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Iron and Manganese Removal Using Slow Sand Filtration - Canadian Experience

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Abstract

A variation of traditional slow sand filtration (TSSF) is being used to remove iron and manganese from well water in two communities in Western Canada. A third plant will be commissioned late 2011. The new filtration technology is marketed as the Manz Polishing Sand Filter ™ or MPSF. It was selected over competing technologies on the basis of its effectiveness in removing iron and manganese, ability to treat water with sulphate reducing bacteria and H_2S, capital cost, operating costs, maintenance costs, energy consumption, chemical requirements, waste production, ease of operation, and reliability. The selection process included on-site piloting.

The ability of TSSF to effectively remove iron and manganese was recognized in the late nineteenth century. However, the use of TSSF for this purpose was considered impractical because of the need for frequent cleaning involving removal of fouled media (sand), a process known as scraping, and periodic media replacement, a process known as resanding of the filter bed. The design of the MPSF retained and improved on key elements of TSSF, responsible for its 'polishing' capabilities; and, the disadvantages of the TSSF were eliminated, including the onerous cleaning process that was replaced with a simple effective backwash process. Media is never removed or lost from the filter. A biological layer is not required for successful operation, allowing loading rates three or more times that of TSSF and a shallower filter bed resulting in a more compact filter design.

The communities which chose to use the MPSF technology are small to medium in size. Two of the treatment plants provide 1,200 m^3 (314,184 gallons) of treated water per day and the third plant is will provide 2,400 m^3 (628,368 gallons) of treated water per day when commissioned. The well water treated in each of the communities was not considered under direct influence of surface water or GWUDI. One of the 1,200 m^3 plants treats water that has an elevated concentration of manganese with evidence of the presence of sulphate reducing bacteria (SRB) and H_2S. This plant has been operating successfully for several years. The second 1,200 m^3 per day plant treats water with elevated concentrations of iron and manganese, SRB contamination and the associated presence of H_2S. This plant has just been commissioned. The 2,400 m^3 per day treatment plant will treat water with significant concentrations of iron and manganese that appear to be naturally sequestered. Sodium hypochlorite is used to oxidize the iron and manganese and provide the necessary chlorine residual in

the two 1,200 m^3 per day plants. The 2,400 m^3 per day plant uses chlorine dioxide for oxidation and the addition of chlorine (using chlorine gas) after filtration to achieve required chlorine residual. The two 1,200 m^3 per day plants dispose of wastewater into the sanitary sewer system. The 2,400 m^3 per day plant recycles virtually all wastewater with small volumes of sludge disposed of in a local sewage lagoon.

The MPSF technology has proven very effective in removing many forms of particulate and dissolved materials with appropriate pre- and post-treatment. Substances traditionally removed by adsorption and co-precipitation may be removed with minimal dosage of coagulants. Other municipal water treatment applications of the MPSF technology include removal of arsenic and heavy metals, fluoride, naturally occurring radioactive materials and particulate and dissolved naturally occurring organic materials.

There are other many applications of the MPSF technology in industry, agriculture and the mining.

Introduction

Slow sand filtration or traditional slow sand filtration (TSSF) has been recognized for more than one hundred years for its ability to effectively remove iron and manganese from water supplies. Its use for this purpose was considered impractical because the filter beds required frequent cleaning, a task that can require significant time and effort and involves the removal of fouled media (sand), a process known as scraping, and periodic replacement of filter media, a process known as resanding. The development of a slow sand filter that is able to be cleaned using a backwash process, the Manz Polishing Sand Filter™ or MPSF has changed this perception. Media is never removed or lost from the filter. Several water treatment plants which use the MPSF technology to remove iron and manganese have been constructed or are in the process of being constructed in Western Canada.

The communities which chose to use the MPSF technology are small to medium in size. Two of the treatment plants provide 1,200 m^3 (314,184 gallons) of treated water per day and the third plant will provide 2,400 m^3 (628,368 gallons) of treated water per day when commissioned. The well water treated in each of the communities was not considered under direct influence of surface water or GWUDI. One of the 1,200 m^3 plants treats water that has an elevated concentration of manganese with evidence of the presence of sulphate reducing bacteria (SRB) and H_2S. This plant has been operating successfully for several years. The second 1,200 m^3 per day plant treats water with elevated concentrations of iron and manganese SRB contamination and the associated presence of H_2S. This plant was recently commissioned. The 2,400 m^3 per day treatment plant will treat water with significant concentrations of iron and manganese that appear to be naturally sequestered. Sodium hypochlorite is used to oxidize the iron and manganese and provide the necessary chlorine residual in the two 1,200 m^3 per day plants. The 2,400 m^3 per day plant uses chlorine dioxide for oxidation and the addition of chlorine (using chlorine gas) after filtration to achieve required chlorine residual. The two 1,200 m^3 per day plants dispose of waste water into the sanitary sewer system. The 2,400 m^3 per day plant recycles virtually all waste water with small volumes of sludge disposed of in a local sewage lagoon.

