Manz Engineering Technical Description 2022: MEL Biological Filter and MEL Polishing Filter

(Manz Engineering Technical Description 2019: MEL Biological Filter and MEL Polishing Filter is attached.)

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1. **General Description**

Manz Engineering Ltd. (MEL) manufactures biological and polishing sand filters, known as MEL-BF and MEL-PF filters respectively. They are part of MEL Filter Systems or MSF which also includes the MEL Carbon Filter or MEL-CF and the MEL Roughing Filter or MEL-RF. (This paper, a brochure and other information on MEL Filter Systems is provided on the web site; www.manzwaterinfo.ca .) The MEL-BF is an important variation of slow sand filtration. It is designed to remove pathogens and other nuisance organisms but will also remove mineral and particulate matter. The MEL-PF is specifically designed to efficiently remove small mineral and organic particulate matter without use of chemicals. The design of the MEL-BF and MEL-PF are an extension of the design of the original BioSand water filter, a design based on traditional slow sand filtration. The operation of the MEL-BF and MEL-PF and BioSand filters are identical – except for surface loading rates (volume of water treated per unit of area of filtering surface per unit of time) as discussed later. The principal difference between them is their method of cleaning. The BioSand filters are cleaned using surface agitation and a gentle backwash to degas the media and the MEL filters are cleaned using an aggressive backwash without surface agitation. The advantages of the MEL filters over the BioSand filter are the ease with which the filters can be cleaned, the simplicity of design and economy of scale. That said, there are more than a million (perhaps millions) of the humanitarian household variation of the BioSand water filter being used in households and schools in disadvantaged communities throughout the world – filters that are locally constructed and successfully used to meet many of the same water treatment challenges resolved using the large MEL filters.

MEL biological filters remove pathogen causing microorganisms from water including helminths, parasites, bacteria and viruses using a process similar to that used by traditional slow sand filters. They will also remove all other types of organisms as well as mineral and organic particulate material. Post-filtration disinfection using chlorination or ultraviolet disinfection is required to completely kill or deactivate bacteria and viruses not removed by the MEL filter. (Slow sand filters will remove 90 to 99 per cent of bacteria and viruses from water.) Parasites and larger organisms, which might not be able to be killed or deactivated by chlorination, are completely removed by the MEL-BF and MEL-PF filters.

MEL polishing sand filters use surface loading rates several times that of MEL biological filters. They are used to remove small mineral and organic particulate material without use of chemicals to achieve a quality objective (suspended solids concentration or turbidity) that meets drinking water guidelines or to a quality where subsequent treatment processes such as ultraviolet disinfection or membrane filtration might be effectively used. The polishing sand filters alone have been demonstrated to provide 5-log removal of giardia cysts and very near this of cryptosporidium oocysts.

MEL filters cannot be used alone to efficiently remove dissolved substances. Dissolved substances will typically pass through the filter with little or no reduction in concentration. Some organic and inorganic toxins may be removed but additional research is required.

MEL filters cannot be successfully used to remove oily and sticky material from water. These substances will be removed by adhering to particle surfaces. However, it is not known how to clean captured oils and other sticky materials from the media.

It is recommended that all MEL filter applications be piloted to guarantee performance prior to development of prototype designs.

2. Media Bed

The design of the media bed used by MEL-BF and MEL-PF filters is very important.

MEL polishing and biological sand filters both use a media bed that is divided into two zones as shown in Figure 1. The top zone is the filtering zone and the bottom is the underdrain zone. The filtering zone is designed to remove particulate material that may include inorganic and organic material that may also have a variety of living organisms. The underdrain zone supports the filtering zone and facilitates the evacuation the filtered water. The filtering and underdrain zones may use several types and sizes of media.

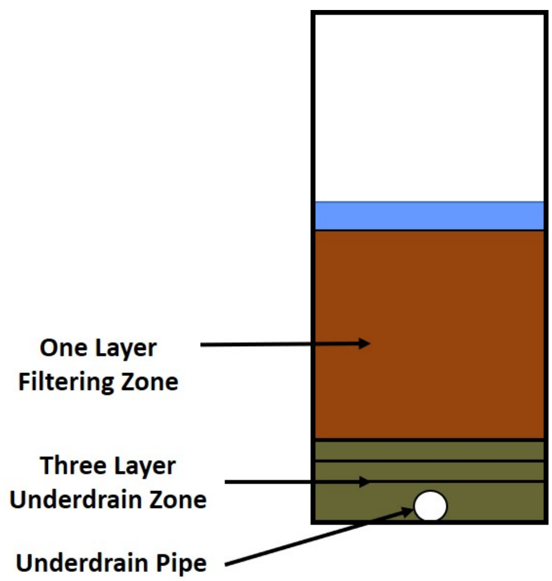

Figure 1. Media zones in MEL-BF and MEL-PF filters.

Typically, the filter media used will be well graded to include media with a range of particles sizes from 0.1mm or to 0.45mm, large enough to be supported by the top of the underdrain media. The filter media is selected such that once commissioning is completed the smallest particles are at the surface and will be able to remove the smallest particulate material of interest. Also, the filtering media must be able to be cleaned using a backwash flow rate that will not disturb the underdrain media. No filtering media is removed or lost during the cleaning process. Filter media should never need to be supplemented, removed or replaced.

1.1 Underdrain Zone

The underdrain zone is designed to allow filtered water to enter the pipe drainage network located at the very bottom of the underdrain zone. See Figure 2 which shows actual photos of underdrain pipe and layers of media used. In the case of the MEL filters the pipes have openings (circular openings, not slotted) with sufficient cumulative area to ensure that all filtered water can be evacuated with minimum head loss. The openings are distributed across the entire filter cross-section such that a vertical flow is evenly distributed throughout the cross-section of the filter (downward or upward). The bottom most layer of underdrain media is comprised of particulate material that is sized sufficiently large to not pass through the holes in the drainage pipes (and plug the pipes). The size of this media has pore spaces (openings between particles) which would likely permit the largest filtering media to pass to the underdrain pipes and plug them off – clearly not desirable. It is therefore necessary to use a second underdrain layer that rests on top of the bottom most layer that is sized so that it will not pass into the pore spaces of the bottom most layer (effective size of the second layer is approximately one-quarter that of the media used in the bottom layer). This layer is said to be supported by the layer below. If the openings of the second layer are still too large to support the largest filtering media a third underdrain layer (effective size approximately one-quarter of the media in the second underdrain layer) is required which has pore openings sufficiently small that the largest filtering media is supported. Three layers of underdrain media arranged in this fashion are usually sufficient. (The design of the underdrain media is constrained by the need to support the largest filtering media on the top of the underdrain and the size of the openings in the underdrain pipes. It is just as logical to select the size of the top layer of the underdrain media as large as possible and still support the filtering media, selecting the layer below this as large as possible and still support the top layer of underdrain, and so on, always checking to determine if the particles will pass through the holes in the underdrain pipes. When the layer has particles that will support the underdrain layers above it and not pass into the underdrain pipes, the design of the underdrain media is completed.)

(It is important to note that the backwash flow rate used in the MEL-PF and MEL-BF filters is quite low compared to modern rapid sand and pressure sand filters. Commercially available underdrain systems used in rapid sand and pressure sand filters will not work in the MEL filters.)

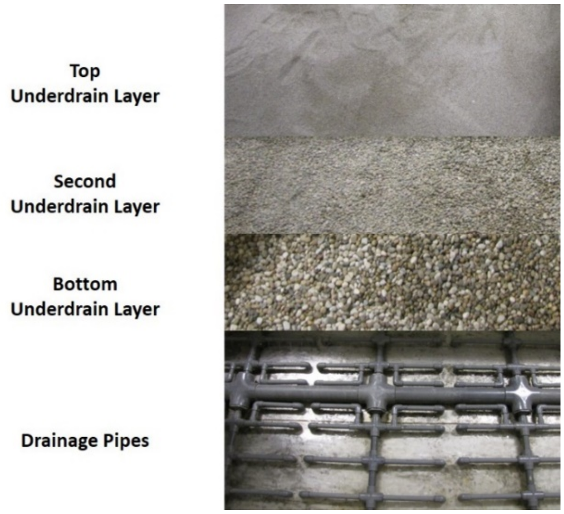

Figure 2. Photos of actual drainage pipes and underdrain layers.

1.2 Filtering Zone

The filtering zone in MEL-BF and MEL-PF filters is designed to efficiently capture particulate material of interest at or near the top of the filtering zone. MEL filters are NOT depth filters such as rapid sand and pressure sand filters in which particulate material is captured throughout the filtering zone. The filtering zone in depth filters includes the entire thickness of the filtering media and it must be cleaned before breakthrough of unfiltered water occurs or just before it occurs. (Breakthrough water is untreated and will contaminate treated water supplies.) MEL filters do not exhibit breakthrough such as that experienced by rapid sand and pressure sand filters or any other type of depth filter. Rather, as MEL filters capture material the pores at or near the top of the media plug off and the filtering rate is gradually reduced to where the filter requires cleaning using a backwash flow to restore filtering capacity.

1.3 Media used in MEL-BF and MEL-PF filters

The media used in the MEL-BF and MEL-PF filters must meet NSF61 standards when used to treat potable water. The media used in MEL-BF filters must comply with AWWA B100 80. The media used in MEL-PF filters doesn't necessarily need to comply with this standard but it is considered good engineering practice to use media that does comply.

The media used in the filtering zone of MEL-BF and MEL-PF filters has an effective size of 0.35 mm or less. Ideally, the media used is well graded and has a fraction of particles less than 0.1 mm in size. Filter sand suppliers can prepare media for use in slow sand filters but the preferred approach is to select one or more standard products to be used singly or in combination. Uniformly graded media, where particles are all the same size, would be useful but is not used because it is either not available or too expensive.

3. Commissioning and Backwash Considerations

MEL filters are commissioned using a backwash flow to redistribute the particles in the filtering zone so that the largest are on the bottom of the zone (just above the top of the underdrain zone) and the smallest are at the top or surface of the zone (top of media). The backwash flow is achieved by pumping filtered water (and unchlorinated water in the case of the MEL-BF filter), into the underdrain pipes such that it flows vertically upward through the underdrain layers and completely fluidizes all of the media in the filtering zone. This process is illustrated in Figure 3. When the flow of water is stopped the particles are now redistributed as desired.

Backwashing will not fluidize any of the particles in the underdrain zone.

