DRYDEN AQUA REPORT

Biofouling and pre-treatment prior to membranes using AFM®

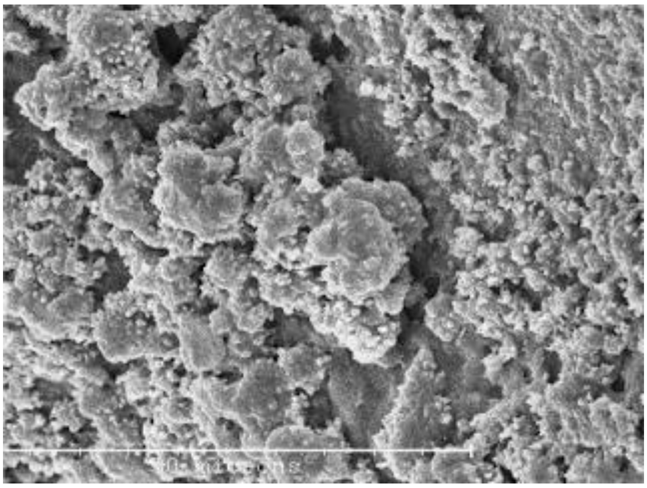
Sand filters are often used prior to RO and UF membranes, when sand filters are operated properly, they will give excellent results. The filters also have the advantage that they are low cost and easy to maintain, however there is always room for improvement as new technology is developed.

Silica sand is a perfect substrate for the growth of bacterium; indeed sand filters make very good biological filters for the treatment of drinking water in the form of slow bed filters. The filters operate at a water flow in the region of 0.1m/hr as a velocity. However when the flow velocity is increased to 5 or 10m/hr the bio-dynamics of the microbiology start to change.

Slow bed sand filters are in a state of endogenous respiration, the filter could be considered as a stable ecosystem that is self-maintaining. However when the flow rates are increased there will be bio-instability in the system. Initially sand filters can give a very good water quality. Initially, the filter will be colonised by heterotrophic bacteria that use organic carbon as a carbon source. During the growth phase the bacteria improve the performance of the sand filter, this period may last for a few weeks to perhaps 12 months, the time frame is dictated by the temperature of the water and the concentration of dissolved organics.

After a given period the heterotrophic bacteria will have used up all of the available living space in the filter, the thickness of the biofilm layer now starts to develop and species diversity of bacteria begins to increase. Around the same time bacterium will be sloughing off the surface of the sand due to the velocity of water passing through the filter. However the bacteria levels and dissolved organic level in the product water will probably be lower than the influent water.

Biofilm could be compared to a plant and the planktonic bacteria as their seed. It is natural for biofilm to discharge bacterium into the water, indeed the discharge of bacterium into the product water may be synchronised by the bacteria. This is a perfectly natural process, so the performance of the filter can be very good, but it is interspaced by periods when the sand is discharging high concentration of bacteria into the product water.

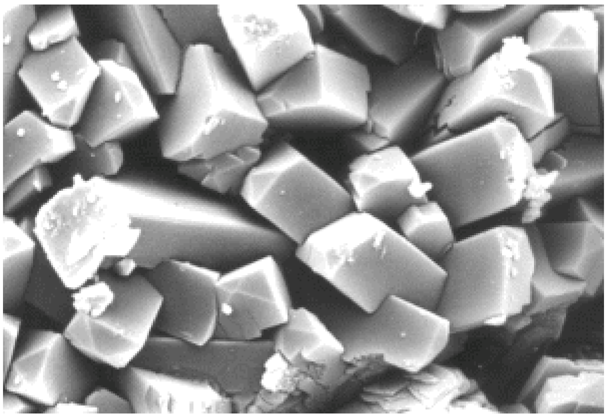


The species diversity of the biofilm is increasing all of the time, and after a few months autotrophic bacteria start to become significant. These bacteria can manufacture organic matter from inorganic carbon. They will normally appear in the lower reaches of the filter bed, they are much slower growing than the heterotrophs but their impact on water quality is significant. The sand now starts to mineralise, the bacteria produce an alginate based biofilm matrix, but they also start laying down a honeycomb mineral structure which gives the biofilm added protection. The shape of the sand grains are changing due to the bio-mineralisation, the production of alginates is increasing and sand is become more unstable. The sand filter has now turned into a factory with the sole purpose to produce as many bacteria as possible.