The use of the MPSF technology for iron and manganese removal is readily demonstrated at the bench scale. The information gained is used to design pilot scale evaluations that are conducted on-site. The design of the water treatment plant is based on results from both the bench and pilot scale evaluations and client needs.

The MPSF technology is proprietary with patents pending in Canada, USA, Europe and several other countries worldwide. It is owned and marketed by Oasis Filter International Ltd. of Calgary, Alberta, Canada (www.oasisfilter.com).

MPSF Technology - Principles of Design, Operation and Cleaning

The MPSF technology is designed using generally accepted principles for the design of TSSF's. However, because the filter is cleaned using a backwash wash process, the depth of the filter bed is minimal since scraping and resanding are not required. Several unique hydraulic features are incorporated to facilitate cleaning using the backwash process including a specially designed underdrain and wastewater removal system. The depth of water on the surface of the media is less than one-half that usually used by TSSSF. The result is a slow sand filter with minimal vertical height and footprint that is simple to operate well and easily cleaned.

As indicated the key to understanding the design of the MPSF is to understand the cleaning or backwash process. Consider Figure 1 which shows a media bed before and during a backwash process.

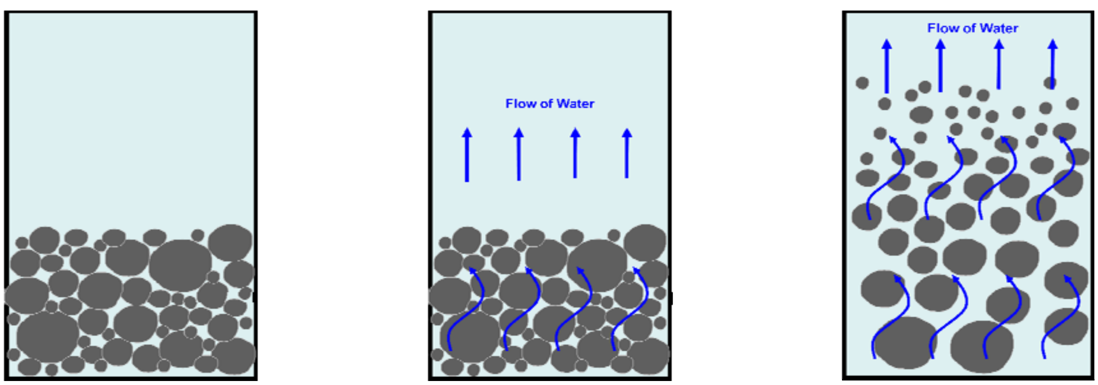


Figure 1. Filter media in water prior to and during a backwash process.

Note that when the bed fluidizes the smallest particles are carried the furthest up and when the backwash flow is stopped the particles settle with the smallest particles at the surface as shown in Figure 2. This phenomenon is fundamental to our understanding of the backwash process and is discussed in every basic engineering text on filtration – particularly rapid and pressure sand filtration.

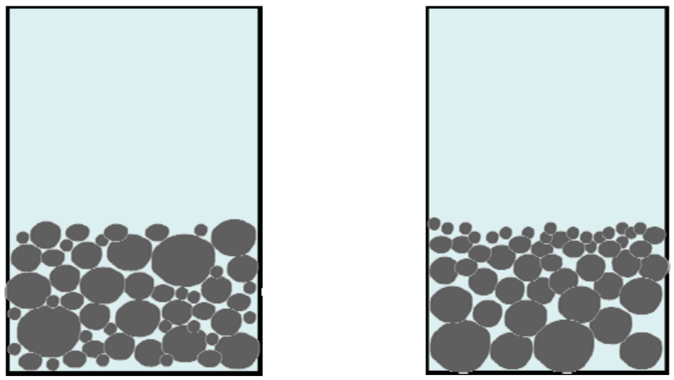


Figure 2. Arrangement of filter media before and after backwash.

The arrangement of the filter media will be the same after every backwash. The same smallest particles will always be at the surface. It is also important to observe that the smallest particles require the least flow rate to be fluidized.

The filter bed used in an MPSF is designed such that the media meets the same criteria as that used for TSSF's, has sufficient very small particles (less than 0.1 mm) and has the ability to achieve desired filtration rates (surface loading rates) at the preferred operating depth.   An MPSF is backwashed several times during the commissioning process prior to being put into production.

Because the MPSF is cleaned using a backwash process it is not necessary to have the very large depth of media such as used in a TSSF which is cleaned by scraping up to five centimetres of media off its surface.   The TSSF will typically have sufficient media to allow for several cleaning procedures before additional media is added.