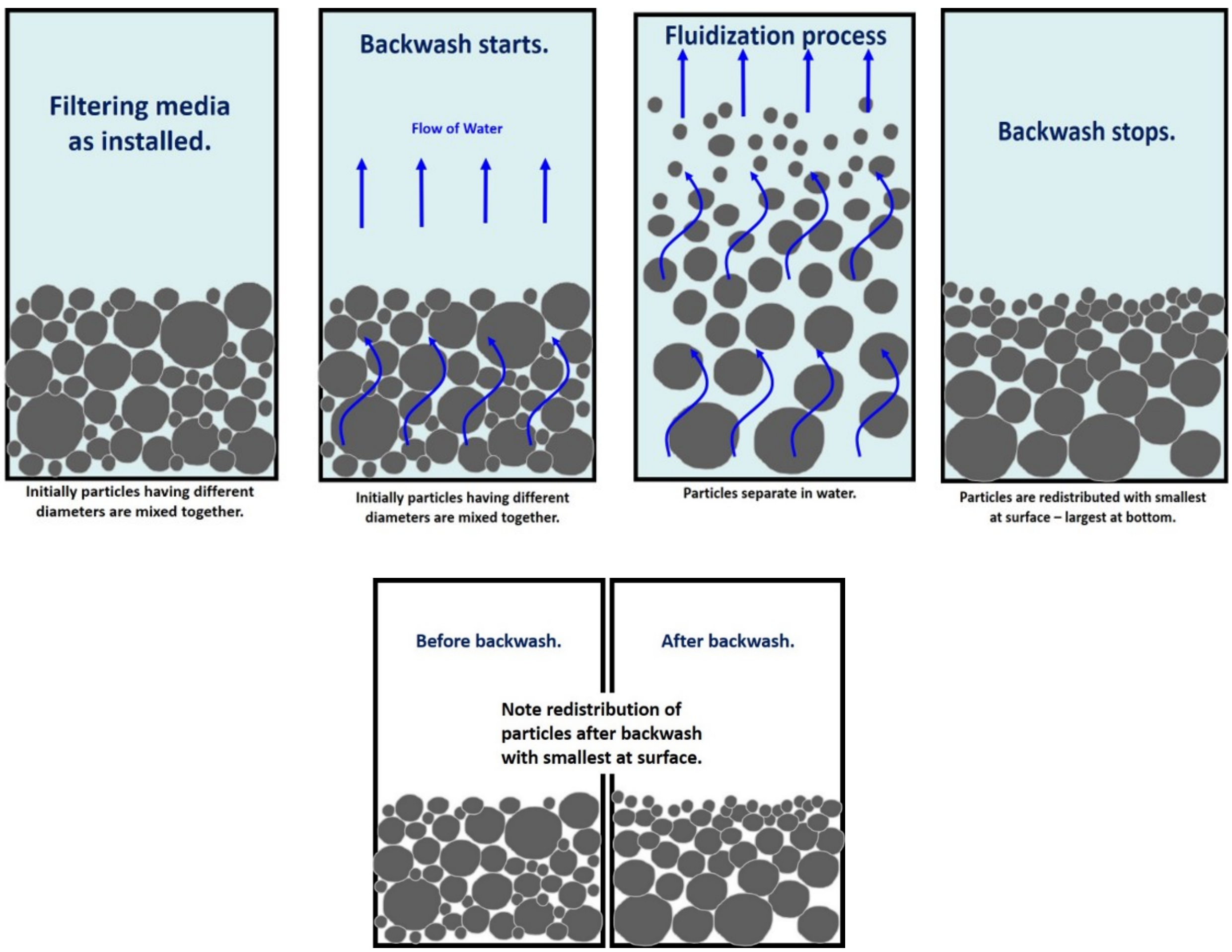

Figure 3. Effect of backwash at time of commissioning on the redistribution/ classifying of filtering media.

If two or more layers of filtering media are initially installed and the media is the same material (e.g., the same crushed quartzite) the layers will mix to form one layer – the layering of the media at time of installation is lost during commissioning.   This is illustrated in Figure 4.

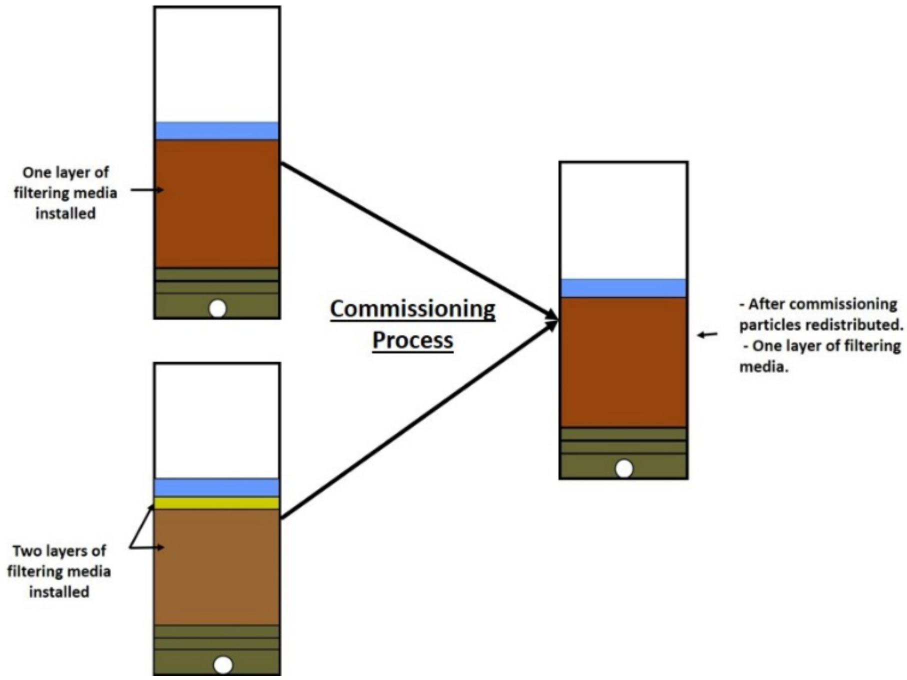

Figure 4. Effect of backwash during commissioning on one or two layers of media initially added to filtering zone.

Research and experience have demonstrated that backwash flow rates ranging as low as 4 L/s/m^2 may be effective but the ability to use 8 to 12 L/s/m^2 is recommended. (Piloting is required to determine optimum backwash rate.)   Figure 3 illustrates the effect of the backwash at time of commissioning on the redistribution of filtering media.

The volume of backwash water used in a MEL filter is limited by the volume available in the filter vessel/ tank above the filtering media. This is unlike rapid and pressure sand filters where backwash flow may be several times that of the MEL filters and will be continually wasted until the wasted water has an acceptably low turbidity.   MEL filters use a fraction of the wastewater produced by rapid and pressure sand filters.

Because the flow rate used to backwash rapid and pressure sand filters is so large the size of the particles in their filtering zone are much larger than that used in MEL filters. The smallest particles in the filtering zone of rapid and pressure sand filters may be the same size as the largest particles in the filtering zone in MEL filters. It is common for media used in rapid and pressure sand filters to be lost from the filter during the backwash process. The loss of media and the change in particle distribution of remaining media requires that periodically the media be completely removed and replaced (a process known as resanding). Rapid and pressure sand filters may use relatively complex designs for their filtering zone to optimize their performance, decrease frequency of backwashing and decreasing frequency of resanding. Media used in rapid sand and pressure sand filters may include activated carbon, silica sand and garnet sand and other specialized media of varying sizes. MEL filters are capable of using complex designs of the media zone as well but this has not yet proven to be necessary.

4. MEL Biological Filters or MEL-BF

When used as a biological filter the MEL filter performs similar to a traditional slow sand filter which is never backwashed. The media in the entire filtering zone in a MEL biological filter must conform to the type and effective size of that specified by industry standards for use in a slow sand filter (AWWA B100.1 and NSF61). The design of the filtering zone and surface loading rates vary with local regulatory guidelines. The minimum depth of the filtering zone is 0.35 m or greater and the surface loading rate is rarely permitted to exceed 400 $L/h/m^2$.

A MEL-RF filter, a roughing filter, may be used if the suspended solids concentration of the water is considered too great for efficient use of the MEL-BF. (Note that the media used in the MEL-RF can be tailored to effectively treat the specific type and concentration of suspended solids.)

A MEL-CF filter, a filter that uses GAC, can be used after the MEL-BF to remove dissolved organics and reduce colour. If the water is chlorinated prior to entering the filter, the GAC will not be colonized by living organisms. It is capable of removing most of the chlorine and dissolved organics, and can be expected to have a very long life. It is very important that the MEL-CF be piloted.

3.1 Operation of the MEL-BF

The particulate removal mechanisms operating in a MEL biological filter are identical to that of a traditional slow sand filter. The surface loading rates are sufficiently low (limited by local industry standards) to permit the formation of biofilm on the surfaces of the media particles located at or near the surface of the media zone. Figure 5 illustrates how particulate matter is captured and the formation of the biofilm on the particles at the surface of the filtering media. The near surface layer of the filtering zone, where the particles are covered in a biofilm, is known as the biolayer (also called a schmutzdecke). The formation of the biolayer does not depend on the development of an accumulation of organic material on the surface of the media as once thought. Biofilms, and therefore a biolayer, will develop if the raw water supply has living organisms in it and the water is well aerated. The biolayer is only a few centimetres deep. The biological processes in the biolayer capture, consume or deactivate most of the bacteria and viruses. All larger organisms are captured and consumed by the biological activity. The advantage of the MEL filter is that the size of the particles at or near the surface of the filtering zone are much smaller than traditional slow sand filters. Consequently, the area of biofilm per unit volume at the surface of a MEL filter is much larger and the MEL filter is potentially more effective in removing microorganisms than traditional slow sand filters. (The greater the area of biofilm the greater the opportunity to capture organisms.) (Parasite removal does not depend on the formation of a biofilm on the media particles.) Biofilms are not lost during the cleaning process.

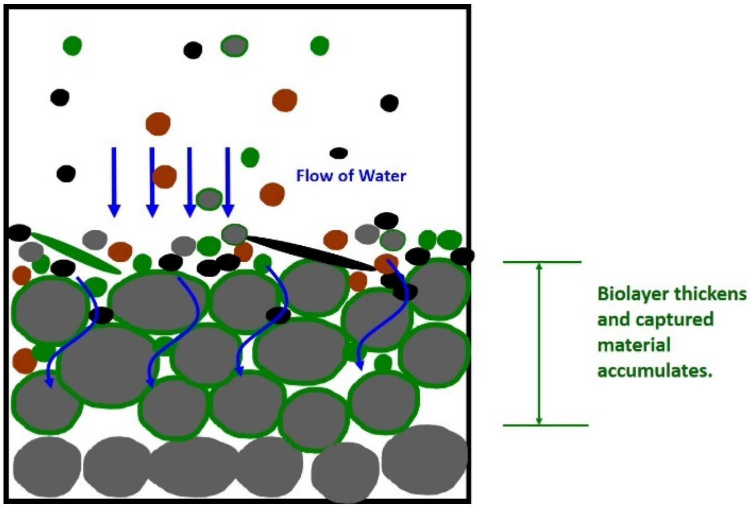

Figure 5. Capture of particulate matter and formation of biofilms and the biolayer.

