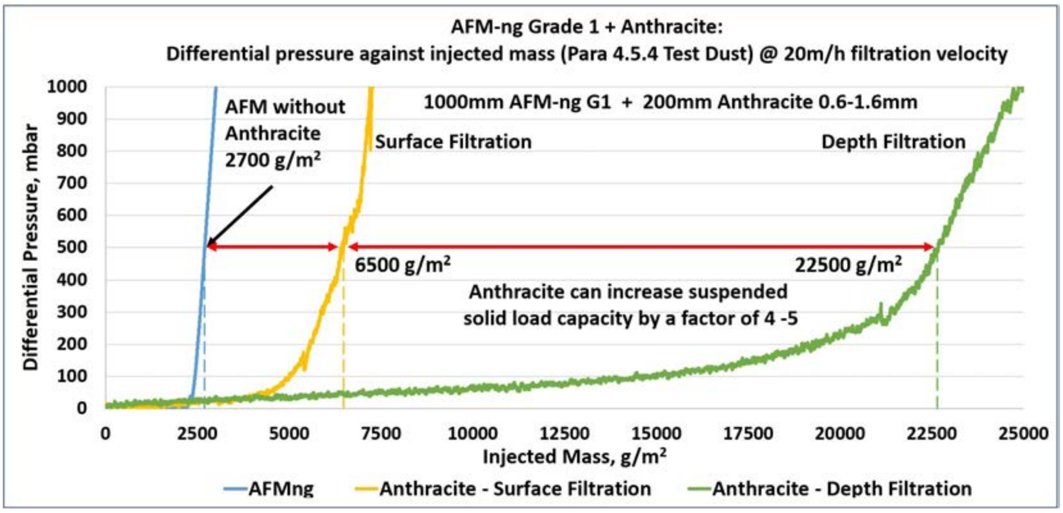
Differential pressure against injected mass

The following graphs present the run phase differential pressure across the bed at 20m/hr, and the mass of solids removed by AFM®. The loadings were generated using engineered A4 ISO 12103-1 and PARA 4.5.4B test dust (particles).

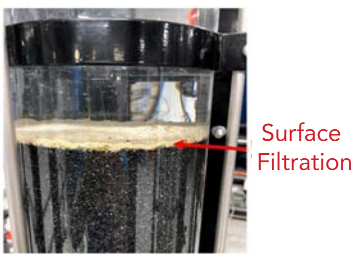
The loading capacity relates to the size of the particles and their mechanical properties and where in practical applications, the loading rate at 500mbar pressure increase (from new AFM or after backwash) reaches 2.7-4.4 kg/m² for AFM® Standard Grade 1 and AFM® ng Grade 1 and for AFM® DIN reaches 6->14kg./m².



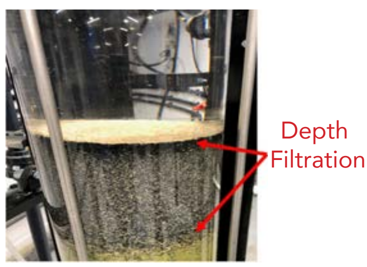




AFM + Anthracite Surface Filtration



AFM + Anthracite Depth & Surface Filtration



6. Filtration mode

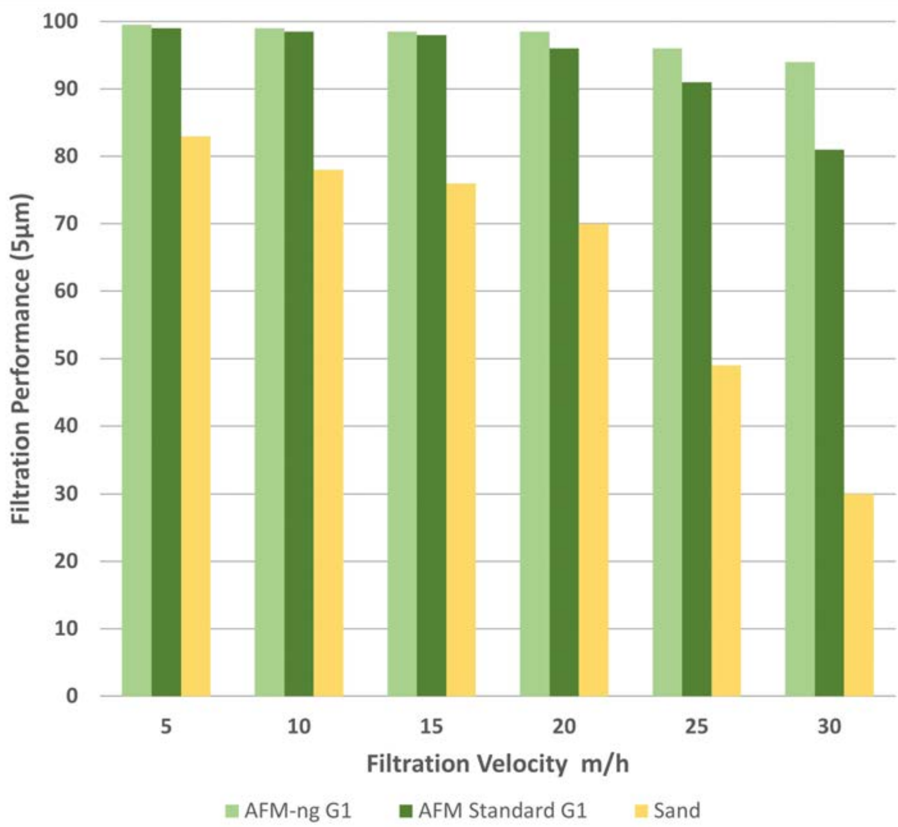
The fine particle retention performance of any media bed filter is inversely proportional to the velocity of water passed through it. Therefore it is always best to operate the filter at the slowest possible filtration velocity to maximise particle retention performance.

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/h and pressure filters at 12m/h. Filters with AFM® under the same operating conditions will always give better performance than sand.

The flow rate or filtration velocity for an AFM® filter depends upon the application and type (gravity or pressure filtration) and design (filter area, height) of the filter. Rapid Gravity Filtration (RGF) velocity is typically in the range of 5-10m/h and for most pressure filters, filtration velocity is between 5 - 20m/h depending on application (Table 5, page 18). For example in drinking water applications, for most pressure filters, the filtration velocity is around 12m/h. This equates to a water flow rate of typical 12m^3/h of water for every 1m^2 of filter bed surface area. RGF filters typically operate at a slower flow velocity of around 6m/h due to pressure head limitations.

The following graph demonstrates the relationship between 0.5-1.0mm grade sand, AFM®ng Grade 1 and AFM®s (Standard) Grade 1 at different flow velocities. By way of example, if we take a water flow velocity at 20m/hr, AFM® will remove 95% of all particles compared to high quality sand only removing 70% 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.

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



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

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Table 5: Application-specific filtration and backwash velocities

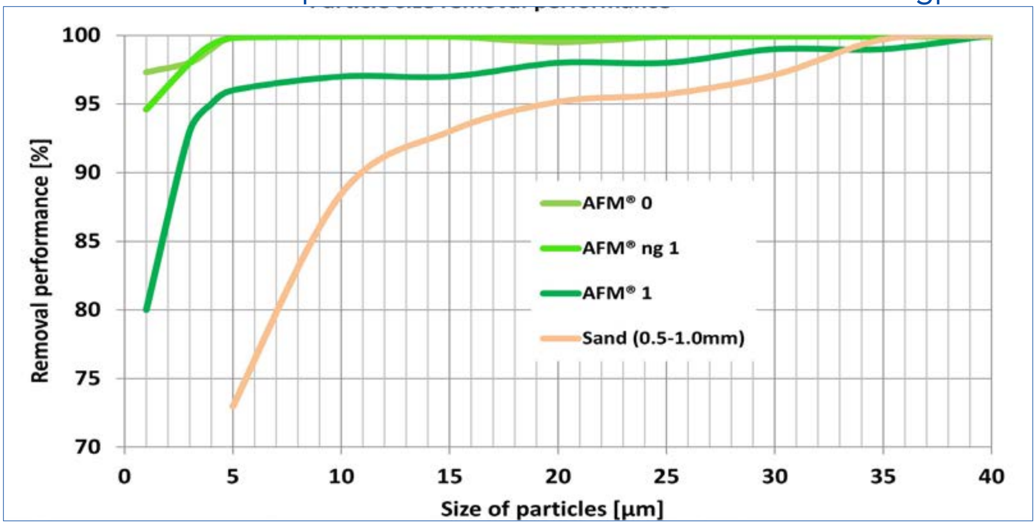
Filtration and backwash velocity for different applications	Filtration velocity (1) m/h		Backwash velocity (2) m/h	
	Pressure Filter	RGF	AFM G1	AFM G0
Ground and surface (drinking) water				
Recommended velocity	10-15	5-10	30-50	20-30
Maximum filtration velocity	20			
Municipal wastewater – secondary / tertiary effluent				
Recommended velocity	5-15	5-10	30-50	20-30
Maximum filtration velocity	15			
Ferric, manganese and arsenic removal				
Recommended velocity	10-15	5-10	>45	-
Maximum filtration velocity	15			
Pre-treatment to UF and RO membranes				
Recommended velocity	10-15	5-10	30-50	20-30
Maximum filtration velocity	20			
Cooling tower (side stream filtration)				
Recommended velocity	15-20	5-10	30-50	20-30
Maximum filtration velocity	25			
Aquaria				
Recommended velocity	10-15	5-10	30-50	20-30
Maximum filtration velocity	30			
Public swimming pools				
Recommended velocity	20-25	-	30-50	-
Maximum filtration velocity	30			
Aquaculture				
a - Incoming Hatchery Water Treatment	15	-	30-50	20-30
b - Incoming Ongrowing Farm Water Treatment	15	-	30-50	20-30
c - Hatchery RAS	15	-	30-50	20-30
d - Ongrowing Farm RAS	20	-	30-50	20-30
a - d Maximum filtration velocity	20		30-50	20-30

Notes:
(1) For above listed applications table 4 on page 15 for suspended solids loading capacity are to be considered
(2) Consider section 7 "Backwash procedure" for correct backwash procedure and applicable filter bed expansion.

AFM® filtration performance

- AFM® Grade 0, has a particle size of 0.25 to 0.50mm is used for fine particle removal and/or if backwash velocity is below 30m/h (12gpm/ft²).
- AFM®s (standard) Grade 1 has a particle size 0.4 to 0.8mm is used for heavy metalsl removal (Fe, Mn, As). It is very efficient in removing positively charged contaminants when water hardness is >50ppm as $CaCO_3$. Very soft water can lead to reduced filtration performance which is also valid for other filter media such as sand.
- AFM®ng Grade 1 has a particle size distribution of 0.4 to 0.8mm. It is especially efficient in removing organic contaminants, oils/fats, pharmaceuticals and microplastics in both hard and soft water.