The operation of the MPSF to remove iron and manganese is shown in Figure 3.   The iron and manganese must be oxidized prior to filtration to allow development of iron and manganese hydroxides and formation of micro-flocs.   The filter media is capturing the micro-flocs of iron and manganese. Note that all the particles are captured on the surface of the filter media. They are not forced into the media as would be the case in rapid and pressure sand filters and there is no tendency for the micro-flocs to attach to the particles of media. The depth of water above the media, the operating head, is approximately 0.35 m.   A maximum of two or three metres of pressure head is required to feed raw water to a filter. Provision is made to insure that the untreated water does not disturb the filter surface when the water level is at its minimum of about 0.05m (5 cm).

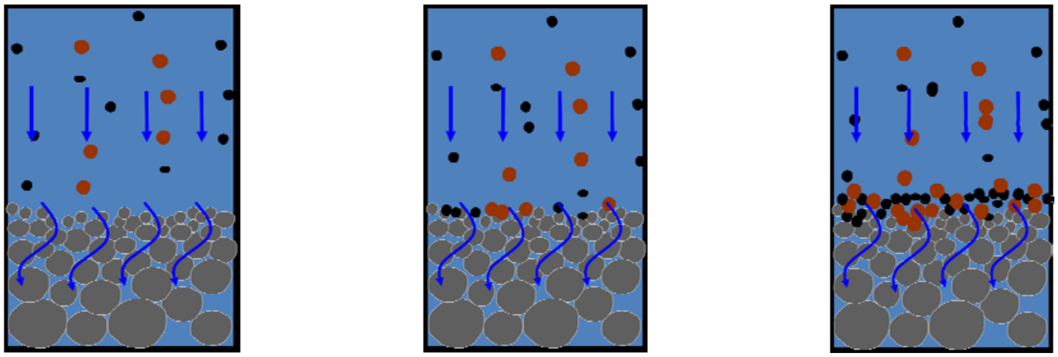


Figure 3. Capture of iron and manganese on media surface.

Eventually the accumulation of particles will reduce the filtration rate to unacceptable levels and the filter needs to be cleaned; that is, backwashed.

The backwash procedure is illustrated in Figure 4. Filtered water is used for the backwash. No wastewater leaves the filter during the backwash process as is the practice with backwashes of rapid and pressure sand filters. Air scour and mechanical agitation of the media surface is not required.

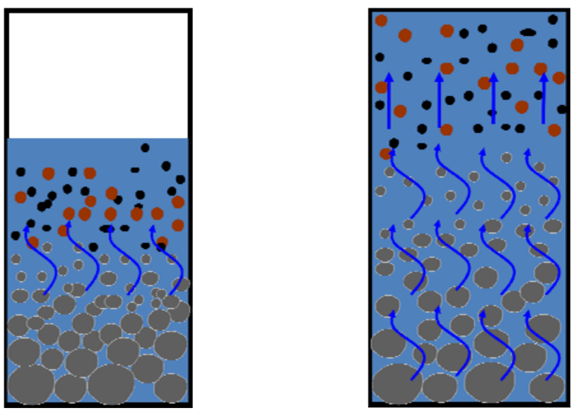


Figure 4. Backwash process.

The backwash will continue until all of the iron and manganese particles are suspended in the water above the level where the surface of the media would be during filtering operations. The volume of backwash water used is approximately 0.8 to 1.1 m^3/m^2 of filter surface depending on the depth of water in the filter when backwash is initiated. The rate of backwash flow is approximately 1.5 to 2 L/second /m^2 of filter surface under 2 to 3 m of pressure head. This is approximately the same rate of flow at the very beginning of the backwash of a typical rapid sand filter. Once the maximum depth of water and fluidized media has been reached, the backwash flow is abruptly stopped and the media allowed to settle as shown in Figure 5. The media requires less than a minute to settle once the backwash flow has been stopped. The wastewater is decanted. It is not possible for media to be lost during the decant process because it was allowed to settle before the decant started. The entire backwash process including the decant process can take twenty to thirty minutes. Once the decant is complete the filter is immediately placed back into production without the filter to waste step.

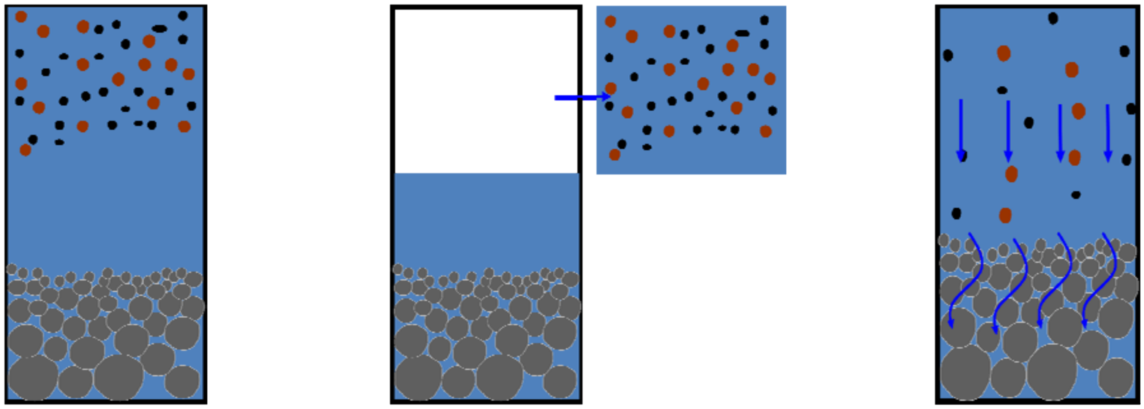


Figure 5. Backwash flow is stopped and media allowed to settle.   Wastewater containing high concentrations of suspended iron and manganese flocs is decanted. The cleaned filter is placed back into production.