The novelty of the MEL biological filter is that its operation may be stopped and started without impairing its ability to remove microorganisms unlike traditional slow sand filters which must be continuously operated to preserve performance. The ability of the MEL biological filter to stop and start operations without losing performance was first used in the design of BioSand water filters and has been successfully demonstrated in many thousands of filters in use around the world for over thirty years. The ability to stop and start filtering without loss of performance is possible because when the operation of the filter is stopped the water level above the media is allowed to decrease to a depth of only a few centimetres (paused water depth) allowing oxygen from the air above the water to diffuse into and through the water to reach the top of the filtering media and supply needed oxygen to organisms there. The biolayer is aerobic. This is illustrated in Figure 6.

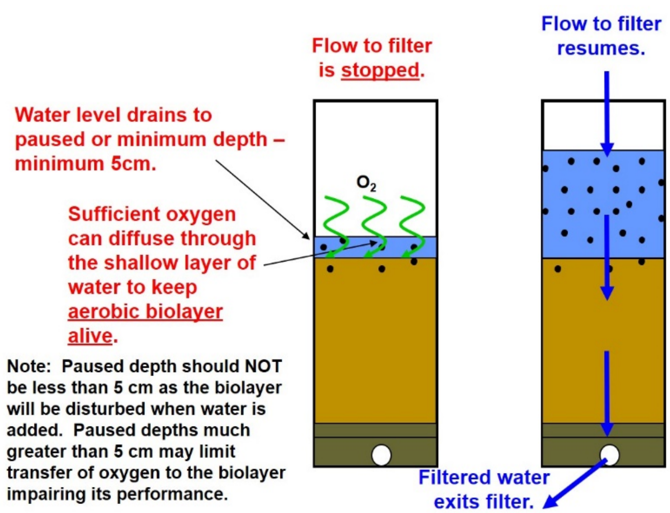

Figure 6. Preserving the performance of the filter when flow is stopped.

Also, the paused water depth must be sufficient to absorb the impact of the water when it is added to the filter when filtering is restarted. When water is added to the filter it must pass through a specially designed diffuser basin which breaks the flow into small droplets that do not have sufficient momentum to disturb the biolayer on the surface of the media.

There is biological activity throughout the entire filter which also contributes to microorganism removal. The nature of the biological activity occurring at depth is not entirely understood.

3.2 Restoring filtering capacity – cleaning the MEL-BF

Both the traditional slow sand filter and the MEL-BF filter will plug off in identical fashions – the pores at the surface of the media are gradually filled with captured particles and so restrict the flow of water.

The filtering capacity and efficacy of a traditional slow sand filter is restored by stopping filter operations and removing a limited depth of the top of the media in the filtering zone. This process will remove all particulate material that has plugged the media and responsible for reducing the flow. The same particulate matter that is removed is coated with the biofilm responsible for removing bacteria and viruses. After cleaning, a traditional slow sand filter requires a period of operation that will allow development of a biofilm on the new particles located at or near the surface of the media zone. This process is known as ripening and may take several days during which filtered water is wasted. The filtering zone used in traditional slow sand filters is sufficiently deep to allow for several cleaning processes before additional filter material must be added. Because the restoration of filtration capacity is so onerous, traditional slow sand filters are limited to treating water with low suspended sediment load and low turbidity.

MEL filters are cleaned using a backwash process as illustrated in Figure 7. The filter operation is stopped and previously filtered but unchlorinated water (water with no residual disinfection capability that would affect the organisms in the biolayer) is pumped into the underdrain system at a flow rate that will not fluidize the underdrain but will fluidize the entire filtering zone similar to that which occurs in the commissioning process. (Fluidization of the underdrain would require a backwash flow rate several times that required to fluidize the media in the filtering zone.) Upon completion of the backwash process the media in the filtration zone is left distributed exactly as before the backwash process occurred. The smallest particles with associated biofilm will still be at the filter surface and the ability of the filter to remove microorganisms is preserved. The fluidizing process disturbs the media throughout the entire filtering zone and a short period of filter-to-waste is normally required until the turbidity of the filtered water is acceptable. (Note that a small amount of particulate material is captured at depth. Normal backwashing will not necessarily remove all of this material.) No filtering media is lost such as that which occurs when rapid sand and pressure sand filters are backwashed. Unlike traditional slow sand filters, it is not necessary to remove media and replace it. Backwashing may be repeated to insure adequate cleaning prior to filter-to-waste.

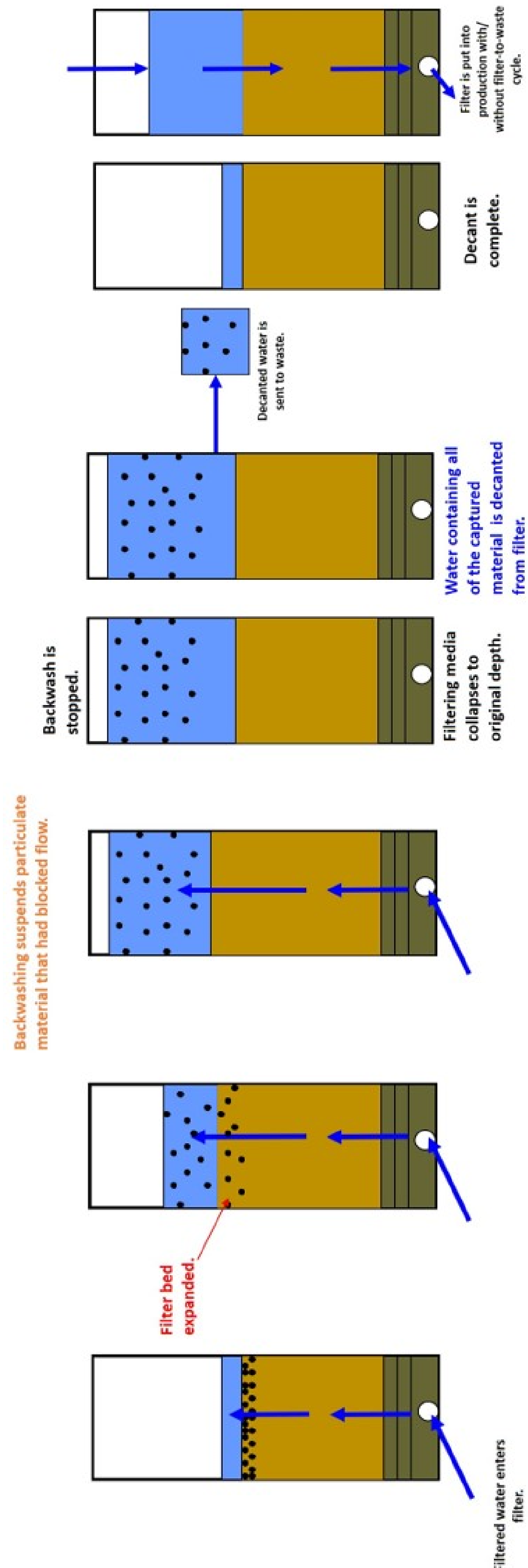

Figure 7. Cleaning a filter using the backwash process.

5. MEL Polishing Sand Filters or MEL-PF

MEL polishing sand filters are intended to be used to remove low concentrations of fine suspended solids, mineral and organic. Water may be chlorinated or unchlorinated. To date chemicals have not been used but remains an option to enhance particulate removal. The MEL-PF filters are designed similar to MEL-BF filters with a filtering zone of 0.35m. The surface loading rates may be as high as 1,200 L/h/m. In circumstances where unchlorinated water is being treated or used for cleaning, the particles near the surface will develop biofilms if there are living organisms in the water and the filters will remove a significant per centage of bacteria and viruses.

Importantly, the polishing sand filters have demonstrated a five-log removal of giardia and near that of cryptosporidium parasites whether water is chlorinated or unchlorinated and biofilms are formed or not (confirmed by independent third-party evaluations as described in MEL Technical Bulletin #2). This ability has greatly expanded the use of MEL-PF filters to successfully treat previously treated (and chlorinated) pipe-distributed municipal water supplies that have been re-contaminated during distribution (often caused by loss of pressure in the distribution system which allows contaminated surface water into the pipes). Typically, the residual chlorine of the treated water will eliminate pathogen hazards associated with bacteria and viruses but not parasites such giardia, cryptosporidium and importantly, those causing amoebic dysentery.

The typical applications are reduction of suspended sediment from surface waters and removal of oxidized iron and manganese from groundwater. Hydrogen sulfide gas may also be removed from groundwater. Arsenic is removed along with newly oxidized iron in a process known as co-precipitation. (Other metals can likely be removed using a similar process though this would need to be demonstrated by pilot studies which are always recommended for most applications of the polishing sand filter.) Reduction in the concentration of suspended solids has allowed successful use of ultraviolet disinfection and membrane filtration for removal of dissolved solids such as dissolved organics that contribute to water colour – a MEL-CF filter may be used for the same purpose.

As previously stated, MEL filters cannot be used alone to effectively remove dissolved substances, mineral or NOC (DOC) which will typically pass through the filter with little or no reduction in concentration.

The MEL-PF filter cannot be used to remove oily and sticky material that adheres to particle surfaces and cannot be cleaned from the media using a backwash process. Removal of oily/ sticky substances will require some form of chemical pre-treatment that would form particulates that could be captured and cleaned from the media. The nature of possible chemical pre-treatment would be specific to the substance intended to be removed. It is likely that significant research would be required to determine which chemical pre-treatment would work. This type of research is outside of MEL's mission.

5.1 Operation of the MEL-PF

MEL polishing sand filters remove particles at or near the surface of the filtering media similar to the biological sand filters and illustrated in Figure 4. As stated, the surface loading rate may be as high as 1,200 L/h/m^2. At these surface loading rates a small portion of particulate removal will occur deeper in the filtering zone. Surface loading rates greater than this have been found to cause compaction of the media (caused by head loss across the filtering zone) resulting in premature decreases in filtration capacity similar to plugging off of pores (restored during the cleaning process). Surface loading rates should be as high as possible but need to be verified using appropriate pilot studies. The larger the surface loading rate, the smaller the filter surface area required to treat the water and less expensive the overall filter installation. The cost of a pilot study is not significant and always justified.