Particle size removal performance of AFM® vs sand at 20m/h - 8gpm/ft²



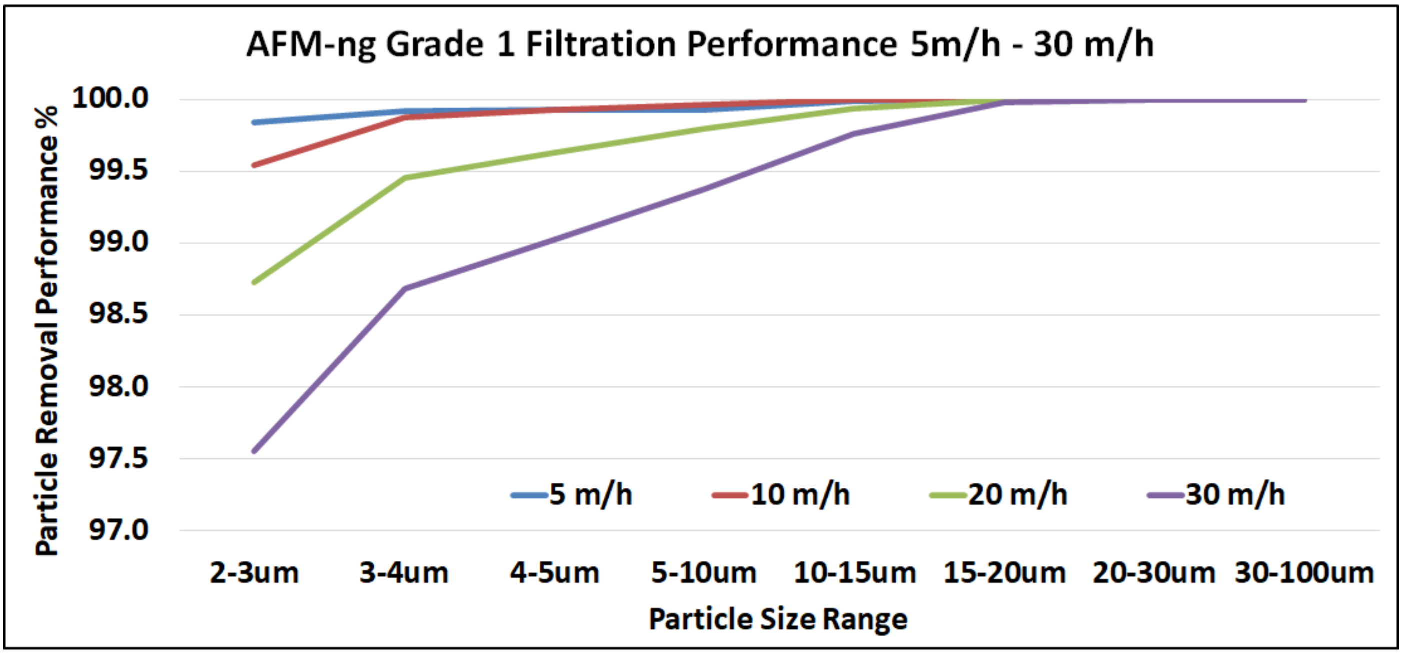
Independent verified by

AFM®ng Grade 1 filtration performance

AFM®ng Grade 1 removes 95% of all particles down to 1µ .Through it's hydrophobic surface property, AFM®ng is best suited for the removal of higher load of fine particles as well as removal of all hydrophobic non-polar contaminants such as organics, lipids/ fats/oils, pharmaceuticals and microplastics with or without the use of flocculants. Coagulation and flocculation can further enhance filtration performance.

Filtration of water with low TDS (<50mg/l), low Calcium hardness (<20mg/l) and low alkalinity (<50mg/l) is always challenging. AFM®ng offers here a significant performance advantage in soft water over sand and AFM®s (standard). When used in conjunction with good coagulation and flocculation it offers exceptional performance removing particles down to 0.1µ.

AFM®ng Grade 1 particle size removal performance at different velocities



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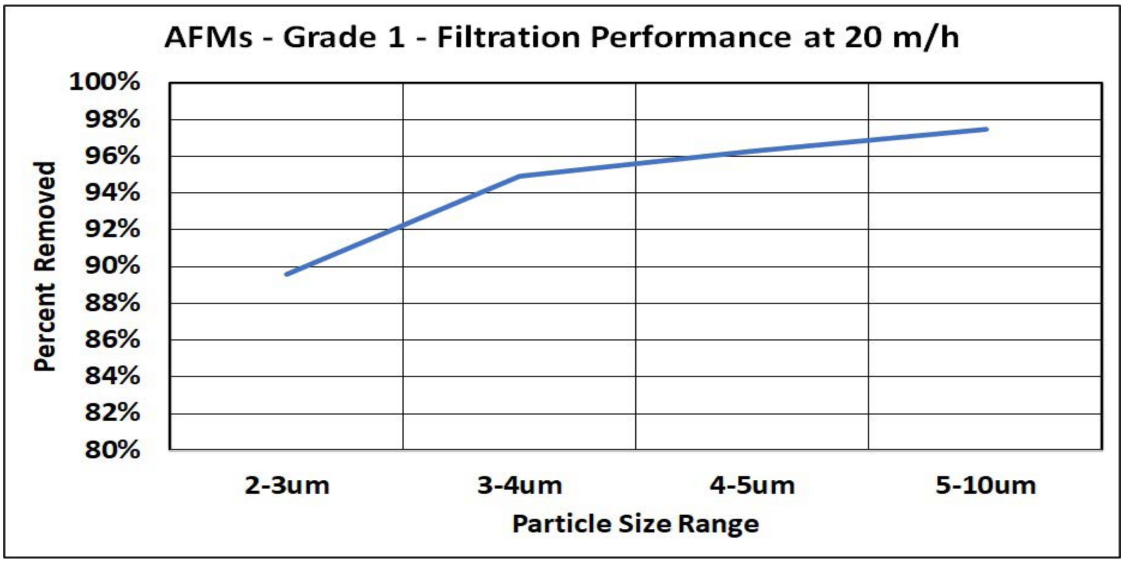
AFM®s (Standard) Grade 1 & Grade 0 filtration performance

AFM®s Grade 1 and Grade 0 are robust and stable, bio-resistant general purpose filtration media with a 20 year performance track record.

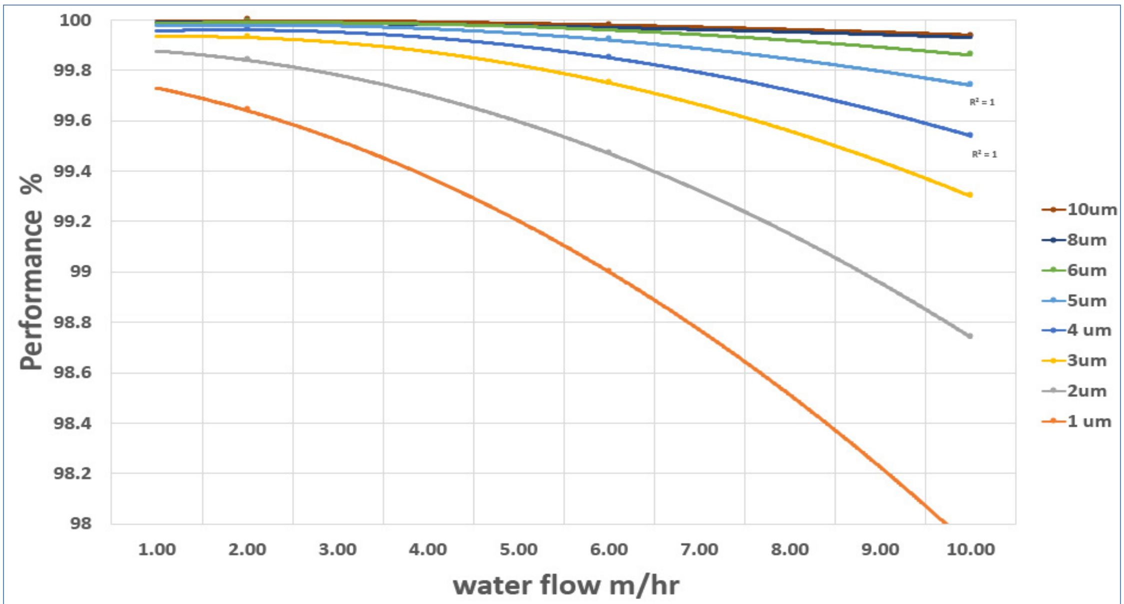
AFM®s Grade 1 is preferably used between water flow velocities from 5 to 20 m/h with 95% of all particles removed down to 4µ (independently verified by IFTS). It is best suited for the removal of positively charged contaminants such as heavy metals and in conjunction with coagulation and flocculation for removal of organics and negatively charged contaminants.

AFM®s Grade 0 removes >98% of all particles down to 1µ (independent verified by IFTS). It can be used as an effective Cryptosporidium oocysts barrier (log 3 reduction). We do not generally recommend the use of flocculants in combination with AFM® Grade 0 as this may block the top surface and reduce filtration performance.

AFM®s Grade 1 particle removal performance



AFM®s Grade 0 particle removal performance at different velocities



Coagulants and flocculants to improve filtration performance

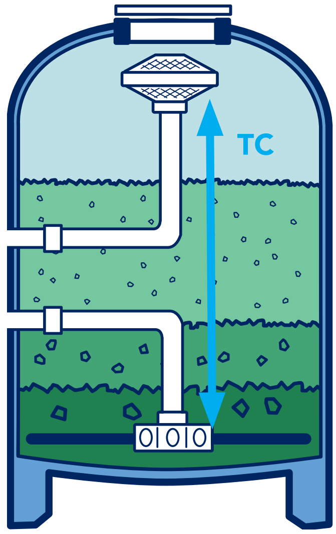
When AFM®ng or AFM®s Grade 1 is used with organic coagulants such as PAC (Poly-Aluminium Chloride) or $FeCl_3$ (Ferric-Chloride) or polymeric cationic or anionic flocculants, the performance and ability to remove fine particles such as fine organic or inorgaic particles is greatly enhanced. AFM®ng and AFM®s Grade 1 can therefore be used to provide an effective Cryptosporidium oocysts barrier up to 20m/h - 8 gpm/ft².

