Why use the R3F Technology for Filtration?

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There are a number of reasons why the R3F Technology provides for a better method of filtration than other options that are in the market place.

All filtration alternatives relate to the use of some type of barrier to separate particles from the fluid or gas going through the barrier. The typical methods are a “surface filtration” through the use of a screen, or “depth filtration” where a media is used and the particles are entrapped in void spaces, or a “cross flow filtration” where a barrier membrane or screen is used as a barrier from particles that are traveling across the screen and the fluid is exiting at right angles to the flow of fluid containing the particles.

If one looks at these three areas of filtration, the benefits of the R3F Technology can be highlighted.

1.0 Surface Filtration (Bag Filters, Melt blown or Pleated Cartridge Filters , or Backwashable Screen or Disk Filters).

Typically many parts of the filtration industry have used some very simple methods of filtration where a screen or a non woven or woven material is used to separate the solids from the fluid or gas. Some examples of these types of filtration products are poly ester or poly propylene bag filters, and poly propylene cartridges which can be constructed in a pleated form or melt blown structure. These types of products are single use and disposable. There is, however, a similarity to the R3F Technology in that they use a circumferential approach to filtration and there by have a much higher surface area to foot print ratio than a typical cross section type depth filter like a sand or multimedia filter. Flow through these types of systems is from the inside - out for bag filters and the outside- in or the opposite way for cartridge or pleated type filters. Companies such as Hayword, Pall, Rosedale, Harmsco and 3M manufacture and sell these types of filters. The level of particle removal in these filters varies with the size of the pore opening in the material or the matrix. Many of these companies will rate the filter on a nominal or absolute basis where absolute is supposed to be 99% removal of a particular particle size. Some of the filters are rated to an absolute value for 1 micron. The difficulty with this approach, however, is that the matrix of structure always has to be the same to obtain the consistent quality and secondly, the filter will blind off rapidly the smaller the micron rating on the filter.

Another typical approach is a backwashable screen or disk filter The screen filters use screens such as wedged steel screens. These filters use a variety of methods to clean the filter but generally include some type of suction type system to remove accumulated particles that have been trapped in the system. Filtration companies such as Ahmiad sell these types of systems. Typically these filters will treat down to the 25 to 50 micron size range but one of their difficulties is the high production of backwash water. Manufacturers of these type of filters will suggest that a typical 150 mm (6 inch) diameter unit will achieve very high flow rates of 8 m3 per hr (30 gpm) to 50 m3/hr (200 gpm). With regard to disk filters these filters resemble a stack of CD's where the flow is from the outside-in where each disk is comprised of a screen. As the pressure builds up to 7- 10 psi the filter then goes into a backwash mode. In back wash, the water is sent into the system on a reverse flow. This causes the disks to expand and separate as well as rotate. This action allows solids to escape in the backwash water. The system is reasonably successful for large particle removal (i.e. 75 micron)

The R3F Technology compares well to these types of systems in that for a single Martin R3F filter using a glass bead media, a $2000 to $3000 unit can provide up to 99% removal (on a particle count basis) of 2 micron particles and is easily back washable at backwash levels that represent 0.3 % to 1% of the through put volumes. As a matter of interest a highly efficient sand filter uses approximately 3% to 5% of the throughput for backwash water. As a result, the Martin R3F Technology allows an operator an alternative to the on-going costs of the disposal and replacement of bag and cartridge filters With regards to the back washable screen filters, the Martin R3F Technology with its standard 150 mm (6 inch) size will provide flow rates in the same range of 8 to 50 m3 per hour when removing particles in the 25 to 50 micron. The typical screen back washable filter would have difficulty accommodating this particle size range especially if the loading was above 50 mg/l of total suspended solids. If the particle size was 100 micron or greater and the level of solids in the water to be filtered was 30 to 50 mg/l, then it is possible a $3500 to 4000 backwashable screen filter could be applied.