The desirable method of operation is to remove all large particles that cannot be removed by the backwash method prior to the raw water entering the polishing sand filters. This may be performed using a variety of filtering methods depending on the nature of the particles suspended in the water supply. Screens, pressure sand filters, self-cleaning mechanical filters or MEL-RF filters are a few of the options available.

Mineral particles that enter the filter and not able to be suspended sufficiently long enough during backwash and removed from the filter when the wastewater is evacuated will become part of the filter bed.

Colloidal sized particles such as clay or very fine silt (often called rock flour) may not be removed. The use of chemicals such as coagulants may be effective aids but must be considered very carefully because of the uncertainty associated with the removal of resulting flocs during cleaning, complexity of chemical use, and cost. If considered, chemical use must be carefully piloted to determine effectiveness and method of management. Mineral coagulating agents are recommended.

Organic particles may be living or dead. Organisms that may need to be removed include aquatic plants, algae, a variety of aquatic animals at varying stages of development, spores, helminths (and their eggs), parasites, bacteria, viruses and bits and pieces of larger organisms that may be in the water. The quantity and nature of particulates in source water may vary with season and weather (e.g., snowmelt, rainstorms, algal blooms). The hazard any organic material presents, is that if cleaning operations are not frequent enough, the organic material may accumulate on the media surface and form large flocs that might be difficult to remove using otherwise routine cleaning processes and must be mechanically removed. There are many different species of algae and their ease of capture and removal may be quite different. Removal of some types of algae actually improves with pre-chlorination, a process that should be evaluated at the bench and pilot scale if considered an option.

Iron and manganese can be removed from water supplies, typically from groundwater sourced from wells. On occasion the iron and manganese will already be oxidized (hydroxide form) and are able to be removed without pre-treatment. If the dissolved iron and manganese are not oxidized, they may be oxidized with low doses of chlorine (usually sodium hypochlorite) that would need to be added to the filtered water before storage anyway. After the chlorine is added the water is temporarily stored and gently agitated in a small tank, called a contact tank, prior to being fed to the filters. The contact tank allows the oxidized metals to floc and form larger particles that the filters are able to remove. If the water is complexed (e.g., naturally chelated by dissolved organics in the water, NOC), stronger oxidants such as potassium permanganate, ozone or chlorine dioxide may be used and chlorine added after filtration to meet regulatory guidelines prior to being stored. Care must be taken not to use additions of oxidants that exceed maximum additions of chemicals as described in NSF/ANSI/CAN 60. Bench and pilot scale studies are very important.

Hydrogen sulfide and sulfate and iron reducing bacteria may be found in wells alone or associated with dissolved iron and manganese. Chlorination will oxidize the hydrogen sulfide and kill the sulfate and iron reducing bacteria. If the water is considered to be under direct influence of surface water, there is the possibility that giardia and cryptosporidium may be present as well. Chlorination sufficient to oxidize dissolved iron and manganese or the hydrogen sulfide alone will kill or deactivate bacteria and viruses and the MEL-PF will remove the parasites if present. The multiple barrier approach may require ultraviolet disinfection and addition of chlorine as required by regulatory agencies prior to storage. It is worth noting that the presence of sulfate or iron reducing bacteria will foul most pressure sand filters including greensand filters to the extent that their media cannot be thoroughly cleaned due to particles sticking together. Treatment capacity is lost due to the gradual development of short circuiting of flow through the media. Media will require periodic replacement. Fouling of this nature cannot occur in MEL-PF filters which will remove the sulfate and iron reducing bacteria similar to any other microorganism.

5.2 Restoring filtering capacity – cleaning the MEL-PF

The filtering capacity of MEL-PF filters is restored in exactly the same manner as that used to restore MEL-BF filters. Filtered or filtered and chlorinated water may be used. Optimum backwash flow rates may be determined using a pilot scale filter but limited to less than 12 L/s/m^2 or less depending on the media used. Backwash rates of 4L/s/m^2 are usually effective.

If the filters are used to remove iron and manganese it is possible to reduce wastewater to zero (almost). The ferric and manganese hydroxide flocs are concentrated in the wastewater removed from the filter. A simple settling tank will allow the flocs to settle and concentrate on the bottom of the tank. The concentrated sludge can be periodically drawn off and disposed of on land or with the sludge in a local municipal wastewater treatment facility. The clarified water can be returned to the transfer tank and filters.

6. Piloting the MEL-BF and MEL-PF Filters

Most of the potential applications of MEL-BF and MEL-PF filters can be evaluated using both bench and pilot scale studies. Figures 8, 9 and 10 show photographs of a MEL bench scale filter and two pilot scale filters, 30cm diameter and 60cm diameter.

Bench scale studies are usually performed in a laboratory though they can also be performed on-site. They are primarily used to determine if the filters can remove particulate material of interest. All processes pertaining to removal of mineral particles and large living and dead organisms, can be evaluated at the bench scale. Success at the bench scale may lead to pilot scale studies – depending on the specific treatment issue being considered. Bulk samples of water to be treated (20 to 40 litres) are supplied to the testing laboratory according to MEL instructions. Bench scale studies can usually be performed in a matter of days.

Backwash related concerns require pilot scale studies. Pilot scale studies that evaluate the removal of iron and manganese may be completed in a matter of days. Pilot scale studies of particulate removal from surface water may require several months to properly consider all of the variations of the quality of the source water with season and weather. It is recommended that pilot scale studies should be performed by MEL or in close collaboration with MEL.

Figure 8. MEL Bench scale filter.

Figure 9. MEL 30 cm pilot scale filter.

Figure 10. MEL 60 cm pilot scale filter.

7. Available Filters

MEL filters are available with the following dimensions:

- 2m x 2m x 2m manufactured by MEL and shipped with media to site.
- 2m x 4m x 2m manufactured by MEL and shipped with media to site.
- 4m x 4m x 2m manufactured by MEL and shipped with media to site.
- 8m x 8m x 2m tank manufactured on site and appurtences, pipework and media supplied by MEL.
- 16m x 16m x 2m tank manufactured on site and appurtences, pipework and media supplied by MEL.
- Custom designs may be provided for additional fee.
- Existing slow sand filter installations may be retrofitted to use MEL filter technology.
- Designs are available for the use of MEL filter technology for use in disadvantaged communities worldwide.

Photos of the 2m x 4m x 2m and 4m x 4m x 2m filters are shown in Figure 11.

 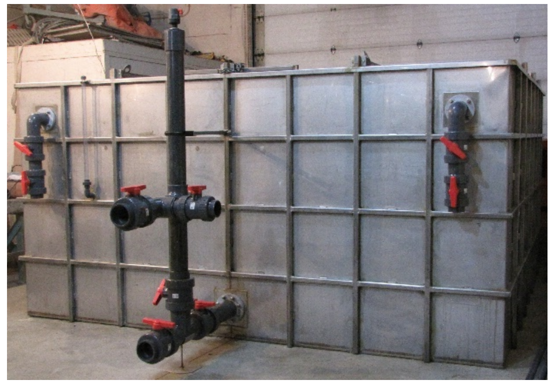

Figure 11. Photos of the MEL 2m x 4m x 2m filter and the MEL 4m x 4m x 2m filter.

Smaller versions of the MEL filters are the Manz BSF 60 and the Cabin Clean Water Filter (CCWF) that are available from a sister company to MEL, Davnor Water Filters Ltd. Photos of these filters are shown in Figures 12 and 13.

The Manz BSF 60 is able to treat 60L/h when operated as a biological filter and up to 240L/h when operated as a polishing sand filter. It is used in a similar manner to the larger MEL filters. The operation and cleaning processes are identical. This filter and its earlier BioSand filter variation has been successfully used to provide potable water to Canadian households for over twenty-five years. The MEL BF60 can also be used for limited piloting of larger scale MEL filter applications – particularly those considering iron and manganese removal.

The CCWF is intended to provide limited amounts of potable water for use in a single household at a filtration rate of 12L/h. If the water source is other than water from a previously treated municipal piped water supply the filtered water should be disinfected using chlorination. (Parasites that cannot be killed or deactivated by chlorination are removed by the filter.) The CCWF has a very wide range of applications that are described in detail on the web site; www.cabincleanwaterfilter.com and in www.manzwaterinfo.ca .

One possible use of the CCWF is bench scale evaluation of treatment options considered for the larger MEL filters.

Figure 12. Photos of the manually and automatically operated Cabin Clean Water Filter.

Figure 13. Photo of the Manz BSF 60 filter.

8. Construction of MEL-BF and MEL-PF Filters

Construction of MEL-BF and MEL-PF filters is very tightly controlled by MEL to provide superior quality control and maximum flexibility in their use while limiting unwanted modifications to design prior to or during installation. Most of the manufacturing is performed by MEL under subcontract.

The filters consist of three elements; a vessel or tank, speciality pipework and appurtences, and the media. The tank is specially designed to accommodate the pipework, appurtences, and the media and to facilitate transport. MEL provides all of the elements as part of the purchase price. The tanks are constructed of stainless steel and the pipework is Schedule 80 high density polyethylene. The tanks are shipped mostly assembled without media which is supplied separately to be installed on-site. The largest filters that can be transported by truck transport are 4m wide x 4m long x 2m deep. Examples of filters being loaded and transported in this fashion are shown in Figures 14 and 15.

Figure 14. MEL 2m x 4m x 2m filters being loaded and transported.

Figure 15. MEL 4m x 4m x 2m filter being loaded and transported.

The tanks may be constructed of other materials such as aluminum or fibreglass or constructed on site using concrete according to designs specified by MEL.   MEL will always supply the pipework, specialty appurtences and media.

Filters can be manufactured to be transported fully assembled with media installed (fully portable). The pipework will need to be manufactured using material that can withstand the jarring that will occur during transport. Completely portable filters simply need to be backwashed prior to being put into operation.

Filters are usually manually operated and cleaned though they can be remotely monitored and the operation and cleaning can be partially or fully automated, a feature that may be important particularly for installations that require centralized or remote monitoring and operation.

9. Engineering Support

Engineers interested in MEL filters will be provided the MEL brochure and this document to assist them in their assessment of the potential utility of the MEL technology to solve their specific treatment problem.

MEL is interested in knowing exactly what the treatment problem is in order to make informed recommendations. MEL needs the following information:

- Description of the treatment problem including some idea of how the availability and quality of the source water supply may vary with season or weather.
- Recent complete water quality analysis of source water that will be used in design.
- Treated water demand.
- Regulatory concerns.
- Description of present and previous treatment methodology used to treat the water and a description of the success of these methods to treat the water including a description of the problems that were encountered.
- Description of treatment technologies being considered.
- Opportunities for wastewater disposal.
- Energy availability.
- Location of client and nature of access to location of water treatment plant. (Transport limitations.)
- Other special concerns.
- Budget limitations.
- Time line for provision of treatment technology.

