# SLOW SAND FILTRATION - DEMAND OPERATED AND CLEANED USING BACKWASH

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## ABSTRACT

A demand operated slow sand filter design that can be demand operated and allows cleaning using a backwash process is described. The new design named the Manz Slow Sand Filter (MSSF), 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 ability to operate the MSSF 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 MSSF 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 MSSF 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 MSSF 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 MSSF technology is 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 MSSF beyond that associated with simple TSSF technology. Treatment systems using the MSSF technology can be very effective for arsenic removal. Backwash volumes are less than one per cent of production compared to greater than five per cent for alternative technologies. The treatment process allows for complete recycling of the backwash water leaving only a very small amount of sludge containing the solids. The MSSF technology can also be used to remove the smallest particulate matter; that is, as a polishing filter, in circumstances where a biolayer may not be required for treatment.

The MSSF technology is modular and can treat water for small to very large communities. Capacities of individual MSSF units range from hundreds to several hundred thousand liters per hour. Treatment plants may incorporate many MSSF units to achieve capacities of several million liters per hour.

MSSF technology or its precursor the Biosand Water Filter (BSF) technology, are in use in more than one hundred countries. One treatment plant using the MSSF technology for manganese removal has been successfully operating in Alberta for more than two years. Two other treatment plants in Alberta and Saskatchewan are under construction. Consideration is being given to retrofitting existing TSSF facilities in British Colombia, Ireland and Colombia to use the MSSF technology.

## 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 Manz Slow Sand Filter (MSSF) 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 MSSF 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.

## 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 MSSF 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 insure 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 the 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 5 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 schmutzdeke. The development of the biolayer or the schmutzdeke 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 schmutzdeke 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 schmutzdeke 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 schmutzdeke is considered a positive contribution Hijnen et al (2004), Hijnen et al (2007) and Heller and Ladeira (2006). Both the schmutzdeke 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 schmutzdeke 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 schmutzdeke 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 ($d_{10}$ between 0.15 and 0.35 mm with uniformity coefficient of 3) and the low operating heads, approximately 1 m. The use of sub-angular media (such as obtained from crushed rock) is thought to improve pathogen removal. It is generally believed that the lower the $d_{10}$ and the uniformity coefficient the better the filter media will perform. It is also required that the media meet American Water Works Associate standards for hardness and purity, AWWA – B -100, a requirement typically achieved by using crushed and washed quartzite or similar materials. It is important that the filter media not have particles made of soft shale or mud stones high in oxidized metals. 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. Raw water temperature will determine the water viscosity and the colder the water the lower the infiltration rate all other factors being equal but this can be compensated for by increasing available head for filtration. The principle concern is the effect very cold temperatures have on biological processes which should be broken in to organism capture and organism metabolic process. 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).

## MANZ SLOW SAND FILTER

The Manz Slow Sand Filter (MSSF) adheres to the same design criteria as recommended for TSSF technology and exhibits the same treatment characteristics as TSSF technology. However, the MSSF 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 MSSF consists of at least two layers of crushed quartzite (silica) with effective sizes of 0.15mm and 0.35mm and uniformity coefficients less than 2. The exact thickness of the two materials is a function of the objective surface loading rate and is determined by pilot study. The use of crushed quartzite, rather than rounded particles of quartzite, is preferred as it is reduces the magnitude of backwash flow rates required to fluidize the filter layers at time of commissioning and in subsequent backwash operations. The depth of the filtration layer is 0.5 m or as specified by appropriate regulatory agency. The commissioning process fluidizes both filtering layers and insures 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 insures 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 insuring that the flow of water into the filter cannot exceed its production. The erosive power of the water from the raw water inlet system is eliminated by passing the water from the mechanical float controlled valves into diffuser basins located above the minimum depth of water in the filter. When the treated water storage is full the flow of raw water to the MSSF 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. 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 MSSF technology is similar to that of its precursor the BioSand Water Filter (BSF) technology, formerly known as intermittently operated slow sand filtration or Manz Intermittent Slow Sand Filter. 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 MSSF 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 an 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 MSSF 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. As mentioned only filtered water, that has not been chlorinated, is used for backwash. The flow rate is equal to the minimum backwash flow recommended for start-up of the backwash process used by rapid sand filters or pressure sand filters, approximately 1 $L/s/m_2$ of filter surface under less than 5 m of head (typically less than 3 m). Backwash of a MSSF may fluidize and flush the entire filtering layer as well but much less aggressively than that used by rapid and pressure sand filters. Wastewater produced by an MSSF is typically less than 1% of filter production.

When the backwash flow is stopped the fluidized layers in the MSSF collapse into layers resembling the original filter bed (post commissioning). Remaining backwash water is ‘squeezed’ out and upward from the filter media and the media bed settles cleaned. No untreated water can enter the media bed. The schmutzdeke 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. 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 because the backwash process is used. Short-circuiting is not possible.

The wastewater produced during the backwash process is removed, after allowing the finest media to settle (about 30 seconds), using perforated pipes located along and attached to the interior walls of the filter. The holes in the pipe are slightly downward facing to avoid capturing any of the fluidized media and are located approximately five centimetres above the surface of the media (all of the water is not removed). The perforated pipes are attached to a siphon spillway system that also acts as an emergency overflow system. The rate of flow through this system is controlled by a dedicated waste water flow control valve (not greater than the capacity to take the wastewater to disposal). A second, waste water operations valve is used to alternatively prevent flow from the filter until backwash is completed and then opened to facilitate the siphon evacuation process. The same valve is left open after backwash is completed to provide emergency overflow protection.