By this stage nitrogen fixing bacteria start to take up residence in the filter alongside the autotrophs near the base of the filter. As the ecological diversity of bacteria increases, the production of organic matter increases. The sand filters are now producing more solids and organic matter than are entering the filter, the problem is that it is coming in sudden discharges that may go un-noticed unless there is continual turbidity monitors on all the filters.

Back-washing the filter bed and using air scour will remove some of the biofilm, but as the sand ages the biofilm becomes more stabilized. If the water temperature is over 25 deg C the doubling time of the heterotrophs can be as short as 15 minutes, so after a few hours the biofilm is restored. At Dryden Aqua we used to manufacture fluidised be sand biofilters, if you have a sand filter in continual 50% bed expansion on back-wash mode it actually makes a great biofilter, so we know that irrespective how vigorously a sand filter is back-washed, you will never remove all the bacterium.

Clinoptilolite a zeolitic sand



At Dryden Aqua, Dr.Howard Dryden did a PhD on the natural zeolite clinoptilolite for the removal of ammonium from freshwater systems. Zeolites do not work well as ion exchange minerals in marine systems due to the competing cations. However in freshwater Clinoptilolite will absorb ammonium which then acts as a food source for the growth of autotrophic bacteria. Zeolites therefore tend to make very poor mechanical filtration media in warm freshwater systems.

For marine applications there are fewer issues with biofouling; however the electron microscope photo shows the crystalline nature of clinoptilolite which makes a perfect habitat for the growth and protection of bacteria. Clinoptilolite also contains free silica, so as a pre-treatment prior to membranes, a food quality silica sand is actually a better media, and of course AFM® is much better than either media.

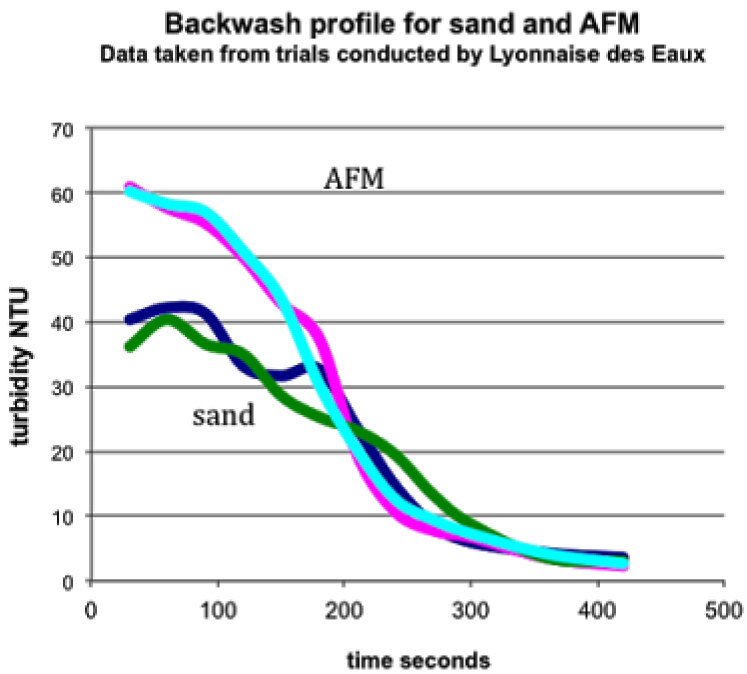
AFM® and Bio-instability in comparison to sand

The biofouling of sand can be measured by taking samples of media after a back-wash, shaking in water to remove (using ultrasonic) them and then measuring the bacterial concentrations. The following was data provided by a laboratory in New Zealand from testing sand and AFM® taken from two swimming pool filters in the same facility.

Sample	Enterococci cfu/100ml	Faecal coliforms cfu/ 100ml	P. aeruginosa cfu/100ml	S. aureus cfu/10ml	APC @ 37 degC cfu/ml
Silica sand	<1	<1	<1	<1	3,600,000
AFM	<1	<1	<1	<1	18
Standard methods of water analysis 20th edition 1998	9230C	9222D	9213E	9213B	9215B Aerobic Plate Count
Client Jonkers filtration P.O Box 708, Kumeu New Zealand	Date received 22/07/04 Dated completed 29/07/04	Laboratory SGS New Zealand Ltd.	Analyst name Marnie Sleeman NZCS	Laboratory Number 3567-04	Filter media sample bacteriological analysis.