7. Backwash procedure

Importance of backwash velocity

As a general rule, as higher the backwash velocity as more efficient the backwash performance. Backwash velocity is inherently linked to backwash time and is best explained with following example.

Example:
DIN Filter with 2m (80 inch) from nozzle plate to top diffusor (TC)
At a backwash velocity of 60m/h = 2min from nozzle plate to top diffusor. In such case we recommend 3min. backwash time.
At a backwash velocity of 30m/h = 4min from nozzle plate to top diffusor. In such case we recommend 6min. backwash time.
We recommend to apply a safety factor of 1.5 (example: 4 min x 1.5 = 6min)



Bed expansion brings the solids to the top of the filter be, but it is the velocity which moves the solids to the top collector and out of the filter. A short and high velocity always offers a better backwash performance versus a slow and long backwash process. This is especially important for heavy particles such as heavy metals.

AFM® backwash process:

1. Initiate backwash water flow to achieve >15% bed expansion as required to achieve a good removal of dirts from the filter. To not mix up the media in the filter vessel, it is recommend to slowly accelerate backwash flow to 100% over a period of 15 to 45 seconds
2. 3-10 min backwash duration (considering backwash velocity) to ensure all dirts are flushed out during the completion of the backwash process. Measuring a stable low turbidity in the backwash water outlet indicates when the backwash is finished.
3. At the end of backwash, slow down the water flow over a period of >10 seconds to allow the bed to properly re-classify
4. 2-3 minutes rinsing to fully re-establish a dense filter-bed as required to reinstate required particle removal performance (preventing solids entering the product water)
5. Start filtration mode (run phase)

Why is air scrubbing required for sand

Sand provides a good substrate for bacterial growth, and thus, air scrubbing is required to remove the biofilm from the sand grains using a complex and long. air / air-water / water only backwash process. Equal distribution of air from the nozzle plate or laterals is required for every backwash process as otherwise the backwash will be insufficient and the filterbed will only be mixed up. Air scrubbing is usually applied on sand filter if the backwash velocity allows for a >15% filter bed expansion. This is the minimum bed expansion required to re-classify the filter bed (media layers) typically requiring a backwash velocity of 50 - 60 m/h.

Air - Water backwash (scouring) **not required for AFM**

For **AFM®s air scrubbing is not required** and where it is recommended to follow the normal backwash flow velocities in Table 6 on Page 22 and as required to achieve a >15% filter bed expansion (see AFM® bed expansion curves, on Page 23). AFM®s may be air scrubbed if the subsequent normal backwash velocity is at least 40 m/h as required for the reclassification of the filter bed.

AFM®ng is hydrophobic and **must not be backwashed with air** to avoid loss of media through the top collector in pressure filters or backwash overflow in Rapid Gravity Filters (RGF).

Consult the recommended and application specific AFM® backwash flow velocities in Table 6, Page 22 and AFM® bed expansion curves on Page 23.

Backwash wind-up

If 100% water flow is immediately applied to a filter, then water-hammer could damage the pipework or the filter internals. It is therefore recommended to wind up the backwash velocity as in the table below.

Type of filter	Wind up time in seconds to reach 100% backwash flow velocity
German DIN standard vertical filter with nozzle plate	15
Vertical filter with standard lateral arrangement	30
Horizontal filters with nozzle plates or laterals	45

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Backwash velocities to achieve the correct bed expansion

The minimum backwash velocity should expand the bed by >20%.
A backwash velocity < 20 m/h is insufficient for any AFM® Type and Grade.

The selected filter height and total bed depth needs to accommodate the filter bed expansion. The backwash velocity depends on several factors, specifically the bulk bed density of the media and water temperature.

As a general rule, the higher the backwash velocity the shorter the backwash time required and the more efficient the backwash performance. Bed expansion brings the solids to the top of the filter bed, but it is the velocity which moves the solids to the top collector and out of the filter. This is especially important for heavy particles such as (heavy) metals

Table 6: Recommended backwash velocity

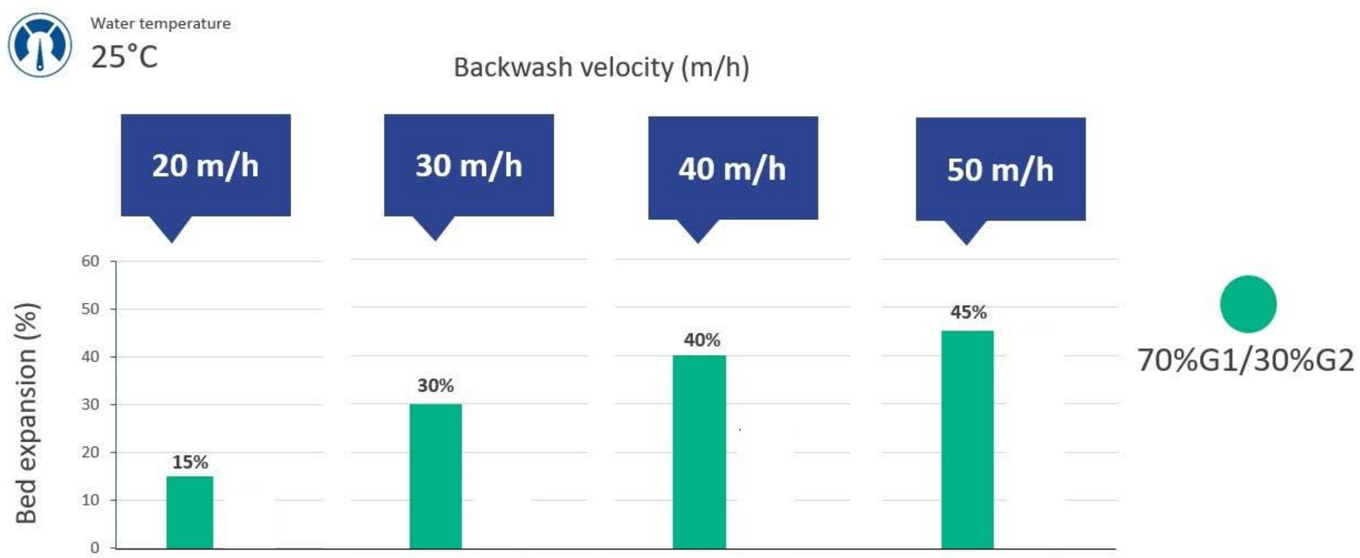
AFM® Grade Layering	Recommended backwash velocity
AFM® Grade 1, 60% / Grade 2, 40%	40m/h
AFM® Grade 1, 70% / Grade 2, 30%	30m/h
AFM® Grade 0, 20% / Grade 1, 50% / Grade 2, 30%	25m/h
AFM® Grade DIN, 100%	60m/h

Note:
AFM® is used as synonym for AFM®s or AFM®ng.
For correct filter layering consult the filtration suspended solids loading capacity in Table 4 on Page 15, and application specific filtration and backwash velocities in Table 5 on Page 18
Above backwash velocities are sufficient to fluidise the bed but, will not always be enough to suspend and evacuate heavier particles or high solids load from the filter (see Table 5, Page 18).

When **AFM® is used as retrofit in sand filter**, the backwash pump capacity needs to be reviewed and may need to be upgraded as required to reach the recommended AFM® backwash velocity. In such case the existing piping system needs to be reviewed and may be adjusted as well to avoid high pressure losses at pipe flow velocities > 2m/s .The AFM® layering (filter bed depth) must be designed to avoid loss of media considering the AFM® bed expansion at selected backwash velocity.

AFM®s Grade 0: For existing filters with < 30 m/h backwash velocity, we recommend the use of AFM®s Grade 0 due to its better bed expansion at lower backwash velocities. AFM®s Grade 0 is recommended for existing installations with low filtration and backwash velocity.

For AFM® filter bed design consider application specific filtration and backwash velocity (table 5, page 18), and filtration suspended solids loading capacity (table 4 page 15)h as well as AFM® filter media grading design on page 12.



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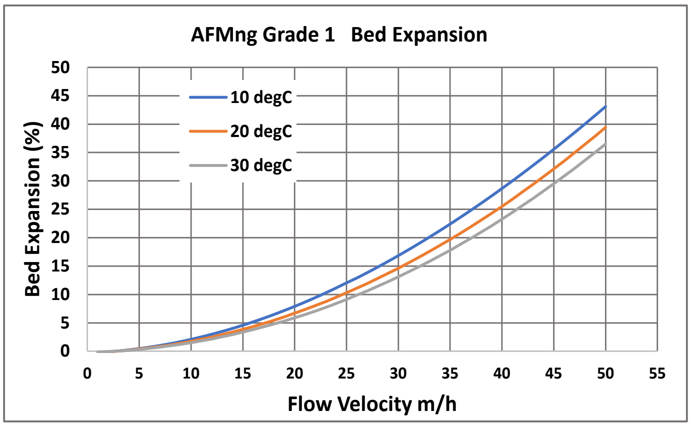
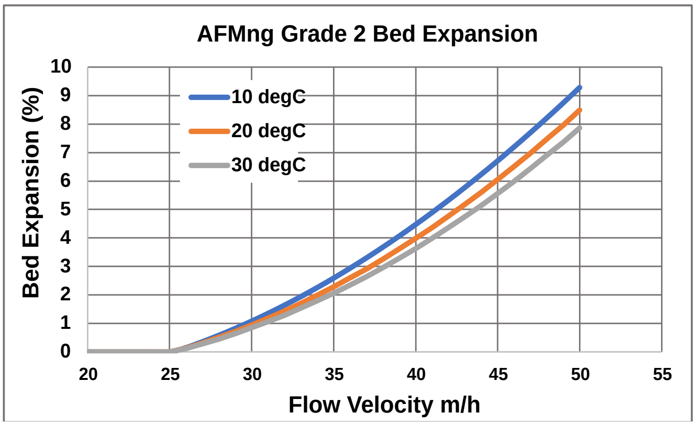
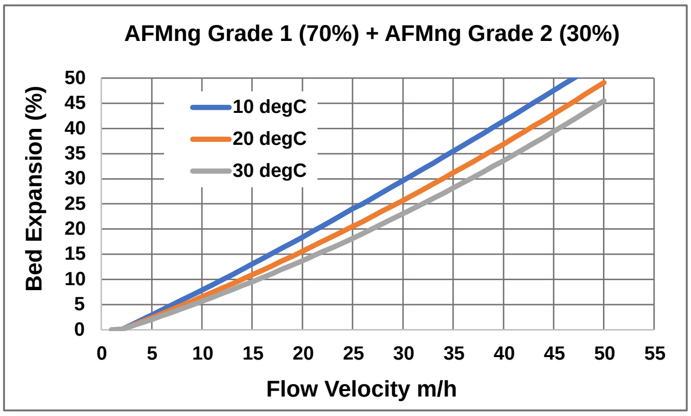
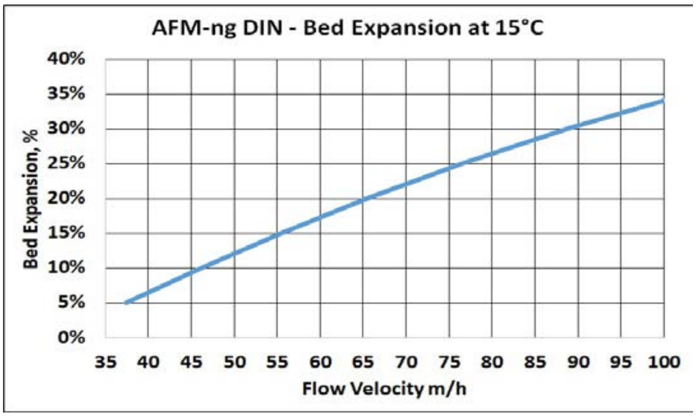
Backwash Bed Expansion AFM®ng