Considering filter operation and cleaning, free board requirements and the objective to meet minimum filter media depth for slow sand filtration the vertical height of a MPSF cell will vary between 1.25 and 2 metres. The underdrain and backwash water supply piping should be covered with at least 5 cm of coarse aggregate, itself covered at least two more layers (5 cm thick) of successively finer aggregate before reaching the filtering media which would be less than 0.4 m in depth.

Basic Treatment Process for the Removal of Iron and Manganese

The basic treatment process for the removal of iron and manganese is as follows:

1. Oxidation of iron and manganese (preferably using aeration, sodium hypochlorite or chlorine dioxide). Bench scale testing is used to guide the selection of the pre-treatment process.
2. Formation of micro-flocs in contact tanks.
3. Filtration using MPSF.
4. Chlorination if not using sodium hypochlorite for oxidation.
5. Storage and distribution.

If not naturally sequestered (e.g. organically complexed) iron may be oxidized by simple aeration.   If sequestration is evident or there is a need to accelerate the oxidation process the water may be chlorinated prior to filtration and storage. Contact tanks are used to insure development of micro-flocs prior to filtration. Water is transferred from the contact tanks by pumps to the filter cells.

If sodium hypochlorite is used to oxidize the iron or manganese the dosages used are large enough to insure that the water leaving the filter has sufficient chlorine residual that additional chlorine is not required prior to storage.

If chlorine dioxide is used it is necessary to chlorinate the water using sodium hypochlorite or chlorine gas prior to storage. Excess chlorite residual is not a problem since it is consumed during the oxidation of the iron and manganese.

Manganese cannot be oxidized efficiently by aeration unless the pH is at least 9.0. The pH of the water can be increased and subsequently decreased but this is not a practical solution so chemical oxidation is preferred. It is important to preserve an oxidation environment in the filter to prevent the manganese from going back into solution. This is simply controlled by ensuring that the water leaving the filter has a chlorine residual. With time the manganese will coat the media particles and filters will become more efficient in both iron and manganese removal.

Iron will form micro-flocs very quickly after oxidation while oxidized manganese may require up to one hour to form micro-flocs that can be removed efficiently by the filters. Contact tanks are used to allow formation of adequately sized micro-flocs.

The chemicals, their dosage and time required to form adequate micro-flocs are determined using bench and pilot scale evaluations. It is preferred not to use potassium permanganate for oxidation because of the control complexities that can inadvertently be introduced resulting in higher level operator certification requirements. Chlorine gas or ozone cannot be used for oxidation purposes because of off-gassing in the filters. As well, water treatment plants that use either chlorine gas or ozone will require their operators to have higher levels of operator certification.

A typical PFD of the treatment process used to remove iron and manganese is shown in Figure 6. The process may be operated using varying degrees of automation.