AFM® does not biofoul, 100% removed on back-wash

Bacteria will grow in an AFM® filter bed, however they cannot stay in the filter. The back-wash performance is close to 100% efficiency confirmed by IFTS. The IFTS data was conducted under controlled conditions in a laboratory in accordance to ISO procedures. Sand also gave a very similar result, however it was new sand not subjected to biofouling. When sand ages the sticky alginate biofilm layer reduces back-wash efficiency as demonstrated by the results from Lyonaise des Eaux.

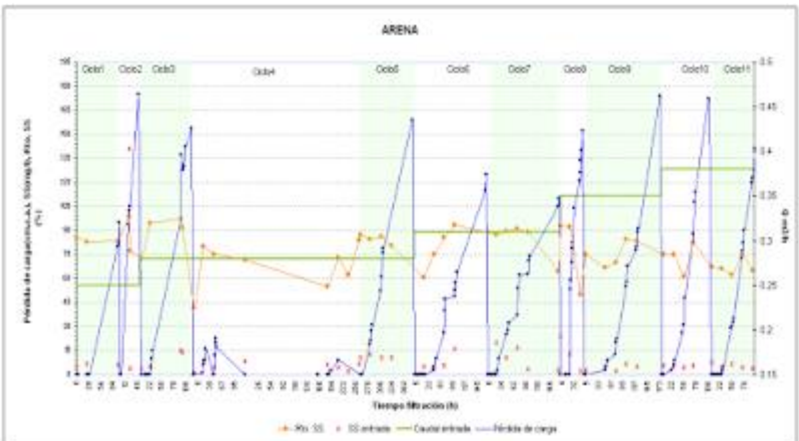


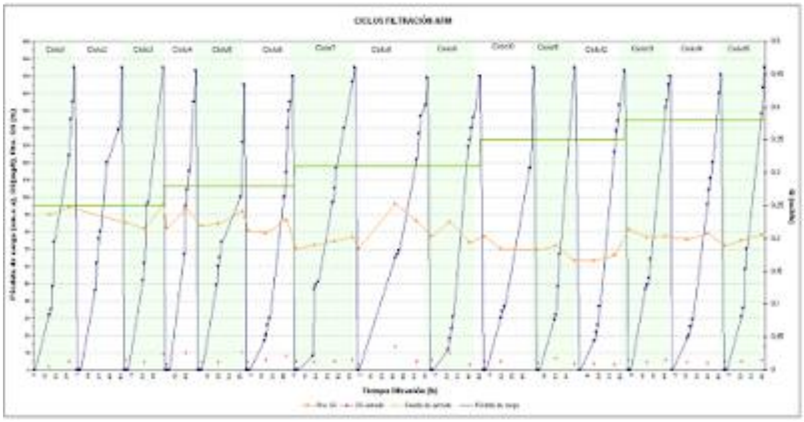
The data was collected from two parallel filters operating on the same water supply at the same time. The two points of merit to note are:

1. The back-wash profile from AFM® is a SIN curve that is repeatable; you can lay one back-wash curve on the next. However the sand filter was a variable. Performance is not predictable and every back-wash (and run phase) was different reflecting the biological variability or change of bacterium species diversity as well as structure in the filter.
2. The area under the AFM® curve is 30% greater; this tells you that 30% more solids were removed by AFM® during the run phase in comparison to sand.

Wormhole channelling and bio-instability

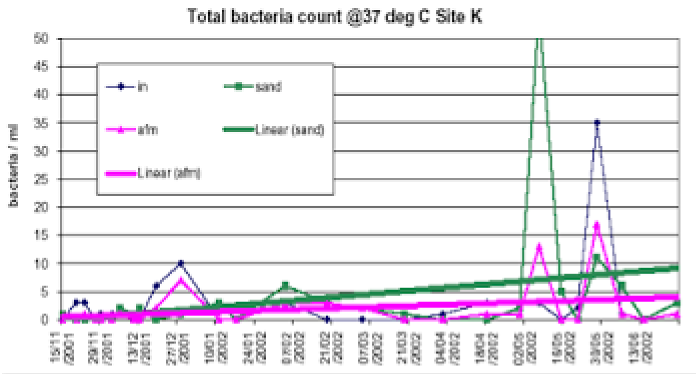
It is also interesting to look at the product water quality and to repeat the back-wash profile over a longer time frame. This work was conducted by a Spanish Water company and the results published in the Spanish Water Journals. The two key graphs from the data are presented below, the first graph is a sand filter run and back-wash series and the second is for AFM®.