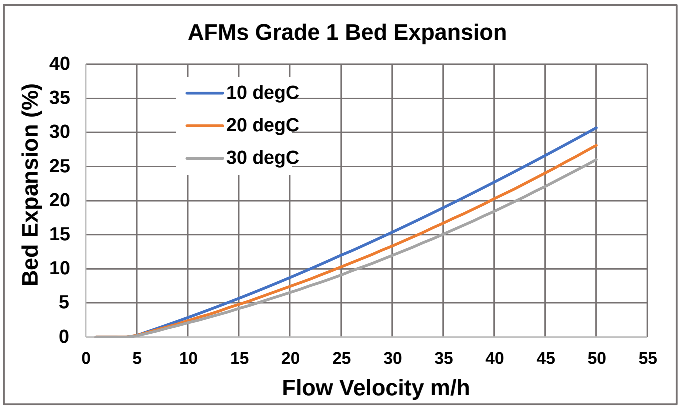


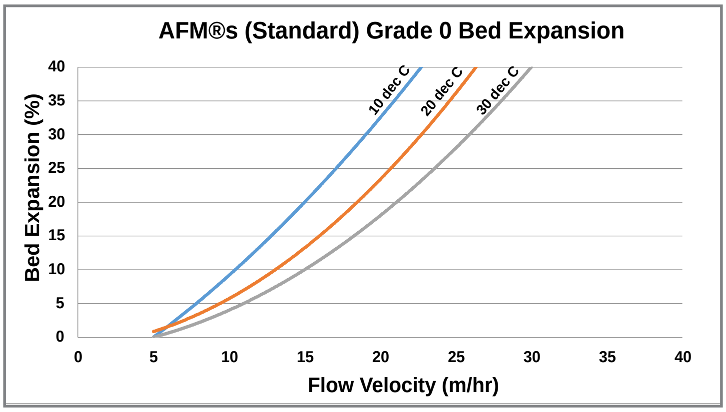






Backwash Bed Expansion AFM®s (Standard)





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.

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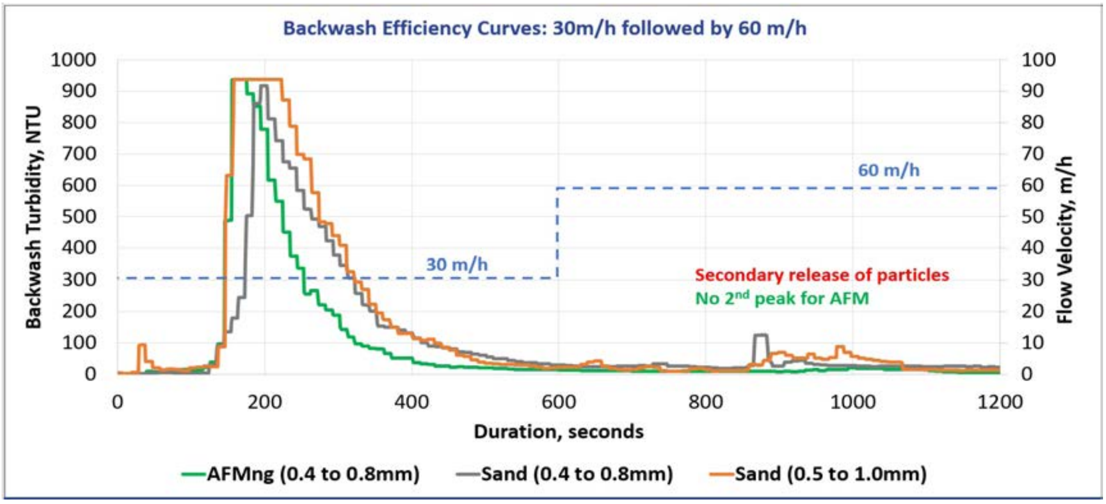
Backwash duration & efficiency



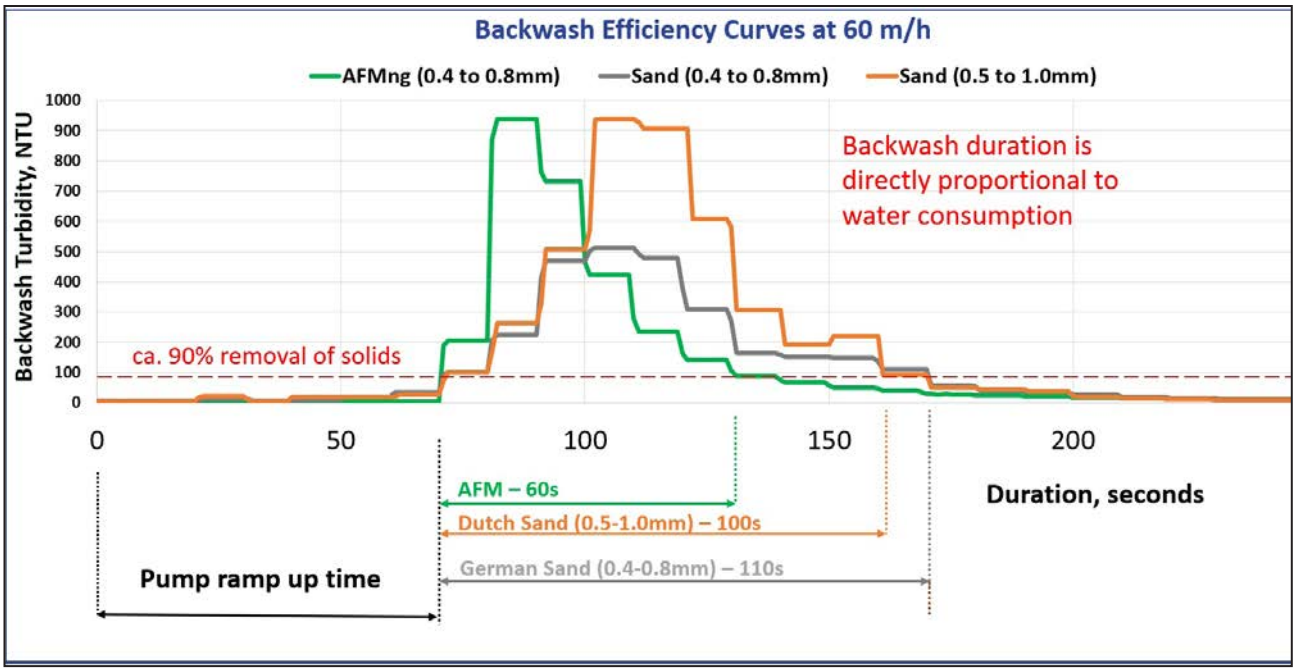
The backwash must progress until the solids are removed from the filter bed, and evacuated from the water above the filter bed. This can only be achieved if the min backwash velocity and a bed expansion of at least 20% is realised. Without these, the filter bed will never be cleaned (see Table 6, page 22), irrespective of how long the bed is backwashed.

A useful technique to evaluate backwash performance is to measure the backwash water turbidity and corresponding profile (see graph above) showing comparison between new AFM and New Sand. This is achieved by measuring the turbidity at the very start of a backwash, and then every ca. 15-30 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.

In most cases the backwash of AFM will be complete already within 300 seconds, however if the bed is not fluidised (<15% bed expansion), 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 sight-glass should be installed in all filters for evaluation of bed condition, bed expansion and backwash efficiency.



Backwash wind down - reclassification of the filterbed

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

Rinse phase

Depending on application a rinse phase may be required. After the backwash, the filter bed needs to settle and compact slightly. During the rinse phase any dislodged solids near the base of the filter bed are discharged to waste. The recommended rinse phase duration for AFM® is 3-5 minutes. 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 downstream filtration systems such as cartridge filters, ultrafiltration or reverse osmosis membranes.

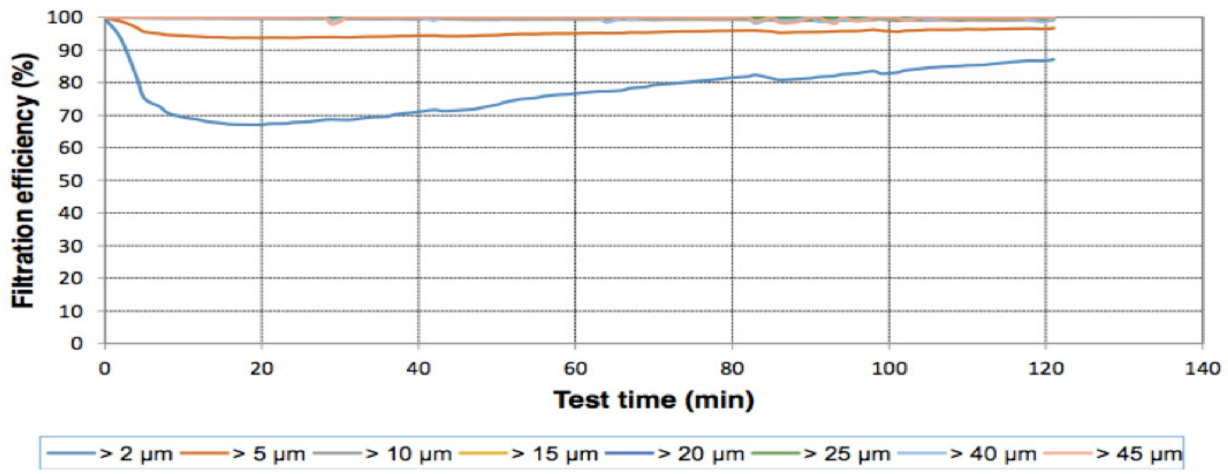
If the backwash profile defines the bed as unstable (frequent changing backwash cycle times, decrease in filtrate quality), respectively not all solids can be removed during backwash (filtrate quality can not be established after backwash), then the rinse phase will require to be increased even up to 30 minutes. The following data from IFTS (Institute of Filtration and Techniques of Separation in France), shows the instantaneous filtration performance at 20 m/h for AFM® and sand

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 was 2µ compared to 5µ with sand.