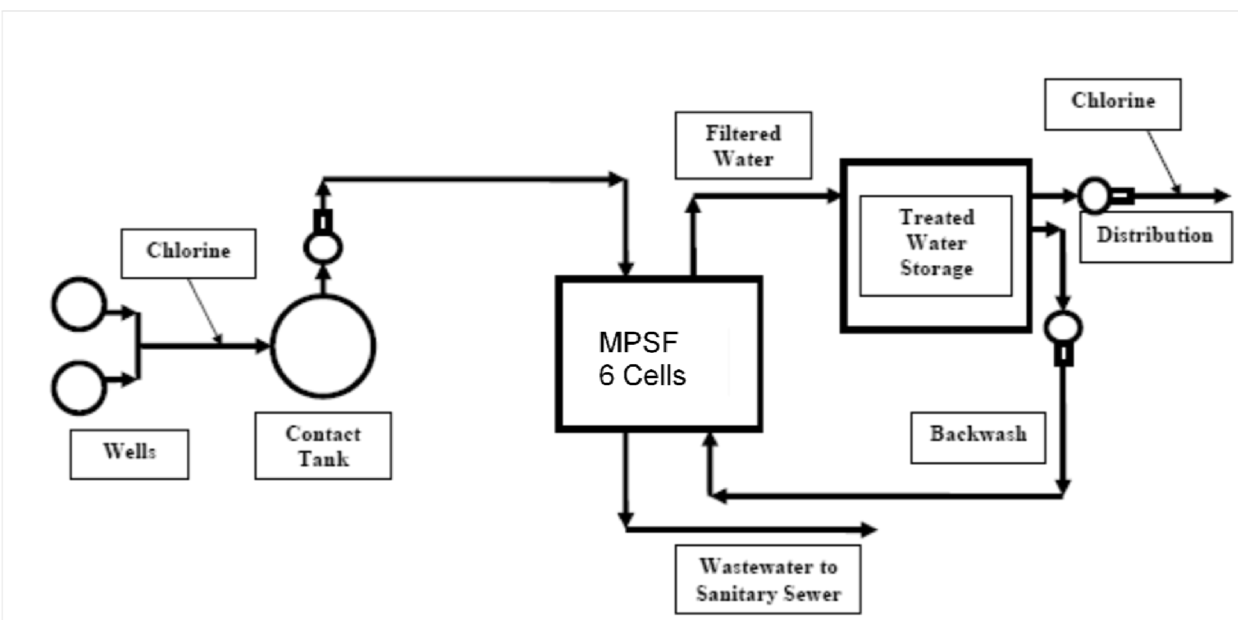


Figure 6. Typical PFD of treatment process using MPSF's for removal of iron or manganese.

If hydrogen sulphide gas is present it will be oxidized during the oxidation process with the resulting raw sulphur particles taken out by the filter or exchanged with the atmosphere in an appropriately vented contact tank if aeration is used.

Iron and sulphate reducing bacteria, alive or dead, will be removed by the filter.

If there are concerns that the groundwater is under direct influence of surface water, also known as GWUDI, it may be necessary to limit the surface loading to that normally used by TSSF, oxidize using chlorine dioxide which is very effective against giardia and cryptosporidium and add UV disinfection prior to sending filtered water to storage. Chlorine dioxide will efficiently oxidize the iron and manganese without the production of unacceptable concentrations of disinfection by-products such as chlorite which is consumed during the oxidation of the iron and manganese. (Other treatment processes may also be used but the design objective is to keep the treatment process sufficiently robust and simple to minimize operator skill level required.)

If there are concerns with elevated TOC/DOC in the groundwater it is probable that a part or all of the iron and manganese are organically complexed. It may be preferable not to use sodium hypochlorite for oxidation as this might result in the formation of elevated concentrations of disinfection by-products such as trihalomethanes (THM's). Chlorine dioxide has several advantages as it will oxidize the organic matter, effectively eliminate the complexing and efficiently oxidize the iron and manganese without the production of unacceptable concentrations of disinfection by-products such as chlorite which, as indicated previously, is consumed during the oxidation of the iron and manganese.

If the groundwater contains elevated concentrations of ammonia the addition of oxidants such as sodium hypochlorite or chlorine dioxide are effective.

Description of Water Treatment Plants

Water Treatment Plant No. 1

The water from the wells is considered not under direct influence of surface water. The water has manganese concentrations recorded as high as 0.4 mg/L. The water smell indicates the presence of hydrogen sulfide; and as might be expected, tests indicated the presence of sulfate reducing bacteria.

The design objectives included:

1. Reducing manganese concentration to below 0.05 mg/L.
2. Eliminating the hydrogen sulphide odour and sulphate reducing bacteria.
3. Providing treatment capacity of 1,200 m3/day or 50,000 litres per hour.
4. Minimum chemical requirements.
5. Minimum level of automation.
6. Minimum complexity – Operator Level 1 certified if possible.

7. Disposing wastewater into existing sanitary sewer and town lagoon.

After piloting the MPSF technology was selected considering:

1. Effectiveness. Able to remove manganese, hydrogen sulfide and sulfur reducing bacteria (SRB).
2. Elimination of any possibility for short circuiting or fouling in the filter cell.
3. Comparable capital cost. Constructed using local contractors.
4. Low operating cost. (Very low operating, energy and maintenance costs. Media is never lost or replaced.)
5. Minimum use of chemicals (only sodium hypochlorite which must be used regardless to meet minimum chlorine residual targets).
6. Minimum production of wastewater (less than 1 per cent of production).
7. Technology is operator friendly – easy to operate well – difficult to damage. Level One Certification required – requires one or so hours of attention each day freeing operators to perform numerous other tasks and providing job opportunities for local people.
8. Capacity can be easily increased.
9. Treatment process is easily upgraded.

The layout of the plant is shown in Figure 7. Note that there are 6 filter cells (MPSF's) each 4m by 4m in area. In this instance the maximum loading of 0.6 m^3/m^2/hour (0.6 m/h) was used. Each cell could produce a maximum of 10,000 L/h or 240,000 L/day immediately after being cleaned. Water enters the plant from one of two supply wells. The water is chlorinated using sodium hydroxide just before it enters the first of two contact tanks. Water is taken from the contact tanks to the filters using a transfer pumps. Water from the filter flows directly into the storage reservoir. Filter cells are completely independent and cleaned once a month one cell at a time.