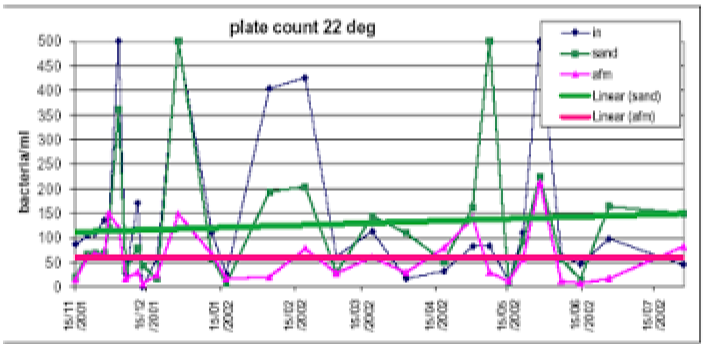




The AFM® profile is like clockwork, the run phase and backwash sequence follow a very precise pattern, whereas the sand filter, operated in parallel and under identical conditions demonstrated a variable performance and channelling. The difference in the performance of the two filters is down to the quality of AFM® and the lack of biofouling.

AFM® and sand run phase performance & bacterium discharge





The stability of AFM® is reflected in performance, another example is a report by Arkal (Amiad) in Israel on the treatment of waste water for irrigation. Tests were conducted, prior to full scale installations, again two filters were operated one with sand and the second with AFM®.The data confirms the superiority of AFM® over sand filters.

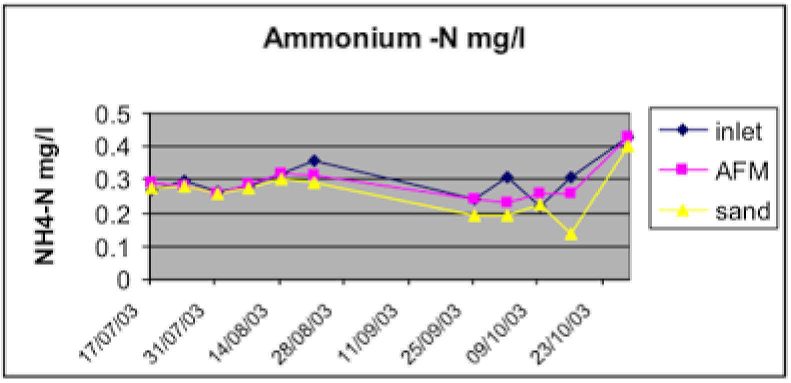
The biofouling sequence has been investigated in more detail by companies such as Scottish Water, the following data is from trial conducted by Scottish Water, Dryden Aqua were just observers and took no part in the tests. The data has been published by the European Commission and appears in the UK Journal WWT. The results are from two identical pressure filters, one with sand and the second with AFM®. The parameters presented below include;

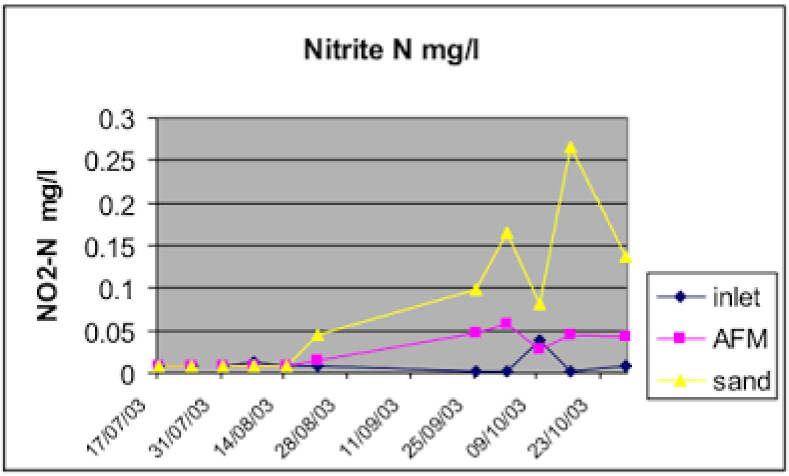
1. Bacterial levels before and after filtration
2. Indirect measurement of autotrophic bacterium colonisation of the filter beds
3. The removal of dissolved organic carbon

Bacterial levels before and after filtration

Total aerobic bacteria were counted before and after a sand and an AFM® filter at 37degC and 22 degC, average trend lines were also added.