The Martin R3F Technology is a perfect application at a much lower cost and more efficient filtration system to the bag filters, single use cartridge filters or the backwashable screen filters.

2.0 Depth Filtration (Sand Filters, Dual or multi media filters, disposable depth filters).

The most common type of filtration system for potable water drinking water systems and other industrial water systems such as for cooling water reuse systems, wash water systems, and utility water systems are the typical cross sectional down flow sand filter or dual media (anthracite and garnet). There are numerous manufacturers of this type of filter.

In addition some of the manufacturers of the single use systems discussed above have also tried to develop a singe use (disposable) depth filter. These cartridge type filters use a winding of polypropylene or a graduated porous melt blown structure that is designed to provide depth filtration.

The down flow sand or dual media filter is a well tested and trusted filtration process. It is clearly the status quo, however, over the last 20 years, an assessment on these filters has identified a number of issues of concern with the down flow filter.

a. Backwash rates and volumes have to be carefully monitored simply because the opportunity to send the backwash water back to the head of the plant has been removed for potable water treatment facilities. As a result the disposal volume of backwash water has to be carefully considered.
b. Backwash rates have to be maintained to ensure proper bed expansion and stratification.
c. Air scouring has been found as an effective tool to improve back wash efficiency but because of the size of the beds, the amounts of air required can be costly.
d. According to the AWWA’s National Assessment of Particle Removal by Filtration -1998, spiking of particles occur in the effluent during normal operations. These spikes can last for 0.5 hours to 10 hours and normally occur during filtration operations. Spiking is a concern because it is during these time periods that cysts (*Cryptosporidium* and *Giardia*) escape from the filtration system. In addition particle removals, is consistent for all particle sizes in a sand filter. In other words if a sand filter removes 95 % of particles in the 2- 4 micron range, then it is likely the filter will remove 95% of particles in the 10 to 15 micron size. The typical down flow dual media filter is not very selective. This could be a detriment if the cysts in a particular water to be treated are in a narrow size range or for that matter, if one wants to have selective filtration of a particular particle size range, the typical down flow dual media filter will have difficulty satisfying this objective.
e. Cross sectional area down- flow filters require a significant amount of floor space. According to a 2001 paper prepared by G Finlayson of GHD Engineering Consultants in Sidney Australia entitled “ Real World Implementation of Microfiltration” , the author suggested that when considering the cost of a particular filtration alternative where such alternative is capable of satisfying the water quality objectives, the following parameters should be considered;
    i. Reliability in consistently producing water that satisfies the objective
    ii. Reliability in Satisfying Water Quantity Objective
    iii. Risk of Operation affecting water quality
    iv. How dependent is the system on the Contractor / Supplier after Construction
    v. Level of Technology Experience in Municipal Water Authorities
    vi. Experience of Technology Designers in Municipal Water Industry
    vii. Ease of Staged Upgrading
    viii. Likelihood that future advances will reduce Costs

In addition he then went on to look at what items make up the cost of a water filtration system. His point here was that there is a tendency to look at the supply costs of the filtration system only without looking at the other costs such as;

i. Design
ii. Site and Civil Works
iii. Buildings
iv. Pump Station
v. Site Piping
vi. Process Plant
vii. Filtration Equipment Supply
viii. Clear Water Storage
ix. Chemical Dosing
x. Wash water system
xi. Power and electrical supply
xii. Control System

If one starts to assess the above functional and cost parameters with the R3F Technology, the benefits become obvious. In fact at the end of this section a comparison has been made between a typical down flow filtration system and a membrane system as reported by Mr. Finlayson and then the Martin R3F Technology has been added in the comparison to show where the "**R3F Filtration technology"** stacks up to the "**Microfiltration Membrane technology"** and the "**Down Flow dual media technology".**

With regards to costs or the typical down flow dual media type system the actual filtration system will cost any where from $400 per m3 per hour ($100 per gpm) to $1200 per m3 per hour ($300 per gpm). As noted above however the infrastructure around the filtration system will have an affect on the actual cost.