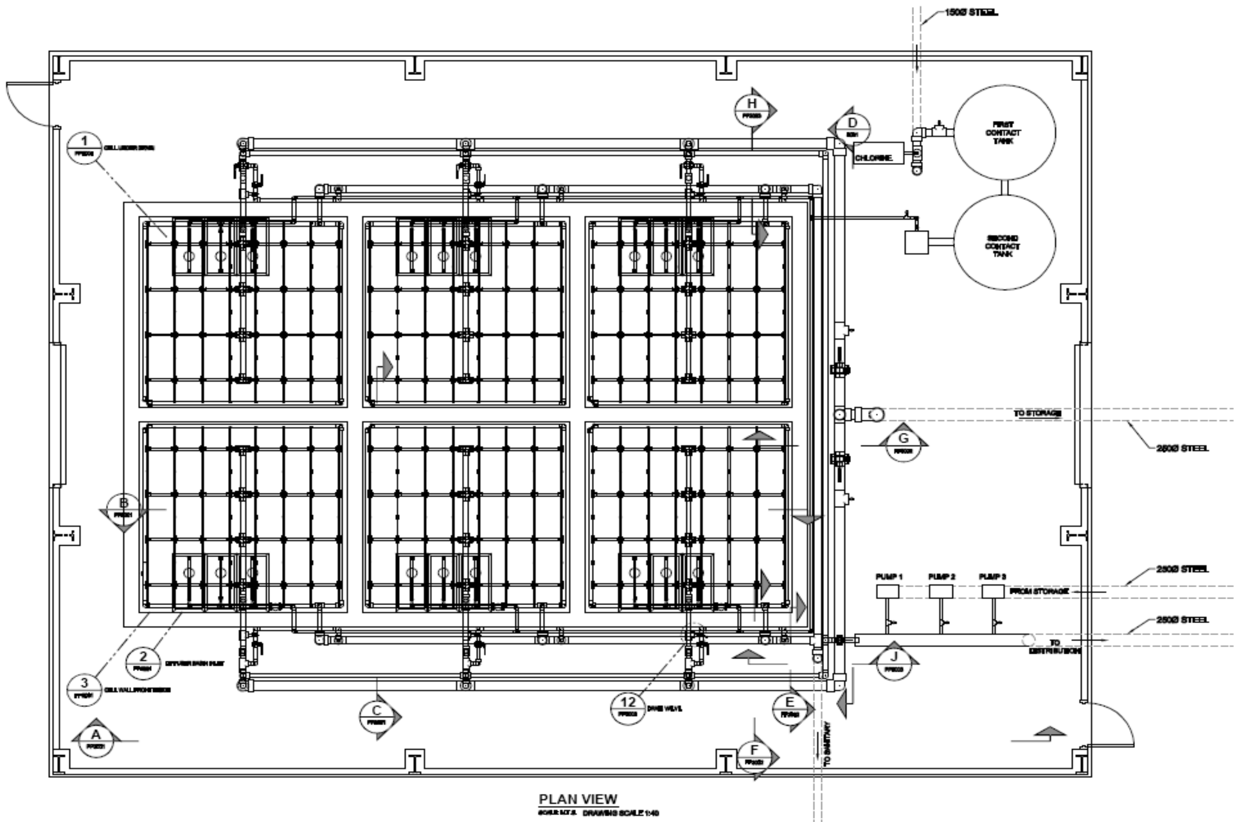


Figure 7. Layout of WTP1.

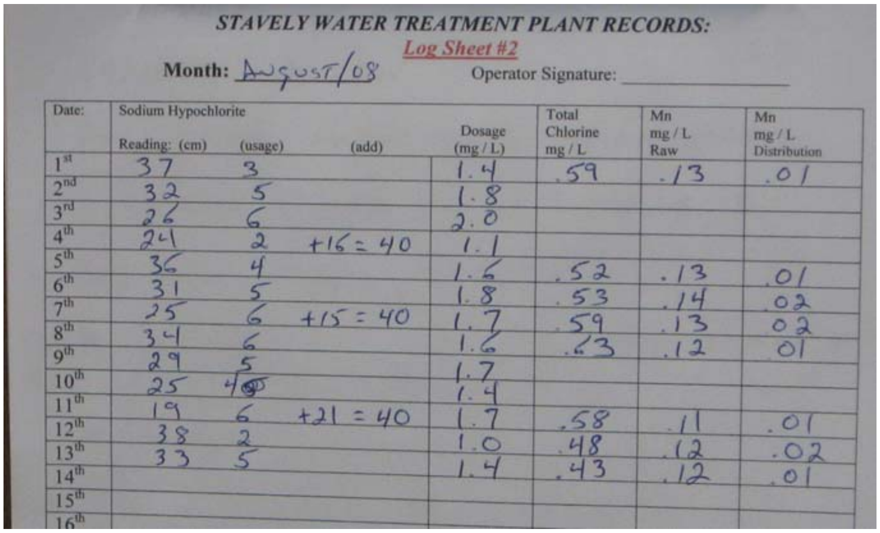
The photographs in Figures 8 to 10 show the treatment plant as constructed.