MEL will identify appropriate filter technology that should be considered including descriptions of relevant previous projects that have used MEL filters. Budget pricing and conditions of sale will be provided.

Should the engineer decide to proceed with consideration of MEL filter technology, MEL will prepare a budget for MEL to provide consulting pertaining to further consideration of the treatment approach that might be used (consulting fees appropriate for a specialist in water treatment engineering). The budget will include consulting fee, the costs for bench scale evaluation if needed and estimates of costs for pilot scale (on-site) evaluation of MEL filter technology and report preparation.

If bench scale evaluations are considered necessary MEL will provide instructions for the acquisition and transport of batch samples to MEL laboratory.

If the engineer decides that MEL technology will be used, MEL will provide all of the necessary technical details of the MEL filtration technology, (specifications, drawings, sample manual), to prepare a detailed design. MEL will review the proposed use of MEL filters with the engineer.

10. Installation Considerations

A minimum of two filters should be used in an installation. Two or more filters can be used together in a group or cluster to provide desired filtration capacity. At least one extra filter, beyond that needed to meet the required maximum treatment demand, is recommended to provide backup should one of the filters be taken out of service.

It is important to note that MEL filters are used in parallel. Each filter is operated and cleaned independently of the other filters. When a filter requires cleaning, it is isolated, cleaned and put back into service without disturbing the operation of other filters.

Installations are supervised/ evaluated by a MEL engineer.

Installations of the 2m x 4m x 2m filter and the 4m x 4m x 2m filter are shown in Figures 16 and 17.

Installations of MEL type clusters of cast-in-place concrete 4m x 4m x 4m filters are shown in Figure 18. Where possible MEL recommends use of the transportable stainless-steel filters.

The 2m x 4m x 2m filters and smaller can be skid mounted or located in shipping containers (seacans).

Figure 16. Photos of MEL 2m x 4m x 2m filter installations.

Figure 17. Photo of MEL 4m x 4m x 2m filter installation.

Figure 18. Photos of cluster of six 4m x 4m x 2m cast-in-place MEL type filters.

11. Commissioning, Training and Technical Support

Filter installations are commissioned when the entire treatment facility is operational. Commissioning is supervised by a MEL engineer. It is advisable that the individuals who will be operating the treatment plant be present during commissioning (and filter installation if possible) as this will provide a very good training opportunity. A thorough manual is provided for the filters which also describes where replacement materials can be obtained if needed. MEL engineers are available to provide technical support when requested.

12. Advantages of the MEL-BF and MEL-PF Filters

Advantages of MEL-BF and MEL-PF filters include:

1. Effectiveness (guaranteed performance when appropriately piloted).
2. Simplicity and flexibility of design (may use variety of construction materials and methods). Necessary construction materials available worldwide. Installation and commissioning are not complex.
3. Easily evaluated using bench and pilot scale studies.
4. Compact compared to traditional slow sand filters.
5. Only slow sand filter technology that can be operated on a demand basis.

6. Scalable – systems available to treat tens of litres to millions of litres per hour.
7. Low capital cost.
8. Simplicity of operation.
9. Minimum operation training.
10. Minimum operator attention.
11. Minimum maintenance requirements.
12. Minimum use of chemicals.
13. Minimum energy requirements.
14. Minimum pressure requirements for raw water feed.
15. Restoring filtration capacity/ filter cleaning uses low pressure backwash. Media is not scraped. Resanding is not required. Mechanical surface agitation is not used.
16. Filter media is not subject to air binding.
17. Breakthrough of untreated water into the treated water supply is not possible.
18. Minimum production of wastewater and waste sludge.
19. Wastewater easily managed (disposed of) because no chemicals used in treatment.
20. Wastewater may be recycled with only the thickened solids going to waste – clarified liquid returned to filter.
21. Modular – treatment systems may be easily expanded in small or large increments to meet future demands.
22. Easily used with other pre- and post-treatment technologies including reverse osmosis, nanofiltration, GAC, ultraviolet disinfection and others.
23. Manual or automated operation.
24. Portability associated with prefabricated MEL Filters.
25. Appropriate for both readily accessible and remote applications.
26. Potential to retrofit existing traditional slow sand filters.
27. Commissioned and decommissioned in increments as required.
28. Several successful projects worldwide. Project descriptions available on request.

13 Comments

The MEL filter technology has been under development for thirty years. It is the only commercially available slow sand filter that can be successfully cleaned using backwash. The technology is mature and well tested. The applications are well understood.

MEL filter technology has a global market.

Manz Engineering Technical Description 2019: MEL – Biological Filtration and MEL – Polishing Filtration

(Slow sand filtration – Demand Operated and Cleaned Using Backwash)

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Summary

A demand operated slow sand filter design that can be demand operated and allows cleaning using a backwash process is described. The new design, developed by Manz Engineering Ltd. (MEL™), meets or exceeds all of the design criteria specified by the AWWA for traditional slow sand filtration (TSSF) and TSSF performance expectations. The ability to operate the filter as required and ease of cleaning greatly expands slow sand filter applications.

The MEL filter systems (MFS™) include two distinct types – the MEL Biological Filter (MEL-BF™) that is intended to replace TSSF's and the MEL Polishing Filter (MEL-PF™) that exploits the unique ability of slow sand filtration to remove particulate material and reduce turbidity without reliance on any biological processes.

The ability to operate the MEL-BF on a demand basis while retaining the treatment characteristics of TSSF is made possible by recognizing that the biological layer on the surface of the media bed (schmutzdeke and the active or biolayer) is aerobic. The MEL-BF is designed such that there is always sufficient oxygen available to the biological layer even when there is no flow through the filter thereby keeping it alive. The ability to backwash the MEL-BF without destroying the biolayer is achieved by recognizing that the biological layer consists of the top most layer of media particles which have each developed a biofilm and by designing the media bed such that the particles that form the biolayer always remain on the surface of the media bed (after a backwash has been completed). Filter media is never removed or replaced. The design of the MEL-BF is more compact than that of the TSSF, less expensive to construct, simple and inexpensive to operate and able to treat a wider range of water quality than the TSSF.

The MEL-BF and MEL-PF (MEL BF/PF) type technologies are presently being used for pathogen removal, turbidity reduction, and iron and manganese removal in both developed and developing country environments. Pre- and post-treatment greatly enhance the range of applications of the MEL-BF beyond that associated with simple TSSF technology. Treatment systems using the MEL-BF or MEL-PF technology can be very effective for arsenic removal in circumstances where there is iron present (can be added) and uranium where there is manganese present (can be added). The MEL-PF technology can be used to remove the smallest particulate matter (including mircoflocs of iron, manganese or alum); that is, as a polishing filter, in circumstances where a biolayer may not be required for treatment. Backwash volumes are less than one per cent of production compared to greater than five per cent for alternative technologies. In certain circumstances the treatment process allows for complete recycling of the backwash water leaving only a very small amount of sludge containing the solids.

The MEL-BF/PF technologies are modular and can treat water for small to very large communities. Capacities of individual MEL-BF/PF units range from hundreds to several hundred thousand liters per hour. Treatment plants may incorporate many MEL-BF/PF units to achieve capacities of several million liters per hour.

MEL-BF/PF type technologies or their precursor the Biosand Water Filter (BSF) technology, are in use in more than one hundred countries. Several water treatment plants which use the MEL-BF/PF type of technology are operating, under construction or in the design phase in Western Canada, Colombia and Kenya.

Introduction

Traditional or conventional designs for sand filtration remain satisfactory and effective water treatment solutions in many large-scale applications. However, the demands for their precise operation to achieve required performance to meet increasingly stringent water treatment regulations often result in excessive capital and operational financial burdens. Water treatment facilities that are complex to operate, that generate excessive volumes of waste water or that must use chemicals, which may be difficult to manage properly and further complicate waste water disposal are not desirable. Complex water treatment facilities require more skilled plant operators, which may not be available or affordable in many circumstances.

The development of the MEL biological filter and the MEL polishing filter (MEL-BF/PF) grew out of the apparent need to provide an effective, physically simple, operationally simple and robust, low-cost water treatment solution for use in small to medium scale water treatment plants in circumstances where capital and operational resources are limited. The MEL-BF combines the water treatment capabilities of the traditional slow sand filtration (TSSF) with the method and apparent convenience of filter cleaning associated with rapid and pressure sand filters. Note that the designs of the MEL-BF/PF have eliminated many restrictions associated with the earliest versions of the technology known as the 'low operating head polishing sand filter'.

Background

It is necessary to review the important characteristics of commonly used sand filtration technologies in order to fully appreciate how the significant advantages of the MEL-BF/PF are realized.

Rapid rate granular media filters (rapid sand filter and pressure sand filter)

Both rapid sand water filters (exposed to the atmosphere) and pressure sand water filters (in a pressure vessel) are typically used as polishing filters after addition of coagulants, flocculation and clarification (sedimentation) processes. Filtration (particle capture) mechanisms operating in rapid rate granular media filters do not include any biological or adsorption (typically) processes. An early thorough review of rapid sand filtration may be found in Hazen (1907). A very good contemporary review of rapid rate granular media filters may be found in Logsdon (2008).

Water treatment plants that treat surface water or groundwater under direct influence of surface water and provide final polishing using rapid rate filters use the following process. Coagulants are added to the raw water to allow the formation of coagulant flocs which will capture the very small particles (including parasite cysts and oocysts) and some dissolved organic and inorganic compounds. Sufficient coagulant must be added to produce flocs that are sufficiently large to be efficiently removed in sedimentation basins or clarifiers where they settle out of the water or may otherwise removed using technologies such as dissolved air flotation (DAF). Other chemicals may be added to enhance floc formation. The 'clarified water' is then sent to the rapid sand or pressure sand filters for final polishing prior to disinfection and storage. To ensure removal of parasites such as giardia and cryptosporidium the turbidity of produced water must be less than 0.1 NTU.

Rapid sand filters are gravity operated sand filters. The required force to cause water to move through the filter bed is provided by the head of the untreated water above the surface of the media, often one meter or more. During operation a rapid sand filter resembles a swimming pool. Rapid sand filters normally have multi-material media beds above a complex underdrain system that also serves as the entry and distribution for very large volumes of treated water (and air if air scour is used) in the backwash process when the filter is cleaned. After a backwash the filter media is stratified with the smallest particles at the surface (assuming a filtration bed is using a single density of media). Different densities of filter media will stratify with least dense (anthracite) at the top and most dense (silica or garnet) on the bottom. Within each layer of different density, the smallest particles with the same density will be at the top of the layer. Intermingling of media of different densities is common.