Finally with regards to the use of the disposable depth filters that are manufactured from a polypropylene or other similar material, the problem with these units are the same as indicated in the previous section on cartridges. There is a very high cost in the disposal of these units and a concern with the consistency of the structure.

Characteristic	Microfiltration ref: Finlayson	Down Flow Dual Media ref: Finlayson	R3F ref: Bromley
Water Quality Produced	always good	can be variable	should always be good with the ability to use redundant back up systems due to the low cost
Water Quantity Produced	can be restricted	always achieve design	should always achieve design
Risk of Operation Affecting water quality	very low	possible	very low with the ability to provide redundant back up system
Commitment to Contractor/ Supplier After Construction	complete commitment for life of facility	minimal	minimal
Level of Technology Experience in Municipal Water Authorities	limited	extensive	need experience levels similar dual media filtration
Experience of Technology Designers in Municipal Water Industry	limited	extensive	need experience levels similar dual media filtration
Ease of Staged Upgrading	straight forward due to Modular nature of technology	more expensive than adding capacity at start	straight forward due to Modular nature of technology
Likelihood that Future Advances will reduce Costs	High (new technology with significant R&D)	Low (very old and mature technology)	High (new technology with significant R&D)

3.0 Crossflow Membrane Systems

Over the last 20 years, the use of cross flow membrane systems has grown dramatically, particularly because of the need to provide a high quality in certain waters such as the pharmaceutical and wafer board industries. However the use of membrane technology has also grown in the treatment of potable waters because of the need to remove cysts such as *Cryptosporidium* and *Giardia.*

Crossflow membrane technology has four key levels as defined by the capability to remove a certain size particle. In a recent AWWA seminar on “Emerging Treatment Technologies-November 2002”, the four categories and the particle size range where removals were greater than 95% are as follows;

a. Microfiltration – 1 to 10 micron which is the range for cysts (Cryptosporidium and Giardia) and bacteria

b. Ultrafiltration - 0.05 to 1 micron which is the range of colloidal particles and viruses.
c. Nanofiltration - 0.001 to 0.05 micron
d. Reverse Osmosis-0.0001 to 0.001 micron which is the molecular range for dissolved salts.

With some of the higher purity requirements in pharmaceutical waters or the need to remove dissolved salts, reverse osmosis systems are certainly the technology of preference. For many treatment requirements, however, the removal of the particle size of 1 to 10 microns is considered as the ideal range of solid separation as it provides a high quality water and for potable water it is the appropriate range to control *Giardia spp. and Cryptosporidium spp.* cyst removal from the water. As a result the most popular cross flow membrane category is microfiltration. One of the benefits of Microfiltration is the fact that the use of pressure to feed the system is much lower than the pressure requirements used in Reverse Osmosis systems. In fact a typical pressure drop across a Microfiltration system is 15 to 35 psi. This is a significant improvement from the early stages of development for this technology when reverse osmosis systems operated at pressures of 800 to 1000 psi. Obviously this made operating costs very high. Many companies now manufacture and sell membrane technology such as Zenon (who were the pioneers in this technology development), U.S. Filter and Pall. A very popular use of the technology is to use it in a high solid content liquid to operate under vacuum at negative 10 to 12 psi and then concentrate the solids even further. The permeate or treated water from these systems is usually a very high quality water that can be easily be reused.

As referenced at the AWWA Emerging Technologies Seminar typical capital costs for the microfiltration equipment only are $0.20 to $0.45 per gallon per day ($300 per gpm to $650 per gpm) and full installation of such a system would be $0.75 to $1.25 per gallon per day or $1100 to $1800 per gpm. Membranes typically last 4 to 6 years and cleaning under a clean – in – place (CIP) takes place approximately once every 30 days and has a duration of approximately 6 hours. The membranes are typically back washed every 15 to 30 minutes for a period 45 to 75 seconds. Backwash water is usually chlorinated to 3 to 8 mg/l and at pressures of 35 psi. Some backwash systems such as with the Zenon systems use air pulsing as part of the backwash procedure. According to a study undertaken by Farahbakhsh and Smith, February 2001, backpulsing results in the loss of productivity since water production is halted and significant quantities of finished water are used during this period. On the other hand backwashing every 15 minutes had a significant effect on the length of run as the run time was doubled compared to a backwash of 30 minutes.