Figure 8. Inlet from well, flow meter and chlorine dosing equipment. (Note lab bench and equipment at left.)

Figure 9. Two contact tanks used to ensure formation of micro-flocs and transfer pumps that take the water to the filters.

Figure 10. Interior view of water treatment plant showing filter cells.

A copy of the operator log is shown in Figure 11. Though the levels of manganese in the untreated water are not particularly large they were well beyond aesthetic limits of 0.05 mg/L. The treatment process reduced the concentration of manganese below 0.02 mg/L. There is no indication of hydrogen sulphide or SRB. The removal rate has remained consistent. The community and operator are very satisfied with the plant's performance and cost of operation which, as expected, is very low.



STAVELY WATER TREATMENT PLANT RECORDS:

Log Sheet #2

Month: August/08 Operator Signature: ____________

Date:	Sodium Hypochlorite Reading: (cm)	(usage)	(add)	Dosage (mg / L)	Total Chlorine mg / L	Mn mg / L Raw	Mn mg / L Distribution
1st	37	3		1.4	.59	.13	.01
2nd	32	5		1.8			
3rd	26	6		2.0			
4th	24	2	+16 = 40	1.1			
5th	36	4		1.6	.52	.13	.01
6th	31	5		1.8	.53	.14	.02
7th	25	6	+15 = 40	1.7	.59	.13	02
8th	34	6		1.6	.63	.12	01
9th	29	5		1.7			
10th	25	4		1.4			
11th	19	6	+21 = 40	1.7	.58	.11	.01
12th	38	2		1.0	.48	.12	.02
13th	33	5		1.4	.43	.12	.01
14th							
15th							
16th							

Figure 11. Operator log.

Water Treatment Plant No. 2

The water from the wells is considered not under direct influence of surface water. It has iron concentrations recorded as high as 1.4 mg/L and manganese concentrations recorded as high as 0.2 mg/L. The water smell indicates the presence of hydrogen sulphide; and as might be expected, tests indicated the presence of sulphate reducing bacteria.

The design objectives included:

1. Reducing manganese concentration to below 0.05 mg/L.
2. Eliminating the hydrogen sulphide odour and sulphate reducing bacteria.
3. Providing treatment capacity of 1,200 m3/day or 50,000 litres per hour.
4. Minimum chemical requirements.
5. Minimum level of automation.
6. Minimum complexity – Operator Level 1 certified if possible.
7. Disposing wastewater into existing sanitary sewer and town lagoon.

These are similar to WTP1.

The process using the MPSF's was chosen for the same reasons as those listed for WTP1 with the addition of the minimum production of waste water. This plant was commissioned in April 2011.

The process and layout are similar to WTP1 except that only four larger filter cells (MPSF's) are used and the contact time is three times greater (about an hour).

This plant is producing water that meets or is better than aesthetic guidelines for iron (0.3 mg/L) and for manganese (0.05 mg/L). Hydrogen sulphide gas has been completely eliminated as has any indication of sulphate reducing bacteria.

It is worth noting the water for this plant comes from more than two hundred metres below the surface. When finally released into the filters some dissolved gases still remain and are being released. The filters are degassed (burped) every few days to eliminate flow blockage from the released gases. The 'burping' process consists of a very short duration reverse flow without any loss of water and only a few minutes of filter down time.

Photographs of WTP2 are shown in Figures 12 to 16.

Figure 12. Water treatment plant located on top of treated water storage.

Figure 13. Interior view of water treatment plant.

Figure 14. Contact tanks and transfer pumps.

Figure 15. Filter cell before commissioning.

Figure 16. Filter cell during operation. Note dark black colour due to presence of manganese.

Water Treatment Plant No. 3

This plant has just been tendered with completion expected late 2011.

Water Treatment Plant No. 3 (WTP3) has elevated levels of iron and manganese. The water is pumped from three wells and was treated using a sequestering agent and chlorination for many years. The iron and manganese could not be oxidized using sodium hypochlorite but could be readily oxidized using chlorine dioxide. Consequently, appropriately sized micro-flocs are quickly formed and contact tanks are minimal in size. Chlorine gas will be used to provide the required chlorine residual for economic reasons. The additional operational complexity is not a major issue in this instance as this plant is one of two being constructed with the other plant requiring operators with Level 3 certification.

A further complication was that wastewater could not be disposed of locally as the treatment plant is located in a pristine rural area where there is no opportunity for wastewater disposal of any kind. It was decided to clarify and recycle the backwash water before it left the plant. The sludge is to be hauled to a local sewage lagoon. The clarification of the wastewater is very simple requiring only conical bottom tanks and a few hours for complete settling.