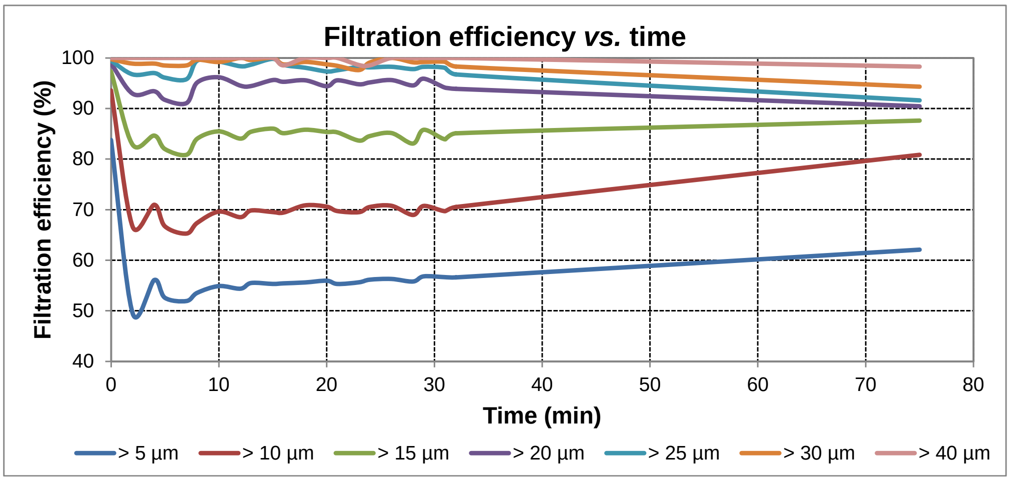
Instantaneous filtration performance after a backwash

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 to take place *(referred to as "ripening" by drinking water technicians).*

AFM® Grade 1 instantaneous filtration performance at 20m/h (no flocculation) down to 2µ



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



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

Annex Index

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Annex 1: Applications overview for AFM®

Application Type	Associated Processes		Typical Removal
Drinking water			%
Surface & Ground Water	FeCl or PACl coagulation prior to AFM		90% TSS
Iron & Mangenese Arsenic removal	Oxidation by aeration, H_2O_2, or NaHOCl prior to AFM®	FeCl coagulation prior to AFM®	95% TSS
Membrane pre-filtration (Sea or Brackish Water)	AFM® filtration to 1µ (AFM® ng Gd1 or AFM® Gd0)	1 micron cartridge filter post filtration	95% TSS SDI <3
Municipal Wastewater			
Tertiary Treatment	Phosphorous & Bacteria, BOD, COD & TOC Pre-filtration to <100 µ + FeCl coagulation then AFM®	Oxidation 30mins with NaHOCl after AFM® filters	95% COD
Industrial Process Water			
Cooling tower sidestream filtration	Organic pollutants & oils, TSS, VSS & particles >1 micron Filtration 15 - 20m/hr with AFM®		95% TSS
Industrial Wastewater			
Low conc' mineral oil (<50mg/l) removal	Oxidation 30 mins by aeration	PAC coagulation with prior to AFM®ng	95% OIW
Chromium or Copper removal	pH correction 7.0-7.5 by MgO_2 or 8.5 (caustic). Reduction by dosage of Calcium polysulphide	Sedimentation 30 min. prior to AFM® at 5 - 10m/h max	95% TSS
Aquaculture / Aquaria			
Seawater Intake Filtration	Pre-screening of macro-algae by mesh or wedgewire screens	AFM® filtration	95% TSS
RAS Systems Hatchery & Ongrowing	Biological Filtration after AFM®	Aeration	95% TSS
Mechanical Filtration in Biological LSS	Biological Filtration Prior to AFM®	Side Stream Protein Skimming	95% TSS
Mechanical Filtration in Chlorinated LSS	Coagulation & Flocculation prior to AFM®	Chlorine + ACO® in external facilities	95% TSS

AFM® can be substituted for sand and most other filter media in any pressure or rapid gravity filter. AFM® is suitable for many applications beyond those identified above and can be used as substitute for e.g. Ultra- or Microfiltration before Reverse Osmosis membrane filtration. It will significantly outperform sand and most other filter media in terms of particle retention, stability, backwash water consumption and service life.

Annex 2: AFM® dual-media beds - Anthracite & Activated Carbon

In the following context for dual-media layers AFM® is used as synonym for AFM® ng and AFM® s

Dual media bed with Anthracite

Anthracite, or other porous media may be used with AFM® in a dual or multi-media layered filter bed. The choice of media depends upon the water treatment application, filtrate quality to be achieved and operational requirements (filtration and backwash velocities, backwash cycles, etc.)

AFM® offers exceptional performance in particle filtration. Under heavy suspended solids (TSS) load >30mg/l it is recommended to use a layer of Anthracite on top of the AFM® to provide a longer run phase between backwashes. Table 1 for AFM® layering on page 12 provides recommendations on the use AFM® when combined with Anthracite.

Anthracite is used on top of the filter bed to remove the bulk of (larger) particles and by this allows to increase solids load and run phase duration (Table 5, Page 15) allowing AFM® to efficiently remove particles down to 1µ at 95% removal efficiency. For heavy loads of solids above 30mg/l, a 100mm to 250mm layer of Anthracite is recommended using following Anthracite particle size/grade:

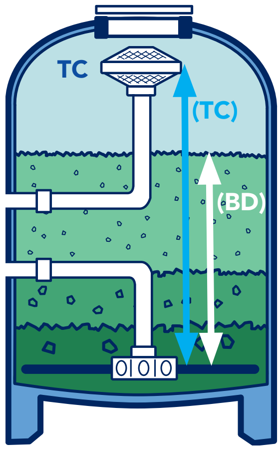
AFM® Grade 1 + 1.2 to 2.5mm or 0.8 to 1.6mm Anthracite

AFM® Grade 0 + 0.8 to 1.6mm Anthracite

At 20% bed expansion for AFM® a 50% bed expansion is to be considered for Anthracite or GAC during backwash. A 17.5% (0.825) free-board from expanded bed is to be considered to avoid loss of media during backwash.

Example AFM® + Anthracite or GAC multimedia filter calculation:

- TC of 1.7m from nozzle plate (or lateral) to top collector (TC)
- 1000mm AFM® grade 1 filtration layer
- 100mm Anthracite or GAC layer
- 20% backwash bed expansion for AFM® and 50% backwash bed expansion for Anthracite/GAC



Expanded BD: TC x 0.825 (free-board) = [(BD, AFM® x 1.2) + (BD, GAC x 1.5)]

1.7m x 0.825 = 1.40 = [(1m x 1.2) + (0.1 x 1.5)] = 1.35

$$\text{BD AFM®+Anthracite/GAC} = \frac{\text{TC x 0.825}}{(\text{BD AFM® x1.2}) + (\text{BD, GAC x 1.5})} = \frac{\text{1.7m x 0.825}}{(1 \times 1.2) + (0.1 \times 1.5)} = 1.038\text{m}$$

$$\text{In reverse, TC} = \frac{[(\text{BD AFM® x 1.2}) + (\text{BD, GAC x 1.5})]}{0.825} = 1.64\text{m}$$

Dual media bed with Activated Carbon and use of Disinfection / Oxidation

AFM® works very well as a support layer for activated carbon, and where bacteria are released as floc, AFM® will capture and prevent their release into the product water.

AFM® can be combined with activated carbon when chlorine or other oxidising agents are used for disinfection purpose. The activated carbon bed will usually be AFM® Grade 1 with a 50 mm to a maximum of 100 mm layer of activated carbon. It is very important not to use 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 to remove chlorine or other oxidising agents, but any more than 100 mm could start to cause issues resulting from biofouling of the activated carbon.

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

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

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:

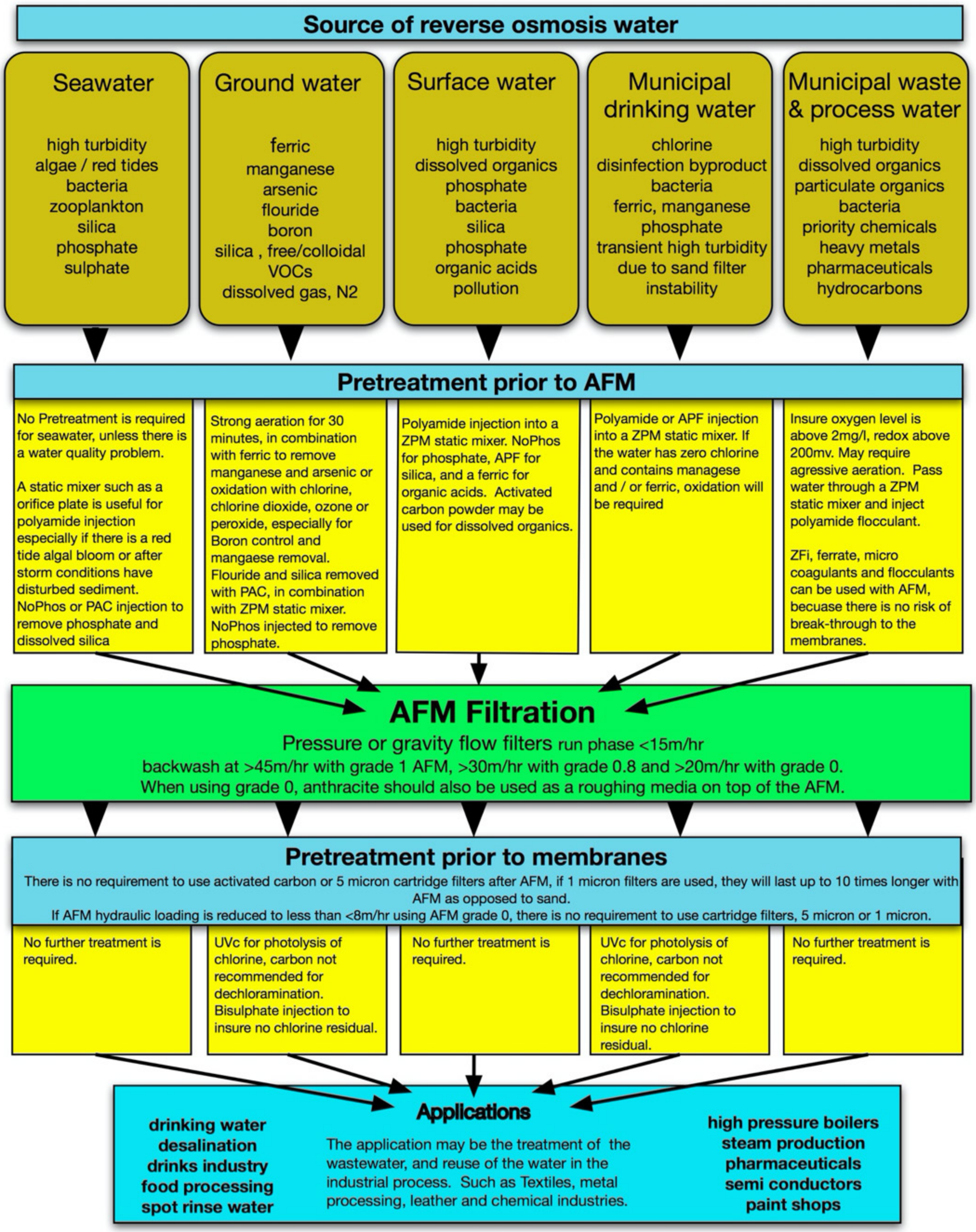
Stage 2a $NH_2Cl + H_2O + C\cdot \leftrightarrow NH_3 + CO\cdot + H^+ + Cl^-$