Pretreatment using alum (2 to 10 mg/l) or PACl (4 to 8 mg/l) of the waters prior to cross flow membrane filtration is also typically required to reduce biofouling. The Farahbaksh et al 2001 study confirmed that fouling was a result of the smaller particles (2 to 15 microns). As a result pretreatment with the alum or PACl improves run time significantly and the effectiveness of backwash. Typically membranes used to treat water after clarification for a typical surface water treatment system can achieve 90% and greater removal of turbidity, and particle counts less than 2 per ml (except after backwash)for particles in the range of 2-15 microns. TOC removals are generally very low. (Farahbakhsh et al, February, 2001). Again according to the same study, energy usage for a membrane system used to treat water after clarification in a potable water treatment plant would be approximately 0.45 kWh to 0.50 kWh/ 1000 litres (1.7kWh to 1.9kWh /1000 gallons).

Another major component to the use of membrane technology is the ability to monitor the integrity of the membrane such that a particle release does not occur and potentially the discharge of cysts. Many municipal drinking water authorities now require continuous membrane monitoring for operations that use membrane technology for potable water treatment.

4.0 Summary

After the testing by the University of Alberta, it was found that the R3F Filtration Technology provides some interesting similarities in performance to microfiltration technology but also provides significant cost and operational benefits when compared to microfiltration, as well as typical downflow dual media sand filtration and the disposable cartridge and bag filtration systems. The R3F Filtration Technology tested at the U of A used glass beads as fine as 20 microns in diameter. Glass beads are perfect spheres and as a result for a bead size of 20 microns a void space of 1.4 microns in width (approximately 7% of the diameter of the sphere) will occur.

The testing at the University has occurred over the last two years but based on this limited testing program and time frame, the following encouraging results were noted

1. In most of the tests at the University, the glass bead size for the filtration media was in the order of 40 to 80 micron diameter resulting in a void space size of 2.5 to 5 microns. It was found that when testing the R3F Technology, it was evident that as the media became smaller the greater percentages of smaller particles were separated from the water being filtered. As indicated earlier this was different than with sand filters which seem to obtain the same percentage removal for all particle sizes but is very similar to membrane filtration which is very selective on particle size based on the pore size of the membrane. As a result the R3F Technology provides the benefit of selective removal which can be used to remove something like cysts/ pathogens (*Giardia spp. and Cryptosporidium spp*).
2. In all cases, during the University testing, the media depth was approximately 27 mm (1.1inches). The unique aspect of the R3F Technology is that operating pressures can be maintained at similar levels to membrane filtration by adjusting the media thickness. For example if the focus is on the removal of 2 micron particles and a 20 micron glass bead media is utilized then the

pressure loss across the media can be maintained at the 20 psi level by reducing the depth of the media to say 13 mm (13000 microns).