Pressure sand filters are wholly contained in a closed vessel specially designed to take the forces resulting from operation under pressure that may be supplied by the raw water intake pump itself. Pressure sand filters are very compact when compared to rapid sand filters. Similar to a rapid sand filter a pressure filter may contain several layers of filtering media of different material. Pressure filters normally use a very compact underdrain/backwash system. When they are not filled with media, pressure sand filters are easily transported. The media is added once the filters are located and necessary piping attached. Large capacity pressure filters may be several meters in diameter. The underdrain system also serves as entry and distribution for very large volumes of treated water and air similar to rapid sand filtration. After a backwash the media is (intended to be) distributed in precisely the same manner as for rapid sand filtration.

Both pressure and rapid sand filters force the water through the filter. Particulate material is captured in narrow ranges of the smallest particles in the filter bed, (multiple locations if a variety of different density media is used), until there are no longer any locations within the media for particulate capture. At this time the water, still containing the offending particulate material, is forced completely through the filter and the filter may exhibit what is known as 'break through' phenomena. Breakthrough is detected by an increase in turbidity of the filtered water (treated water is continuously monitored using in-line turbidity meters and alarms). Well before breakthrough occurs rapid and pressure sand filters are cleaned using a very aggressive backwash process. Air scour and surface sprays may be used to assist the cleaning process. Waste water is disposed of while the backwash process is taking place frequently resulting in the smallest media particles being lost. The backwash process is continued until the waste water produced is considered sufficiently free of particulate matter. The filter is then operated with produced water sent to waste until it exhibits a sufficiently low turbidity (less than 0.1 NTU to insure removal of cysts and oocysts) at which time it is diverted to treated water storage. The filtered water is always disinfected prior to being stored to kill or deactivate any parasites, bacteria or viruses (e.g. using ultra violet disinfection and chlorine) that might still remain in the filtered water. The volume of waste water produced by rapid sand and pressure sand filters during the backwash process is quite large (up to 5% or more of total production). During a backwash the media in the filter bed stratifies into layers with the finest and lightest material on the top. If the backwash process or the pre-treatment used prior to filtration is not carefully performed the filter media can be seriously damaged (formation of mud balls, short circuiting, flushing of fines, etc.). Coagulants and other floc development or capture enhancement chemicals can present a waste water disposal problem.

Alone, rapid rate granular filters do not remove pathogens, of any type, from water. These filters are always intended to be used after treatment using effective particulate removal processes to provide removal of residual products such as small flocs that have escaped the clarification process.

Traditional slow sand filter (TSSF)

Traditional slow sand filters or slow sand filters are known for their ability to remove very small inorganic and organic, living and dead particulate materials from water. Descriptions of slow sand filtration technology can be found in Logsdon (2008), Hendricks, ed. (1991), Logsdon ed. (1991) and Huisman and Wood (1974). It is interesting to note that recommended design, operation and cleaning has not changed significantly for more than 100 years, Turneaure and Russell (1901) and Hazen (1907). Filtration mechanisms operating in TSSF's include all those operating in rapid rate granular media filtration plus biological processes that contribute to their effectiveness in removing pathogens. TSSF's are operated at a much lower surface loading rate 1/20 to 1/50 that of rapid rate filters and so require 20 to 50 times the surface area. TSSF's are not recommended for treating water with turbidity exceeding 10 NTU, for removing iron and manganese or when pre-treatment involving use of coagulants is required (such as for removal of clay particles) because cleaning slow sand filters to recover filtration capacity is very labour intensive.

TSSF's have the ability to remove pathogens (helminths, parasites, bacteria and viruses) and non-pathogenic organisms including algae from water. A very thorough review of all TSSF processes and dynamics may be found in Campos, et al (1996a) and (1996b). The removal of bacteria and viruses is the result of the formation of a biologically active layer in the upper few centimetres of the media surface (active or biolayer) and the development of a layer of organic material (living and dead) and other inorganic material on the surface of the media known as the schmutzdecke. The development of the biolayer or the schmutzdecke requires from one or two weeks to several months depending on the quality of the raw water including its temperature. Intuitively, the lower the concentration of living organisms in the raw water and the lower the water temperature the longer the biolayer will take to develop. Campos, et al (1996a) suggests that the effective thickness of the biolayer can only be 2 cm in depth. A thicker schmutzdecke usually forms if the filters are located outdoors with exposure to sunlight when there is opportunity for substantial algae growth. The biolayer in the top few centimetres of the media (or deeper depending on a variety of factors that include size of media and surface loading rate) where the particles develop a biofilm on their surface. Photographs of particles taken from the top of a TSSF that illustrate the development of biofilms on the particles forming the biolayer may be found in Joubert and Pillay (2008). Historically the development of the schmutzdecke was considered essential for TSSF's to develop their ability to remove pathogens; however, it is now understood that it is only necessary to develop the biolayer, though the presence of a schmutzdecke is considered a positive contribution Hijnen et al (2004), Hijnen et al (2007) and Heller and Ladeira (2006). Both the schmutzdecke and the biolayer are aerobic and depend on continuous operation for provision of dissolved oxygen to stay alive.

Organisms captured within the filter do not leave the filter due to predation and disintegration or some other mechanism within the biolayer, filter material or the schmutzdecke if it is present. Studies using a pilot filter using fine ultra-clean sand without any biology demonstrated very high removal of cryptosporidium oocysts - most near the media surface Harter et al (2000). It is not unreasonable to conclude that were the oocysts filtered (removed) in the context of the normal biology presented by a operating slow sand filter most of the oocysts captured would have been predated and oocyst breakthrough would not occur. This view is supported by
Heller and Ladeira (2006) who report a study involving an experimental TSSF column (0.75 m deep with sand having a d_{10} = 0.25 mm and uniformity coefficient = 2.40) to examine the effectiveness of TSSF on oocyst removal and the fate of Cryptosporidium oocysts in a filter column. They observed four and five log removal of oocysts by the filter and in an assay of oocysts in the filter sand found very few oocysts generally and no oocysts below 0.6 m (at flow rates of 0.25 $m^3/m^{2/}h$). They report other studies where no oocysts were found below 2.5 cm from the media surface. Heller and Ladeira also reported a lack of correlation between filtered water turbidity and the removal of oocysts and suggest that the use of turbidity as an indicator of oocyst removal (at least in the case of TSSF) may not be valid or at least warrants further investigation.

A survey of useful methods with which to remove Giardia cysts and Cryptosporidium oocysts from drinking water may be found in AERT (1994) where TSSF technology is recognized as being very effective.

The productivity of a TSSF decreases as the pores at or near the surface of the media become clogged. TSSF's do not exhibit 'break through' of inadequately treated raw water. Filtration rates simply become unacceptably low. When the filtration rate is too low the filter is cleaned by removing the top few centimetres of media (including the schmutzdecke if it has formed). The bacteria and virus removal characteristics recover with development of the biolayer, a process that might require several days to weeks to complete. It is assumed that removal of parasites is directly correlated with the reestablishment of the biolayer though reduction of turbidity of filtered water below 0.5 NTU is considered sufficient (a process known as filtering-to-waste). As previously mentioned, Heller and Ladeira (2006) could not demonstrate the correlation between low turbidity and parasite removal. It may be that the correlation is accurate for treatment systems using coagulation, flocculation, clarification and rapid rate granular media filtration but not slow sand filtration. Because traditional slow sand filters are so difficult to clean their use is not recommended for filtering water with turbidity greater than 10 NTU or water containing oxidized iron and manganese (more than 0.3 and 0.05 mg/L respectively).

Note that well operated TSSF's will remove all helminths and parasites, reduce turbidity below 0.5 and remove 95% or more bacteria and viruses. It is important to emphasize that with post filtration disinfection all bacteria and viruses remaining in the filtered water are destroyed. Chorine additions to treated water (or water that does not require treatment) are required throughout North America to the extent that minimum residual chlorine concentrations are detected at all points-of-use throughout the community being served.

The ability of a slow sand filter to form the biolayer is related to the low surface loading rate, typically 0.1 to 0.4 $m^3/h/m^2$ in combination with use of clean small diameter filter media. It is required that the media meet American Water Works Associate standards for hardness and purity, AWWA – B -100. (In Canada the media must also be NSF 61 certified.) The AWWA Manual of Design for Slow Sand Filtration, Hendricks ed. (1991) specifies a minimum depth of filter bed, not including the underdrain materials, of between 0.3 to 0.8 meters. TSSF's have used beds of more than 1.0-meter-deep to allow several 'cleanings' which each remove up to 5 cm each before a 're-bedding' or 'topping-up' of the filter bed is required. Flow rate through the filter bed is controlled using valves or weirs with adjustable height.

There are concerns regarding effect of temperature on the performance of TSSF's particularly water that is near freezing. The principal concern is the effect very cold temperatures have on biological processes. Despite well published experiences indicating failure of TSSF's to remove parasites, Giardia cysts or Cryptosporidium oocysts, from near freezing water it is generally agreed that properly designed and operated TSSF's are effective in removing parasites even when the temperature of the raw water is near freezing Hendricks and Bellamy in Logsdon ed. (1991).

MEL Biological Filter

The MEL biological filter (MEL-BF) adheres to the same design criteria as recommended for TSSF technology and exhibits the same treatment characteristics as TSSF technology. However, the MEL-BF technology can be demand operated and cleaned using a unique backwash system.

Principles of design, operation and performance

The bed of filter media used in a MEL-BF consists of one layer of media suitable for use in a slow sand filter. There are no restrictions beyond AWWA B-100 guidelines (rounded, crushed or mixtures of rounded and crushed particulate may be used). The depth of the filtration layer is 0.45 m or more, or as specified by appropriate regulatory agency. The commissioning process fluidizes the filtering layer and ensures that the finest particles (less than 0.15 mm) are at the media surface to provide superior filtration.

The flow of filtered water is controlled using a 'weir-type' outlet system (outlet standpipe) connected directly to the filter underdrain system. This concept is similar to that used with traditional slow sand filters. The use of the outlet standpipe ensures that the filter bed cannot be dewatered. The maximum flow from the filter (often specified by regulatory authorities) is established by the design of the media bed and the provision and adjustment of a production control valve when the filter is commissioned. During normal operation the flow of water into the filter and the maximum depth of water over the filter bed are established by mechanical float valves attached to the raw water inlet pipes within the filter itself ensuring that the flow of water into the filter cannot exceed its production (depth sensors and automated valves may also be used). The erosive power of the water from the raw water inlet system is eliminated by feeding the untreated water into diffuser basins located above the minimum depth of water in the filter. When the treated water storage is full the flow is stopped and the depth of water in the filter is allowed to drop to a minimum level that allows sufficient oxygen to diffuse to the biolayer to keep it alive and healthy (similar to the BioSand Water Filter). The rate of filtered water flow, filter bed design and hydraulic head loss across the filter bed ensure that the filter will meet water treatment expectations consistent with that of slow sand filters performing the same treatment function.