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 MSSF is expected to allow use of the same filter bed for at least ten years. BSF treatment systems that are cleaned using a surface agitation, reverse flow for degassing and a decant similar to the MSSF have been in operation for more than eight 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 MSSF would need to be replaced.

A filter-to-waste procedure can easily be incorporated if necessary. A filter-to-waste provision always available 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.

MSSF 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 MSSF.

The following observations can be made:

1. The TSSF and MSSF 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 MSSF 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 MSSF 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 MSSF are cleaned when their capacity drops to unacceptably low levels (50% of maximum production is normal).

4. The TSSF and MSSF 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.
5. Except for having a relatively larger surface area, the MSSF cells are structurally compact and simple to construct. Their construction costs are very low.
6. The TSSF, RSF and MSSF are all appropriate for use in large scale applications.
7. The PSF and MSSF are particularly appropriate for use in small scale applications.
8. The TSSF produces almost no waste water; the MSSF 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 MSSF 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 MSSF 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 MSSF is low to very low when compared to the costs of operation and maintenance of the RSF and PSF.

## CONCLUDING REMARKS

The MSSF 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 secondary 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. Several significant water treatment plants located in the Provinces of Alberta and Saskatchewan are using a variation of the MSSF, known as the Manz Polishing Sand Filter or MPSF, to remove iron, manganese, iron bacteria and hydrogen sulphide from groundwater (arsenic removal is practical and uncomplicated). There are many other applications for the MPSF technology, not bound by most regulatory agencies, but simply by performance.

Both the MSSF and MPSF technologies may be inexpensively evaluated using bench scale and pilot scale studies.

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**Table 1.0 Sand Filter Comparison.**

| Characteristic | Traditional Slow Sand Filter (TSSF) | Rapid Sand Filter (RSF) | Pressure Sand Filter (PSF) | Manz Slow Sand Filter (MSF) |
|---|---|---|---|---|
| | | | | |
| **Effectiveness in removing:** | | | | |
| Pathogens | | | | |
| Parasites | Very effective | Possible | Possible | Very effective |
| Bacteria | Very effective | Not effective | Not effective | Very effective |
| Viruses | Very effective | Not effective | Not effective | Very effective |
| Particulates | | | | |
| Silt | 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. |
| Clay | | | | |
| Organic | | | | |
| Oxidized | | | | |
| Iron | Effective but not usually practical. | Not sufficiently effective or normally used. | Not sufficiently effective or normally used. | Very effective and practical. |
| Manganese | | | | |
| 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 |
| Fluoride | 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 |
| Dissolved organics | Not used because pre-treatment impractical | Very effective and practical with required pre-treatment | Very effective and practical with required pre-treatment | Very effective and practical with required pre-treatment |
| | | | | |
| **Opportunity for Breakthrough** | Not possible. | Normal. Used to indicate need to clean. | Normal. Used to indicate need to clean. | Not possible. |
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| **Structural Issues** |  |  |  |  |
| Relative surface area. | Very large. | Small. | Very Small. | Large. |
| Relative height. | Deep. | Very deep. | Shallow. | Shallow. |
| Piping requirements. | Minimal. | Extensive. | Extensive. | Minimal. |
| Engineering and Construction complexity. | Minimal. | Complex. | Minimal. | Minimal. |
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| **Rel. Production Capacity Practical Range.** | Community scale. | Community scale. (Impractical at small scales.) | Small community. (Impractical at large scales.) | Household to community scale. |
|  |  |  |  |  |
| **Rel. Volume Wastewater Production.** | Nil. | Very large amounts. | Very large amounts. | Very low amounts. |
|  |  |  |  |  |
| **Operational Complexity** | Very Simple. | Complex. | Relatively complex. | Simple. |
|  |  |  |  |  |
| **Relative Construction Cost** | Low. | High. | Relatively high. (Usually come as assembled components or package plants.) | Very low. |
| Need for cover in winter. | Yes. | Yes. | Yes. | Yes. |
|  |  |  |  |  |
| **Relative Operating and Cleaning Cost.** |  |  |  |  |
| Manpower – skill level required to successfully operate filter in long term. | Low | High. | High. | Low. |
| Manpower. | Low but can be significant if water has high conc. of suspended solids. (Not convenient to clean.) | Low. | Low. | Very low. |

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|---|---|---|---|---|
| Method of cleaning. | Manual scraping. | Vigorous backwash usually automatically initiated with filtration to waste. | Vigorous backwash usually automatically initiated with filtration to waste. | Limited backwash intended to clean filter surface layer that may be automatically or manually initiated. |
| Filter to waste requirements. | Not required (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. | Not required (suspended solids and parasites removed without formation of biolayer) |
| 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. |
| Wastewater generation. | Almost nil. | Very high. | Very high. | Very low. |
| Energy (pumps, etc.) | Very low. | High. | Very high. | Low. |
| Overall cost of op/maint. | Low. | High. | High. | Low. |
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