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

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

AFM® is often used in combination with activated 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.

Annex 3: AFM®ng for pre-filtration to reverse osmosis membranes



Introduction to Reverse Osmosis (RO) pretreatment

The pretreatment of raw water prior to reverse osmosis (RO) membranes is a critical process step making a significant difference to the economics, sustainability and ease of operation of an RO water treatment system. RO membranes for desalination / 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. For selected small to medium size (ca. 100-1000m^3/d) industrial applications, activated carbon or UVc irradiation may be used as well in pretreatment before RO. 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, optimizes and therefore highly improves the pretreatment 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 fine particulate matters or phosphate from municipal effluents, but sand has free silica which eventually precipitate and leads to blocking of the RO membrane, consequently reducing its performance, especially if there is aluminium in the water or if aluminium based coagulants are used.

AFM®ng filtration as pretreatment prior to RO

AFM® is an activated mesoporous aluminosilcate with glass as a structural substrate and a direct replacement for sand with similar operational criteria. AFM® has a surface area much greater than sand. The very large surface area of AFM®ng with its hydrophobic surface property will remove particles down to 1µ with 96% removal efficiency. AFM®ng will furthermore highly improve removal of organics and provides an excellent performance in removal of hydrocarbons.

When AFM®ng is combined with pre-coagulation and/or flocculation, mechanical filtration performance is improved by up to 10 times to a nominal filtration down to 0.1µ. In addition to removing solids, the coagulation reactions will further improve dissolved organics such as proteins, lipids, amino acids and inorganic components including phosphate and free silica.

AFM®ng performance has been independently verified by IFTS (Institute of Filtration and Technical Separation) in France.

Test identification

Test date : 03/10/2019 Operator : ML

Customer reference

Filter ref. : AFM 21 ng (0,4 - 0,8mm) Sample 2

Independent verified by ifts

Test parameters

Test fluid : Filtered water Test dust : ISO CTD Batch n. : 13388C

Test results

Parameters		Contaminant injection				Particle counting			
		Flow rate (L/h)	Concentration (mg/L)			Counter	Sensor	Flow rate (mL/min)	Volume (mL)
			Initial	Final	Average				
Test flow rate (m3/h)	0,37	10,02	202	181	191,5	PAMAS 2132	WaterViewer	25	25
Temperature (°C)	23,4								
Concentration (mg/L)	5,2								
Test duration (min)	362								

Initial cleanliness (#/mL)

Particle number/mL	Sizes (µm)	> 1	> 2	> 4	> 6	> 8	> 10	> 20	> 25
	Upstream	110,52	75,64	33,6	12,96	7,48	5,68	2,4	1,76
	Downstream	42	23,84	10,16	5,12	4,08	3,88	3,32	2,92

Filtration efficiency and Particle number (#/mL)

Sizes (µm)		> 1		> 2		> 4		> 6		> 8		> 10		> 20		> 25	
Upstream	E (%)	12702	94,6	8737	96,9	3359	99,3	1338	99,9	559	99,9	274	99,9	20	99	8	98,9
Downstream		684		270		25		2		0		0		0		0	

Annex 4: AFM® for tertiary treatment of waste water

Both AFM®ng and AFM®s are used for the tertiary treatment of municipal or industrial wastewater in gravity flow of pressure filters. AFM®ng and AFM®s have many benefits over sand filtration, which include the following:

- No biofouling and does not coagulate or experience transient channelling
- Predictable and repeatable performance
- Turbidity and TSS reduction better than 90%
- Perfect for ferric removal as well as very good at removing phosphate and arsenic
- AFM®ng is specifically adapted to removal of hydrophobic particles and will remove 94.6% of 1μ particles.

Operational criteria	Range		Notes
Bed depth	500mm	2000mm	Typical bed depth is 1200mm with 200mm of 1 to 2mm anthracite on top of the bed
Run phase water flow	5 m/hr	15 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 pressure increase
Backwash water flow	>40m/hr	50m/hr	Backwash for 5 minutes, or until the water runs clear. Air purge not required
Rinse phase duration	2 minutes	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

AFM® tertiary waste water treatment performance comparison*

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		
AFM® Pressure filter	10.60	0.89	96	2.98	0.24	92	23000	10000	58	3.59
RGF sand filter with sand	7.14	2.2	69	3.5	2.23	36	23120	12300	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

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

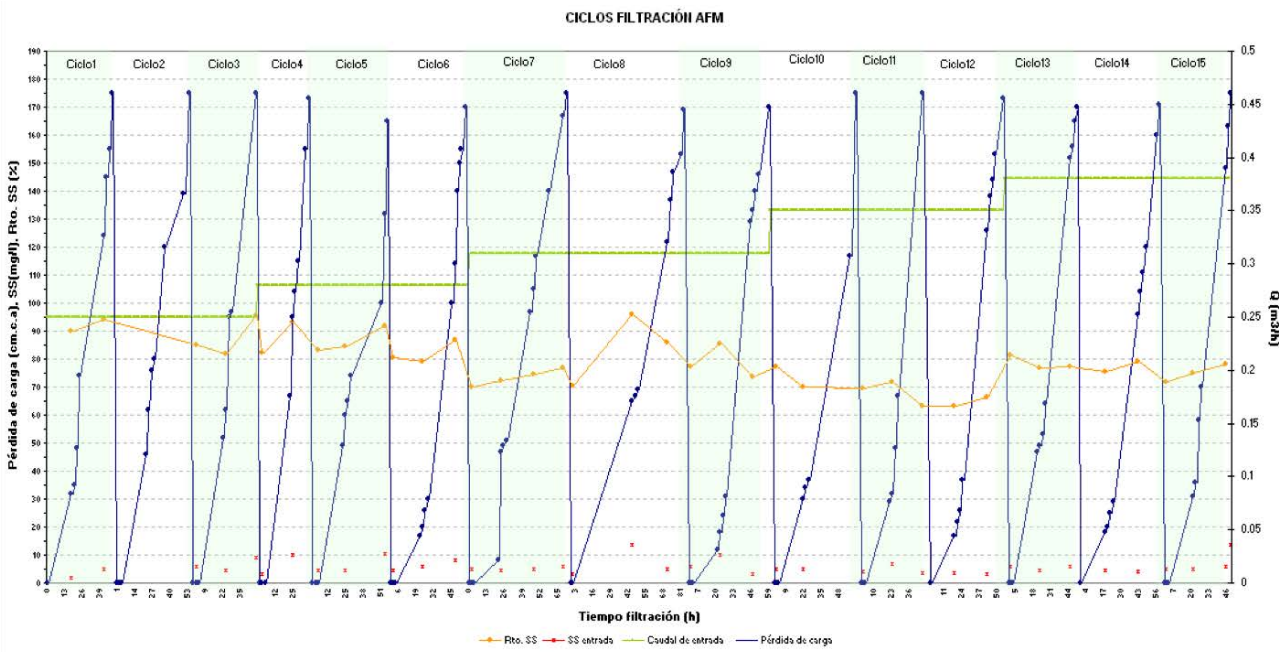
AFM® municipal wastewater performance profile

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

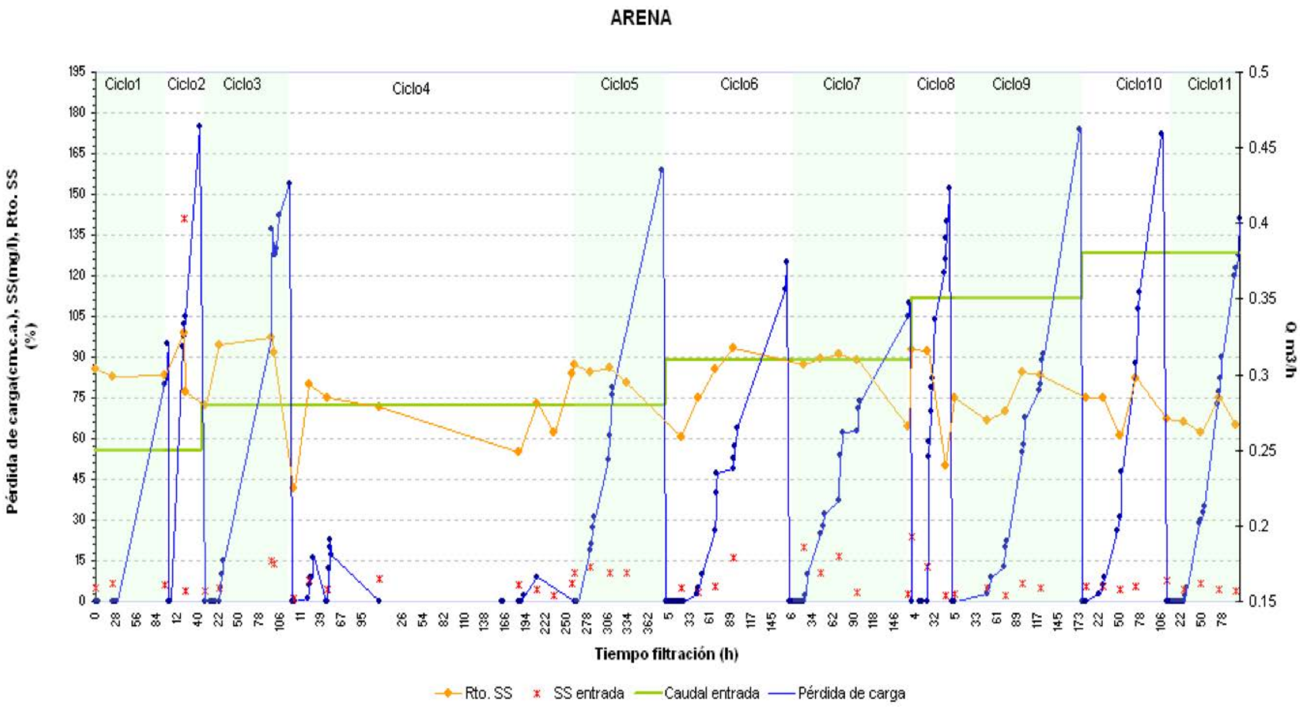
The AFM® filter works at constant high filtration and backwash efficiency with each filtration and backwash phase shows the same performance The data confirms the stability of AFM®s and the high quality of product water that can be achieved. In comparison the sand filter was unstable and the large interval between the backwash peeks confirms channelling of water through the sand bed.