The operation of the MEL-BF technology is similar to that of its precursor the BioSand Water Filter (BSF) technology, formerly known as intermittently operated slow sand filtration. The BSF technology is now only recommended for use at the household level though systems have been constructed to produce more than 100,000 L/h. Good descriptions of the household scale of the BSF technology as used at the household level in more than 100 countries around the world may be found in the web site: www.manzwaterinfo.ca. The BSF technology is considered the best point-of-use technology available for use in developing countries Sobsey et al (2008). The BSF technology had already been extensively evaluated for both bacteria and parasite removal Palmateer et al (1997) where the technology demonstrated 3 and 4 log removals for Cryptosporidium and Giardia respectively as well as 95% removal of bacteria and substantial removal of organic and inorganic toxins. The parasite challenge was onerous in the sense that the filter was administered a 20 L water sample with 1,000,000 Cryptosporidium oocysts and 100,000 Giardia cysts and tested over a 30-day period. The evaluation reported by Palmateer, et al is especially interesting when it is realized that a portion of the filter surface was continually being scoured during routine operations because of an inadequately fitting diffuser basin, a problem that was only identified after the paper had been published. It is certain that the bacteria removal would have been higher, approaching 99%, and the oocyst removal 4 log or better; however, the technology performed as well as the best operating TSSF's. The design of the MEL-BF allows for demand operation; that is, used as required to fill the treated water reservoir without loss of performance.

Cleaning using backwash

The outlet system is also connected to a filtered water supply that is not chlorinated and can be used for filter backwashing. Once it is determined that filter production is unacceptably low, (perhaps determined by the examination of sight-glasses permitting observation of water depth in the filter and outlet head), filter production is isolated and backwash water is allowed into the underdrain system. An air-vacuum control valve attached to the top of the outlet standpipe ensures that the filter produces treated water with the outlet under atmospheric pressure and backwashes under full backwash pump pressure.

The backwash of a MEL-BF is only intended to thoroughly break up the upper few centimetres of media (where virtually all of the material is collected), de-gas the media and re-suspend captured material. Only filtered water, that has not been chlorinated, is used for backwash. Backwash of a MEL-BF may fluidize and flush the entire filtering layer but is still much less aggressive than that used by rapid and pressure sand filters. Air scour is never used. Wastewater produced by a MEL-BF is typically less than 1% of filter production.

When the backwash flow is stopped the fluidized media in the MEL-BF collapse into the pre-backwash form. Remaining backwash water in the filter media is 'squeezed' out and upward from the filter media and the media bed settles cleaned. No untreated water can enter the media bed. The biolayer will be not be lost during the backwash process. The same fine particles that formed the top of the filter media when the filter was commissioned remain at the top of the media bed after each backwash. Examination of particle size distribution of the surface of the filtering layer indicate effective size of 0.1 mm (much less than the 0.35 mm recommended). These are the same particles that formed biofilms and constitute the biolayer or active layer. The biolayer is in place after every backwash - no matter how frequently the backwash is required. The implication is that filter performance is not temporarily impaired by the backwash process. Removal of pathogens, parasites (Giardia and Cryptosporidium), bacteria and viruses can be expected to be similar to that prior to backwashing, flow rate considerations withstanding.

Any problems associated with air binding are eliminated when the backwash process is used. When treating water that has significant dissolved gases or cold water that is warmed in the filter bed it may be necessary to provide a short reverse flow, not a true backwash, without generating any wastewater, to eliminate any air binding problems.

Backwashing eliminates the possibility of short-circuiting.

The wastewater produced during the backwash process is removed, after allowing the finest media to settle (about 30 seconds).

Should the filter develop significant quantities of large, floating debris (not usually a problem if the filters are covered) it may be necessary to locate troughs slightly above the normal backwash which would allow surface skimming.

The backwash process used to clean the MEL-BF is expected to allow use of the same filter bed for more than ten years. BSF treatment systems that are cleaned using a surface agitation, reverse flow for degassing and a decant similar to the MEL-BF have been in operation for more than ten years. Media is never lost and organic material resulting from sloughing of mature biofilms will be removed during the backwash process. It is difficult to identify the circumstances where the filter media used in an MEL-BF would need to be replaced.

A filter-to-waste procedure can easily be incorporated if necessary. A filter-to-waste provision is essential to accommodate filter commissioning.

It is advisable to divide the entire filtration plant into equal segments (at least two) that can be cleaned independently using lower capacity distribution pumps or backwash water head tanks and produce flow rates and volumes of wastewater that can be economically evacuated and disposed of through existing sanitary sewers if necessary.

MEL-BF systems are scalable from a few hundred to several million litres per hour.

Comparison of sand filters

Table 1.0 compares the effectiveness, physical and operational characteristics and costs associated with traditional slow sand filters, rapid sand filters, pressure sand filters and the MEL-BF.

The following observations can be made:

1. The TSSF and MEL-BF technologies are very effective in removing pathogens.
2. All types of slow sand filters are very effective at removing inorganic or organic particulate material with or without pre-treatment. The TSSF is limited because of the significant effort required to clean it.
3. The TSSF and MEL-BF/PF will not exhibit break through phenomena. It is impossible for these filters to produce untreated water. Unlike rapid sand and pressure sand filters, TSSF and MEL-BF/PF continue to improve their ability to treat water until such time as the captured material completely stops the flow of water through them. The TSSF and MEL-BF/PF are cleaned when their capacity drops to unacceptably low levels (50% of maximum production is normal).
4. The TSSF and MEL-BF/PF technologies are all very effective in removing oxidized iron and manganese though the TSSF is not practical because of the significant effort required to clean it. The MEL-PF technology is used when there is no need to remove pathogens and pretreatment using chlorine or other oxidants are necessary.
5. Except for having a relatively larger surface area, the MEL-BF cells are structurally compact and simple to construct.

6. The TSSF, RSF and MEL-BF/PF are all appropriate for use in large scale applications.
7. The PSF and MEL-BF/PF are particularly appropriate for use in small scale applications.
8. The TSSF produces almost no waste water; the MEL-BF/PF produces only minor amounts of waste water; and, the RSF and PSF produce very large amounts of waste water.
9. The TSSF is simple to operate but it requires significant effort to clean.
10. The MEL-BF/PF are simple to operate and simple to clean.
11. The RSF and PSF are complex to operate effectively and relatively simple to clean.
12. The operator skill levels required to successfully operate TSSF and MEL-BF/PF are relatively low; while, the skill levels required to successfully operate RSF and PSF is quite high.
13. The relative overall costs of operation and maintenance of the TSSF and MEL-BF/PF is low to very low when compared to the costs of operation and maintenance of the RSF and PSF.

Filter-to-waste - Turbidity reduction and pathogen removal

Filter-to-waste is always recommended as the final step of cleaning rapid and pressure sand filters (multi-media or otherwise) and after scraping traditional slow sand filters. The filter-to-waste step consists of producing filtered water to waste until the turbidity of the filtered water is below a threshold value, typically 1 NTU, a value at which UV disinfection and chlorine disinfection are considered effective.

The filter-to-waste step is logical after rapid and pressure sand filters which are intended to remove particulate material only with limited reduction in pathogens. The low turbidity allows effective use of UV and/or chlorination to kill or deactivate any remaining pathogens. (Note that there can be considerable reduction in parasites and other pathogens during the clarification process preceding filtration; but clarification is always followed by filtration and disinfection. Present practice includes use of UV to kill any remaining parasites and chlorine to kill any remaining bacteria and viruses.) This sequence of treatment is an example of the ‘multi-barrier’ approach to water treatment.

In contrast traditional slow sand filters are intended to remove pathogens (virtually all parasites and most bacteria and viruses); and, also achieve significant turbidity reduction without pre-treatment. Turbidity reduction, after slow sand filtration, is definitely not a reliable indicator of pathogen reduction. Pathogen reduction is the result of the formation of the biological layer (schmutzdeke) which may require several days to reform if the filter has been scraped. The multi-barrier view (that might include UV and chlorine disinfection for example) is not correctly managed if slow sand filters are put back into production without knowledge of the formation of an effective biological layer – the existence of which can only be determined by assessing bacteria removal – NOT turbidity reduction.

The use of turbidity reduction as a measure of slow sand filtration performance has been confused with performance measurement of rapid and pressure sand filtration (and associated pre-treatment). Recall that turbidity reduction below 1 NTU is essential for use of UV and chlorine disinfection which WILL kill or deactivate pathogens remaining after any filtration process provided that the concentration of other interfering substances such as dissolved organics are sufficiently low. Present expectations of rapid sand, pressure sand and traditional slow sand filtration are similar – the reduction of turbidity to less than 1 NTU after which other disinfection approaches can be effectively used. The expectation of traditional slow sand filtration to eliminate parasites and reduce turbidity to a point where bacteria and viruses are readily killed or deactivated using chlorine alone has been replaced with the expectation of simple turbidity reduction.

Application considerations

Because the MEL-BF is cleaned using a backwash process that preserves the biological layer, its ability to remove pathogens is not impaired, even if a filter-waste-procedure is used to realize turbidity levels of 1 NTU or less. (Note that the backwash procedure will dislodge particles captured at depth in the media that might not be eliminated during the limited backwash procedure used; but, the filer-waste-procedure, if necessary is very short duration.) Unlike traditional slow sand filters that are scraped and whose performance is determined using turbidity reduction, the MEL-BF technology maintains the long-held view that slow sand filters provide a significant role in the multi-barrier approach to water treatment for potable use. The ease of cleaning and preservation of the biological layer allows more frequent cleaning and operation nearer maximum capacity unlike traditional slow sand filters which are normally scraped when their capacity drops to fifty per cent of maximum or less.

Demand operation of the MEL-BF allows effective use of slow sand filtration in circumstances where continuous operation of a slow sand filtration is impractical and stop-start operations would destroy the effectiveness of the biological layer to remove pathogens.

The ability to operate the MEL-BF technology on a demand basis and clean using a backwash process as often as required without loss of performance and minimal media replacement suggests retrofitting existing traditional slow sand filters to achieve greater production with a decrease in operational cost using most of existing infrastructure (minimal capital expenditure).