It was found that using a media of 40 to 80 microns and one pass through a 27mm (1.1 inch) bed depth, the R3F Filtration Technology could remove 95 to 99% of 2 to 15 micron particle size and approximately 95% removals of B subtilis spores which was used as a surrogate for cysts / pathogens. It should be noted, however, that there was no correlation between particle counts and spore removal. In addition based on the literature and the fact that B subtilis spores are smaller than *Giardia spp. and Cryptosporidium spp* ,it was felt the R3F Filtration technology using the 40 to 80 micron bead size could accomplish a 2 log removal of *Giardia spp. and Cryptosporidium spp* but no tests were undertaken to confirm this hypopthesis. The actual testing for spore removal showed overall log spore removals on Mil-Spec 12 glass bead and Mil-Spec 13 glass bead media were 1.21 ±0.06 and 1.63 ±0.07, respectively. Due to the low standard deviation, the importance of repeatability of those runs demonstrates the consistency of R3F technology using the glass bead media for B. subtilis spore removal. The relationship between B. subtilis spore removal and *Giardia spp. and Cryptosporidium spp.* removals was not demonstrated because no experimental testing occurred for *Giardia spp. and Cryptosporidium spp.* removals. Nevertheless, based on literature reviews, Hijnen (2000) demonstrated in experimental work undertaken in the Netherlands that he achieved 2 log removal of protozoan (oo)cysts on rapid sand filtration, which was a little higher than 1.7 log removal of B. subtilis spores he achieved on the same rapid sand filter. Hijnen (2000) also indicated that B. subtilis spore can be regarded as a potential surrogate for protozoan (oo) cysts but the removal efficiency for the spores will be to some extent lower than the removal of (oo)cysts. The R3F filtration units had slightly less log spore removal compared to some conventional deep-bed sand filters (e.g. 2 log) but this can be attributed to no coagulation/ flocculation/ sedimentation processes being performed prior to the spore filtration tests. Due to the zeta potential of B. subtilis spores which tend to be repulsive, the spores could escape through the media. With the use of standard aluminium or ferric metal coagulants, as would be used with typical water treatment clarification processes, it is anticipated that removals would have been higher. For Giardia cysts, several investigations have demonstrated little (<1 log) to no removal by sand and dual-media filters (Al-Ani et al, 1986), and tri-media filters (Horn et al, 1988) during no-coagulation conditions.

In addition, in the experimentation it was found that there was almost an additional 1 log loss of B. subtilis spore which occurred in the tankage and piping prior to the R3F units. This is considered significant when comparing the removal of *Giardia spp. and Cryptosporidium spp* using the R3F Technology and other technologies. For example if, in the testing of the R3F Technology, the experiments had not accounted for this loss in the system prior to the filter, one could have reported removals 1 log higher than actually occurred.

Others have also reported on spore loss prior to the actual unit being tested. In a study by Huck et al (2002), it was reported that the spore loss in equipment prior to the filtration being tested was much less (< 0.10 log) .The designed system layout and materials of apparatus may attribute to this difference. This difference is important and certainly must be considered in discussions regarding pathogen removal.

3. It was also found that to restore the media after use, a backwash to volume throughput was as low as 0.3% and as high as 3% depending on the water quality being filtered. (i.e. the lower the influent particle count ,the lower the backwash water requirements.) The filter was tested with influent particle counts has high as 30000 particles/ ml and as low as 200 particles/ml
4. With the simplicity of the R3F Technology, manufacturing costs are very low. Selling prices will be based on what the market will bear, however, the technology allows for the ability to achieve microfiltration levels at capital and operating costs that are similar to sand filtration.
5. The significant benefit of the R3F technology over sand filtration is the much lower need for floor space and infrastructure. This creates a significant cost saving over sand or typical cross sectional area filtration systems. Another significant benefit is the ability to change out media because of a change in filtration needs or a situation where the media has been contaminated. In the R3F Technology, the media would be fluidized to the upper end of the column and discharged out the media outlet. Media can be added the same way. This is a far simpler procedure than having to vacuum out or shovel out the media as is the case with sand or dual media filters.
6. To accomplish high levels of filtration, the R3F Technology can easily be used in series and by using this approach, the operator can obtain a number of safe guards in the integrity of the system by monitoring between filter columns and sampling effluent. In membrane systems, continuous membrane integrity monitoring is very costly. With the low cost of each filter column in the R3F Technology, redundancy is not a significant issue and the ability to monitor effluent streams with back up filtration is very economical.
7. Finally the significant benefit of the R3F Filtration Technology over bag filters and disposable cartridges is the fact that the Technology is backwashable and will result in a significant operational cost saving and quick pay backs.

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