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.

AFM® Grade 1 filter tertiary treatment



Sand filter tertiary treatment, using 16 x 30 sand



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Annex 5: AFM® for removal of Ferric, Manganese and Arsenic

Chemical parameter	Soluble fraction	Insoluble	Typical Drinking water standard	AFM® removal 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;

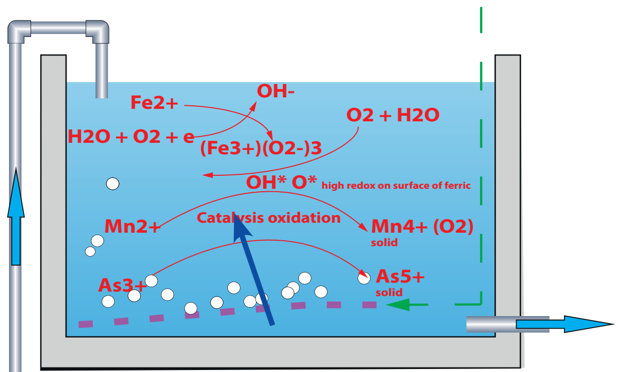
1. Oxidation reactions by aeration to convert metals from soluble ionic form to insoluble oxidised precipitate.
2. pH correction by aeration/oxidation
3. Decantation may be required if the concentrations are above 5 mg/l, if not proceed to AFM® filtration
4. Enhanced coagulation by ZPM cavitating mixer.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

Oxidation

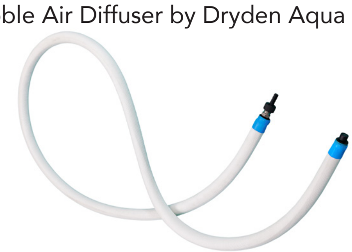
Manganese and arsenic are removed by co-precipitation and catalytic oxidation by ferric. For the process to work the ferric needs to be at least 5 times higher concentration than either the arsenic or the manganese. If the concentration of ferric is sufficient, then simple aeration of the water for a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

The process is simple and where it the arsenic concentration can be reduced to around 10ppb or below 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.



Fine Bubble Air Diffuser by Dryden Aqua



Aeration

This is achieved through aeration of the water. The water is aerated for a period of no less than 30 minutes. If water flow is 50 m3/hr the aeration level is $50m^3/h$ of air and tank volume is $25m^3$ of water. Dryden Aqua manufacture fine bubble drop in air diffusers for this application.

AFM® Operation for Metals removal

	AFM® Operation	Notes
Bed depth AFM®	1000 mm	Recommended bed depth / AFM® Bulk bed density 1.25kg/l
Run phase water flow	10-15 m/h	Slower filtration velocity increases filtration performance
Typical operating pressures	0.1 - 0.5	Do not exceed 0.4 bar pressure increase
Backwash water flow	>45m/hr	Backwash ca. 5 minutes, until the water runs clear. No Air purge required

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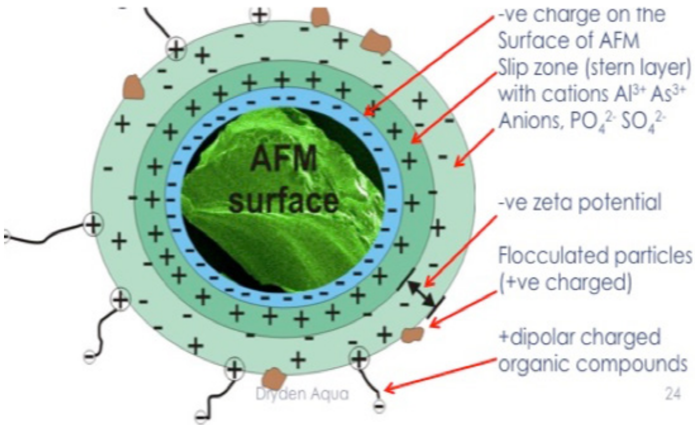
Annex 6: AFM® for removal of phosphate from water

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
3. Soluble reactive phosphate also referred to as ortho-phosphate.

AFM®s 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®s 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.

Phosphate removal processes

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.

- The precipitating salts must be added via an aggressive static mixer, after the pump but before the filter
- Lanthanum addition is stoichiometric at a molar ratio of 1:1
- 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.
- 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. Magnesium injection will require adjusting to determine the optimum ratio.
- 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
- 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
- The AFM® filtration process to remove the phosphate suspended solids will result in adsorption reactions of phosphate PO_4^{2-} directly onto the AFM®

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Annex 7: AFM® for parasitic 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, which contains the parasitic eggs, for irrigation.

The parasite egg is large at 40 µ and easy to remove by AFM® tertiary treatment. Sand will also remove the eggs, 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 length.

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.

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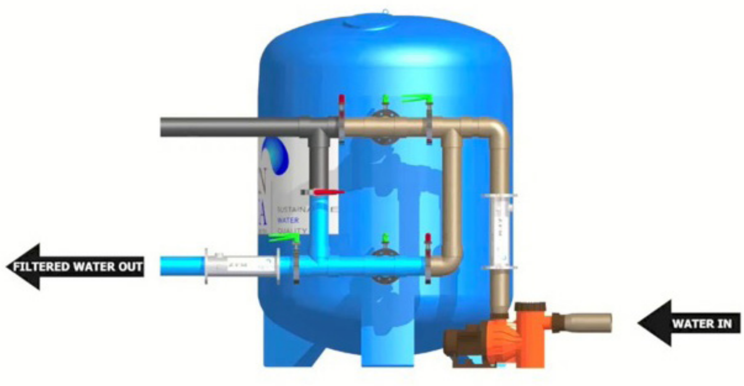
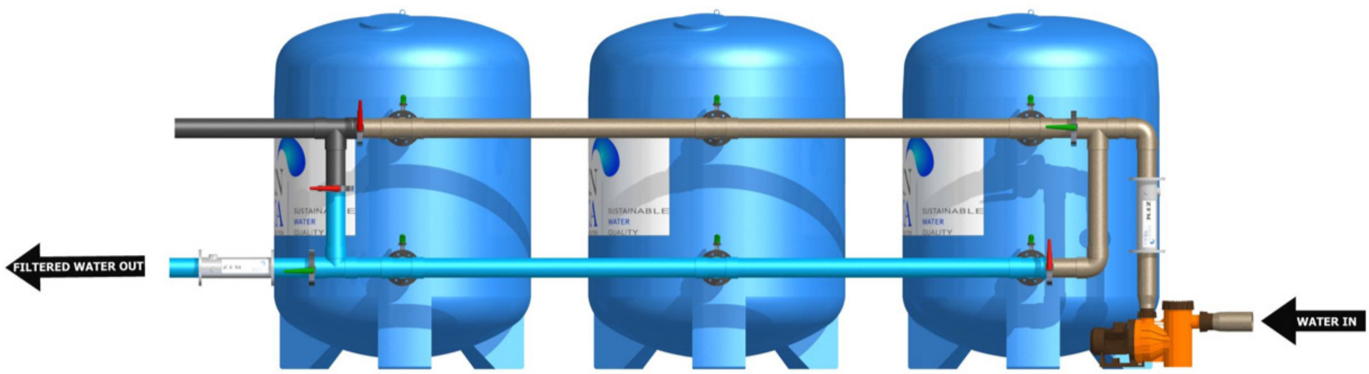
Annex 8: Pressure filter system schematics

Single filter 5 valve configuration

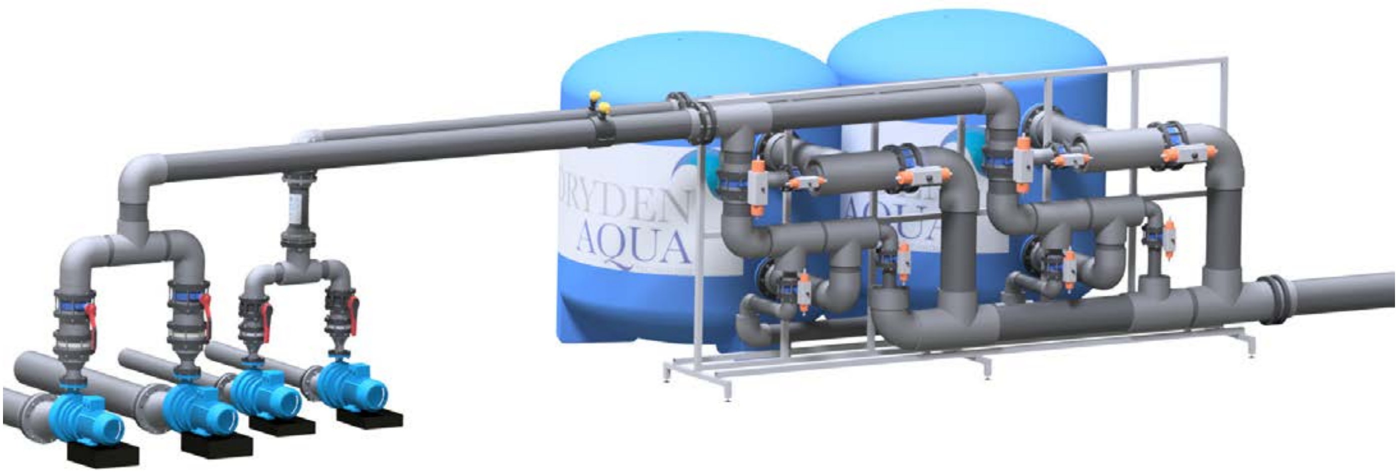


Single filter BESGO valve configuration

Multi filter configuration



Multi filter configuration with pneumatic actuated valves and separate backwash pumps