Because the media is infrequently if ever replaced the use MEL-BF technology has much lower maintenance costs and offers significant advantages over use of traditional slow sand filters in more remote locations.

The use of MEL-PF technology, with or without pre-treatment, performs exactly the same treatment function as rapid sand or pressure sand filtration, with or without pre-treatment and should be given at least the same credit in multi-barrier treatment assessments (e.g. when used with UV and chlorine disinfection).

Regulatory considerations

Slow sand filtration is believed to have been first demonstrated on a community scale in England around 1830. Note that this is well before the evolution of germ theory and its relationship to human disease. Use of slow sand filtration resulted in a healthier population; but it was far from clear why this was so. Obviously, the use of slow sand filtration could be considered a ‘discovery’. Very early in the twentieth century the technology might be considered ‘mature’ at which time there were probably thousands of slow sand filters in use around the world. A portion of these filters worked well and a significant portion didn't. Investigations were undertaken to determine the necessary design parameters that needed to be followed to ensure that slow sand filters, once constructed, would meet performance expectations while considering actual construction specifications, construction technologies, construction environment, cost, method of operation, consumer expectations, performance and maintenance. Many of these design parameters are nearly one hundred years old and based on empirical evidence rather that a scientific understanding of how slow sand filtration actually works. Unfortunately, many of these 'design parameters' have become 'design standards' adopted by various regulatory agencies to 'protect' their constituents. While this approach may have served a useful purpose a little as twenty-five years ago it certainly does not fulfill its mandate today.

The objectives of 'water treatment for human consumption' are well understood as is the potential for water treatment using 'slow sand filtration'. The guidelines that had served society very well for many decades can also be viewed as limiting. It is relatively easy and inexpensive to evaluate modern variations of slow sand filtration such as the MEL-BF and MEL-PF technologies at the pilot scale level. Pilot scale evaluation of any treatment technology should be undertaken before that technology is recommended for use. (Pilot scale studies might cost as little as a fraction of one per cent of the completed water treatment plant.) Once proven effective a treatment technology, that has been designed following sound scientific and engineering principles and has demonstrated its efficacy, should be able to be adopted without the burden of conforming to 'design and operational guidelines' that were developed solely on the basis of experiences more than one hundred years old.

It is appreciated that regulatory agencies and therefore the engineering sector which designs water treatment plants for their clients are not rewarded for taking undo risks. However, the risks of evaluating and adopting novel treatment approaches are no more than adopting historical approaches entrenched in guidelines that are themselves now limited in terms of their applicability to solving contemporary treatment problems. There are numerous novel treatment technologies that when used together, perhaps with very old treatment technologies, provide effective, inexpensive solutions to previously intractable treatment problems. It is important that the use of these novel treatment approaches be encouraged so that they can be proposed, demonstrated and applied. Regulatory agencies can greatly benefit the communities they serve by facilitating this process.

Concluding remarks

The MEL-BF technology eliminates many of the disadvantages of TSSF while providing for operation on a demand basis with cleaning using a backwash process. These features suggest several non-traditional applications for water treatment using slow sand filtration including; treatment of surface water supplies with high suspended solids loads such as those occurring seasonally or after rainfall events, administration of a variety of pre- and post-treatments to remove colloidal clay or natural organic matter (to reduce colour, odour and disinfection by-products); filter water from waste water treatment plants that have been treated to tertiary standards for disposal or to a quality suitable for reuse in industry or irrigation; and, to treat water produced in greenhouse applications and food processing applications to a recyclable condition.

The ability to backwash a slow sand filter opens the way to exploit the effectiveness of TSSF to remove very small particulate matter (using the MEL-PF). Several significant water treatment plants located in the Provinces of Alberta and Saskatchewan are using a previous variation of the MEL-PF, known as the Manz Polishing Sand Filter or MPSF, to remove iron, manganese, iron bacteria and hydrogen sulphide from groundwater (arsenic and uranium removal is practical and uncomplicated). There are many other applications for the MEL-BF/PF technology, not bound by most regulatory agencies, but simply by performance.

Both the MEL-BF and MEL-PF technologies may be inexpensively evaluated using bench scale and pilot scale studies.

Note that all the MEL-BF and MEL-PF technologies are the result of the continuous review and development of demand operated and backwashed slow sand filtration (since 1990). Their design and operation is not subject to the same constraints and limitations associated with the Manz Slow Sand Filter and Manz Polishing Sand Filter (previously known as the low operating head polishing sand filter) or the BioSand Water Filter.

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Table 1.0 Sand Filter Comparison.

Characteristic	Traditional Slow Sand Filter (TSSF)	Rapid Sand Filter (RSF)	Pressure Sand Filter (PSF)	MEL Biological Filter (BF)	MEL Polishing Filter (PF)
Effectiveness in removing:					
Pathogens Parasites Bacteria Viruses	 Very effective. Very effective. Very effective.	 Possible. Not effective. Not effective.	 Possible. Not effective. Not effective.	 Very effective. Very effective. Very effective.	Effectiveness will be a function of flow rate and nature of pretreatment.
Particulates Silt Clay Organic	Very effective and practical at low turbidity.	Effective as part of conventional treatment systems. (These include use of coagulants and clarification prior to filtration.)	Effective as part of conventional treatment systems. (These include use of coagulants and clarification prior to filtration.)	Very effective and practical at all turbidities. Pre-treatment may be useful to reduce frequency of backwash.	Very effective and practical at all turbidities. Pre-treatment may be useful to reduce frequency of backwash.
Oxidized Iron Manganese	Effective but not usually practical.	Not sufficiently effective or normally used.	Not sufficiently effective or normally used.	Very effective and practical but may be limited by pretreatment.	Very effective and practical.
Arsenic	Not used because pre-treatment impractical.	Not sufficiently effective or normally used.	Not sufficiently effective or normally used.	Very effective and practical with required pre-treatment.	Very effective and practical with required pre-treatment
Uranium	Not used because pre-treatment impractical.	Not sufficiently effective or normally used.	Not sufficiently effective or normally	Very effective and practical with	Very effective and practical with

			used . (Other pres. filters used.)	required pre-treatment.	required pre-treatment.
Fluoride	Not used because pre-treatment impractical.	Not sufficiently effective or normally used.	Not sufficiently effective or normally used.	Potentially effective and practical with required pre-treatment.	Potentially effective and practical with required pre-treatment.
Characteristic	**Traditional Slow Sand Filter (TSSF)**	**Rapid Sand Filter (RSF)**	**Pressure Sand Filter (PSF)**	**MEL Biological Filter (BF)**	**MEL Polishing Filter (PF)**
Dissolved organics	Not used because pre-treatment impractical.	Very effective and practical with required pre-treatment.	Very effective and practical with required pre-treatment.	Potentially effective and practical with required pre-treatment.	Potentially effective and practical with required pre-treatment.
Surface Loading					
Maximum	0.2 to 0.4 $m^3/h/m^2$ – dependent on regulatory agency.	8 $m^3/h/m^2$	8 $m^3/h/m^2$	0.2 to 0.4 $m^3/h/m^2$ – dependent on regulatory agency.	0.6 to 1.5 $m^3/h/m^2$
Operational	0.1 to 0.2 $m^3/h/m^2$	5 $m^3/h/m^2$ - function of head loss.	5 $m^3/h/m^2$ – function of head loss.	0.16 to 0.32 $m^3/h/m^2$	0.5 to 1.2 $m^3/h/m^2$
Opportunity for Breakthrough	Not possible.	Normal. Used to indicate need to clean.	Normal. Used to indicate need to clean.	Not possible.	Not possible.
Air Binding	Significant problem in cold climates.	Not an issue.	Not an issue.	Eliminated.	Eliminated.
Structural Issues					
Relative surface area.	Very large.	Small.	Very Small.	Large.	Large.
Relative height.	Deep.	Very deep.	Shallow.	Shallow.	Shallow.

Piping requirements.	Minimal.	Extensive.	Extensive.	Minimal.	Minimal.
Engineering and Construction complexity.	Minimal.	Complex.	Minimal.	Minimal.	Minimal.
Rel. Production Capacity Practical Range.	Community scale.	Community scale. (Impractical at small scales.)	Small community. (Impractical at large scales.)	Household to community scale.	Household to community scale.
Characteristic	**Traditional Slow Sand Filter (TSSF)**	**Rapid Sand Filter (RSF)**	**Pressure Sand Filter (PSF)**	**MEL Biological Filter (BF)**	**MEL Polishing Filter (PF)**
Rel. Volume Wastewater Production.	Nil.	Very large amounts.	Very large amounts.	Very low amounts.	Very low amounts.
Operational Complexity	Very Simple.	Complex.	Relatively complex.	Simple.	Simple.
Relative Construction Cost	Low.	High.	Relatively high. (Usually come as assembled components or package plants.)	Very low.	Very low.
Relative Operating and Cleaning Cost.					

Manpower – skill level required to successfully operate filter in long term.	Low	High.	High.	Low.	Low.
Manpower.	Low but can be significant if water has high conc. of suspended solids. (Not convenient to clean.)	Low.	Low.	Very low.	Very low.
Method of cleaning.	Manual scraping.	Vigorous backwash that includes air scour and mechanical agitation, usually automatically initiated and must include filtration to waste.	Vigorous backwash usually automatically initiated with filtration to waste.	Limited backwash intended to clean filter media near surface that may be automatically or manually initiated.	Limited backwash intended to clean filter media near surface that may be automatically or manually initiated.
Characteristic	**Traditional Slow Sand Filter (TSSF)**	**Rapid Sand Filter (RSF)**	**Pressure Sand Filter (PSF)**	**MEL Biological Filter (BF)**	**MEL Polishing Filter (PF)**
Filter to waste requirements.	May not be required depending on turbidity of produced water (suspended solids and parasites removed without formation of biolayer)	Required to flush filter media and until properly conditioned.	Required to flush filter media and until properly conditioned.	May not be required depending on turbidity of produced water (suspended solids and parasites removed without damage to biolayer)	May not be required.
Chemicals in wastewater.	Nil, as pre-treatment is not practical.	Present because pre-treatment using coagulants is required to achieve system performance.	Typically, present because pre-treatment using coagulants is required to achieve system performance.	Nil, if pre-treatment is not used. Pre-treatment is often not necessary for adequate filter performance.	Depends on nature of pretreatment but may not be present at all.

Wastewater generation.	Almost nil.	Very high.	Very high.	Very low.	Very low.
Energy (pumps, etc.)	Very low.	High.	Very high.	Low.	Low.
Overall cost of op/maintenance.	Low.	High.	High.	Low.	Low.