Both the sand and the AFM® filters tracked the influent bacterium concentrations, however periodically the sand filter would dump bacterium into the water; this behaviour was not observed with the AFM® filter.



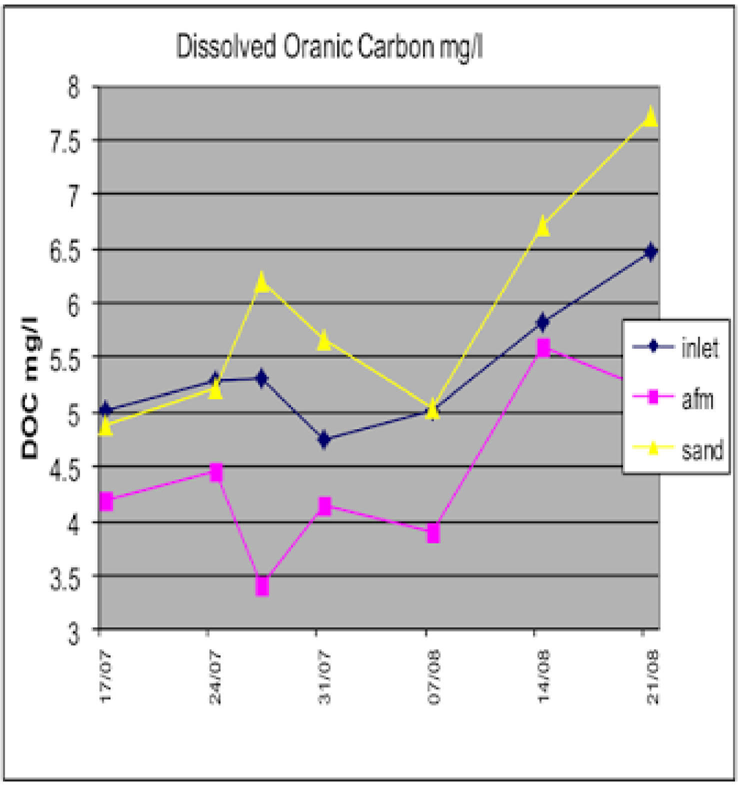


There was a low concentration of ammonium in the product water, autotrophic bacteria will convert the ammonium to nitrite and then to nitrate. This can be indirectly observed by a reduction of ammonium concentration and an increase in nitrite. The two graphs below show this happening for the sand filter, while there was no change with the AFM® filter. The result clearly demonstrates the autotrophic bacterial colonisation of the sand. While this could be beneficial for sand filtration during the early stages, it soon results in the production of bacterial cell biomass and DOC (dissolved organic carbon) levels start to increase.

Dissolved Organic Carbon

AFM® is a selective molecular sieve absorber; dissolved organic matter will be adsorbed onto the surface of AFM® and then released during the back-wash. The graph below confirms that AFM® can reduce DOC. During the first few weeks or months of a sand filter, the biofilm is very good at reducing DOC by conversion into bacterial cell biomass. However rapid gravity or pressure sand filters are not in a state of endogenous respiration, so they have to discharge organics back into the product water.

Once the autotrophic bacteria become established the level of DOC in the product water will often be higher than the influent concentration.



Conclusion

The data presented in this report, is all by independent organisations, water companies and accredited laboratories from across the world.

The data confirms that AFM® does not become a biofilter, this is a really easy parameter to check, simply open up a filter after a back-wash and measure the bacterial levels; they will be close to zero. The French NGO also wanted to check the performance of AFM®, this time against a glass product called Garo filter media manufactured in France. The results confirm that Garo crushed glass became a biofilter, yet AFM® remained clear. All of the data over a 15 year period confirms AFM® does not biofoul, nor does it experience worm-hole channelling. Independent verifiable data confirms AFM® to be at least twice the performance of sand and more than three times the performance of crushed glass.

AFM® is the perfect filtration media for drinking water as well as waste water treatment, and when used as a pre-treatment it will outperform membranes and diatomaceous earth to protect RO membranes from particulate matter down to sub-micron levels as well as many dissolved chemicals.

- *Dr. Howard Dryden*