Annex 9: 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

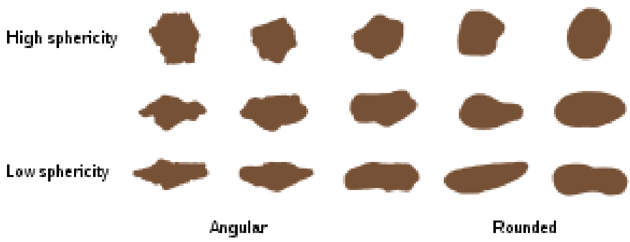
- A measure of the sharpness of a particle's edges and corners. This relates to angularity. Again, this ratio is a measure of the degree to which a particle approximates the shape of a sphere or a cube. The roundness of a sphere or cube is 1.0. The adopted standard for the roundness of glass grains is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

Aspect ratio

- A measure of the flatness and elongation of the particle. 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

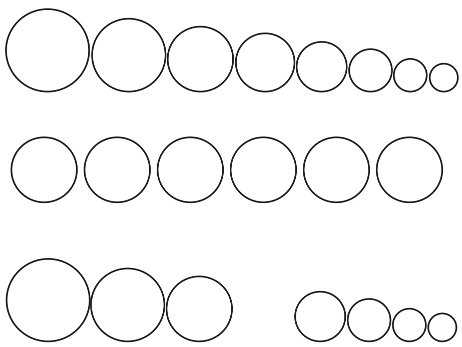
- All 3 of these ratios provide an indication of how well the granular material will perform as a filter media. The aspect ratio is particularly important in that very flat and elongated particles can, over prolonged backwashing, build up in the filter bed and create a 'mirror' layer. This 'mirror' layer 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.



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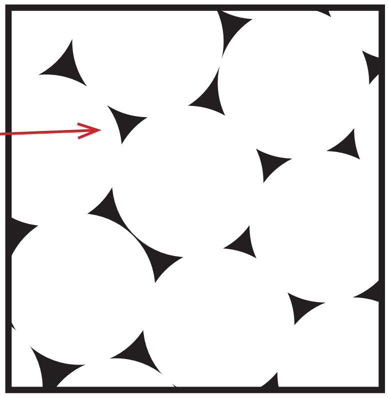
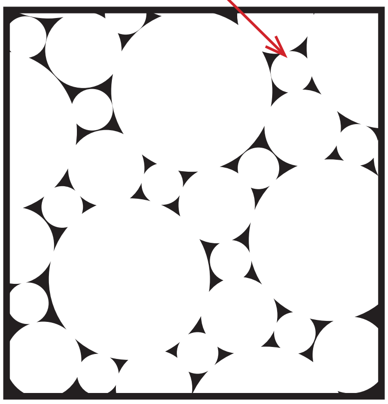
Uniformity Coefficient (UC):

- 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 the interstitial porosity:



- This uniformity means, for example, that it is easier to predict the filtration and hydraulic performance of a filter. Engineers would tend to use tightly graded media to address specific filtration needs. They would specify Uniformity Coefficient and Effective size values.
- Where the media is well graded in terms of size, the interstitial porosity becomes much more variable. This results in improved filtration performance in terms of the size range of waste particles removed:



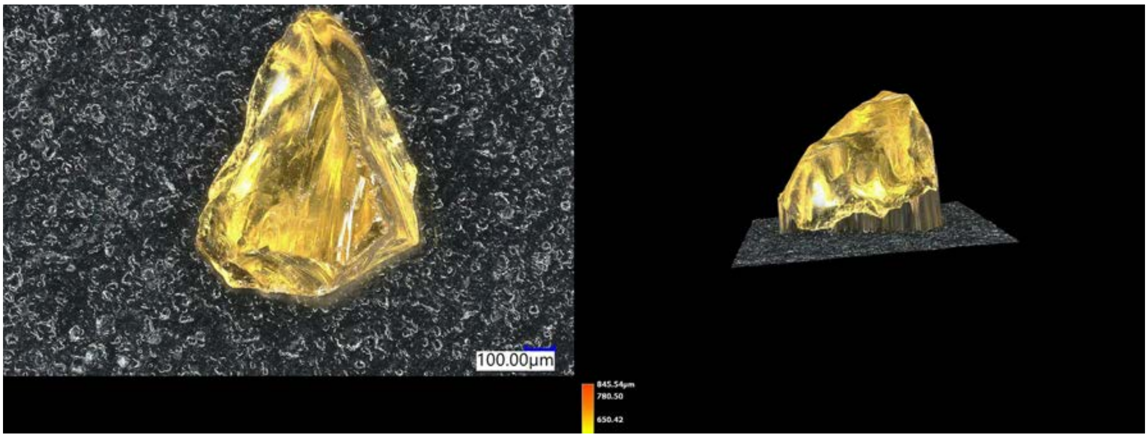
Uniformity Coefficient (UC)

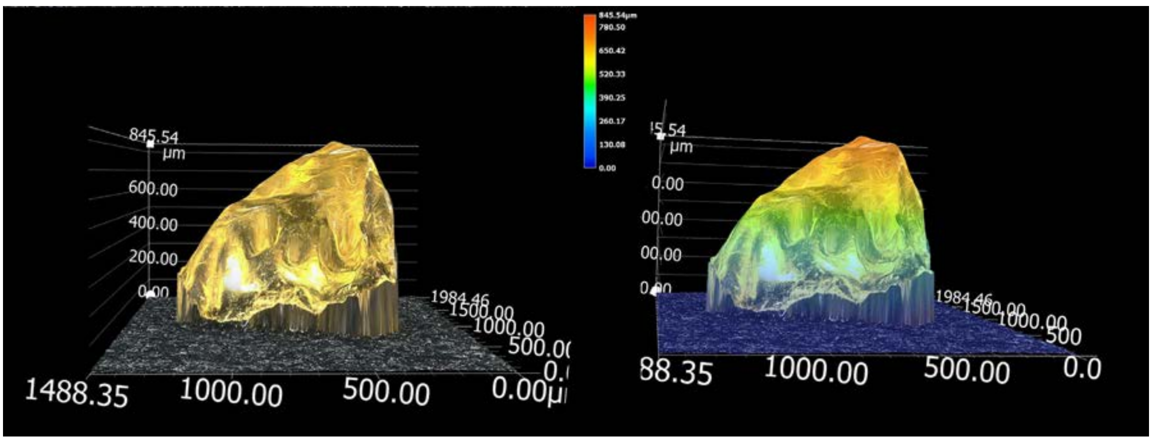
- Calculated by using the following equation:
  - D60/D10 = UC
  - Where D60 = mesh size (mm) at which 60% of the media passes through
  - D10 = mesh size (mm) at which 10% of the media passes through

Effective Size (ES)

- Effective site (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





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Annex 10: Glossary of Technical Terms

TSS - Total Suspended Solids[1]

Total suspended solids (TSS) is that portion of the Total Solids that are retained on a no-ash glass fiber filter disc[1]. The wetted and weighed filter disc is placed in a filtering apparatus and a suction is applied A measured volume of wastewater is passed through the filter. The filter containing the residue is then dried in an oven for one hour at 103 to 105°C. The sample is then cooled and weighed. The difference in weight of the dry filter before and after solids are passed through is the TSS milligrams (mg) of suspended solids per liter (l) of (waste)water filtered. The TSS test indicates whether it is likely that solids suspended in a wastewater can be removed by settling, floating or filtering.

[1] Norms applicable for the determination of total suspended solids: ISO 11923:1997, DIN EN 872:2005-04, ASTM D5907-18

TDS - Total Dissolved Solids[2]

The total dissolved solids (TDS) are the solids in the filtrate from the TSS test. The liquid which passes through the TSS filter is collected in a weighed dish and evaporated for an hour at 180°C ± 2°C. The dish is then re-weighed with the TDS equaling the difference between the dish weight before and after filling with filtrate and drying, in mg per liter of filtrate. Again, this inexpensive test can be run in less than two hours and will indicate the chemical or biological solids in wastewater which cannot be removed through settling, floating or filtration.

[2] Norms applicable for the determination of total dissolved solids: DIN EN 15216:2008, ASTM D5907-18

NTU - Nephelometric Turbidity Unit, P.BOD = turbidity/2 + 5

Nephelometric Turbidity Unit (NTU) measured scattered light at 90 degrees from the incident light beam. Turbidity is the cloudiness or haziness of a fluid caused by large numbers of individual particles that are generally invisible to the naked eye. The measurement of turbidity is a key test of water quality. Fluids can contain suspended solid matter consisting of particles of many different sizes. While some suspended material will be large enough and heavy enough to settle rapidly to the bottom of the container if a liquid sample is left to stand (the settable solids), very small particles will settle only very slowly or not at all if the sample is regularly agitated or the particles are colloidal. These small solid particles cause the liquid to appear turbid.

SDI - Silt Density Index

A measure of the fouling capacity of water before reverse osmosis systems. The test measures the rate at which a 0.45-micrometre filter is plugged when subjected to a constant water pressure of 206.8 kPa (30 psi). The SDI gives the percentage drop per minute in the flow rate of the water through the filter, averaged over a period of time such as 15 minutes

Nominal Filtration

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

TOC	Total Organic Carbon is a measure of the total amount of carbon in organic compounds in pure water and aqueous systems
BOD	Biological Oxidation Demand is a measure of the amount of oxygen that is required for the bacteria to degrade the organic components present in water. Same as $KMnO_4$
COD	Chemical Oxygen Demand; total measurement of all chemicals (organics & in-organics) in the water
DOC	Dissolved Organic Carbon
VOC	Volatile Organic Carbon (purge-able)
SOC	Suspended Organic Carbon
SIC	Suspended Inorganic Carbon
NPOC	Non Purge-able, Acidified
TIC	Total Inorganic Carbon
TDC	Total Dissolved Carbon
AOX	Adsorbable organic halides, a group of halogenated organic substances that are able to adsorb onto activated carbon. e.g.PCB's
POPS	Persistent Organic Pollutants
pH	Hydrogen ion concentration; at pH 7 = 10 -7 moles (6.02 x 10 23) of H+
EC	Electro Chemical Conductivity (potential)
RedOx	Reduction/Oxidation potential in milli volts

Zeta Potential Electrical charge potential on particle

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.

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