As sketch of WTP3 as it is proposed to be built is shown in Figure 17. Note that there are two banks of 6 filter cells. Water enters the plant from three wells. Chlorine dioxide is added as it enters the first contact tank (two larger tanks on the left). Wastewater is collected in subsurface tanks and transferred to conical bottom clarifiers (small tanks on the right of the sketch) after which the clarified effluent is transferred back to the larger contact tanks and recycled through the filters without ever leaving the plant. There is minimal solid waste.

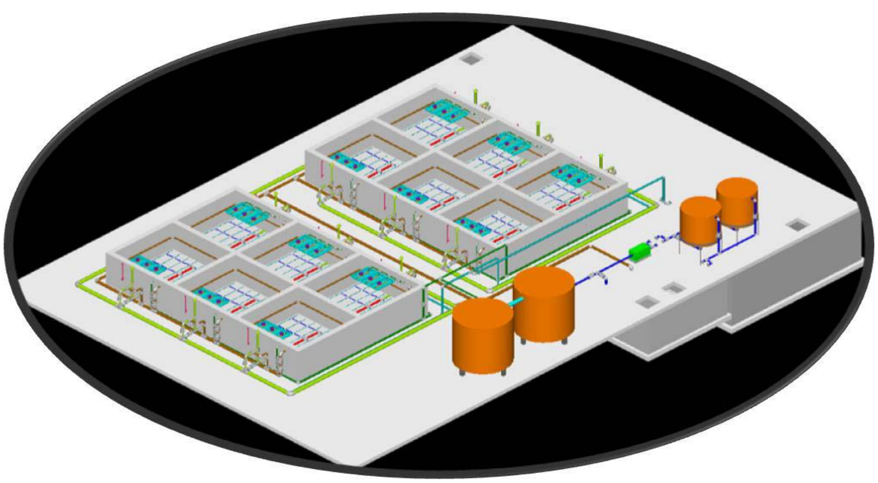


Figure 17. Sketch of WTP3.

Advantages of the MPSF Technology

Modularity and Scalability

Individual filter cells may vary in physical size from one metre to twenty metres in width, length or diameter. The shape may be square, rectangular, circular or any other cross-section of interest. The depth of the filter remains approximately two metres because of the ability to locate major elements of the underdrain system below the floor of the filter cells.

A filter plant should include at least two filter cells. Many more can be used depending on the capacity required. The filter cells can be arranged as required.

It is possible to reduce filter footprint using a unique and yet untried 'stacking' technique. Because the filter cells are relatively short with most piping external to the cells on filter cell sides it is reasonable to consider 'stacking' filter cells as in a multi-story automobile parking garage.

Water treatment plants which use the MPSF technology may serve very small to very large communities. Additional MPSF's may be added as required as population and associated demand grow.

In circumstances where a community is served from a variety of dispersed supplies it is economical to provide water treatment using the MPSF technology at each site prior to supplying the main distribution system.

Construction

Filters may be constructed using a variety of materials depending on client needs. The vessels may be constructed using cast-in-place concrete, concrete blocks, brick, stainless steel, aluminum, epoxy coated steel, fibre glass, or polyethylene. The piping is typically constructed using schedule 80 pvc but may also be constructed of stainless steel if the filter is expected to withstand extraordinary mechanical forces . The design of the filter bed is a complex function of media type and shape and particle size distribution. Preferred media is crushed quartz though weathered (rounded) quartz may also work well. The design of the filtering layer can only be exactly determined by experimentation using a small prototype of an actual filter, an evaluation that insures the media is capable of achieving desired filtration characteristics and can be backwashed successfully at reasonable backwash flow rates.

The design of the filter bed is integral to the proper functioning of the MPSF technology. Recall that the media is never replaced and is expected to last for the life of the filter (at least 20 years). The extra care and expense in media selection and transportation is easily justified.

Retrofitting Existing TSSF's to Use MPSF Technology

Water treatment plants that are presently using TSSF's may readily be retrofitted to use MPSF technology. All internal piping and filter media would be replaced. Additional piping would be required to satisfy the operational and backwash requirements for the MPSF units. The vessels and much of the main external piping connecting individual filters may still be used.

The result of retrofitting is the increase in production capacity (because operation tends to be nearer maximum capacity)and greatly reduced operational and maintenance costs.

Energy Consumption

The MPSF's require relatively little energy to operate and clean. It is only necessary for the raw water supply to have sufficient pressure to feed individual filters, approximately two to three metres of pressure head is required, in contrast with rapid and pressure sand filter systems that may require more than ten metres. Backwash flow rate is quite low and provided under low pressure compared to both rapid and pressure filters which require high flow rates provided at high pressure. As a consequence of only requiring low flow rates under low pressure the pumping requirements and associated energy consumption is comparatively little (for both well and backwash pumps).

In cold climates where temperatures drop below freezing it is necessary to locate the entire water treatment plant in a heated building. The larger footprint associated with the use of the MPSF technology (resulting in plants with at least one-third larger foot print) results in the need for a larger structure and greater heating requirements. The increased costs associated with additional heating are minimal when compared to other energy savings.

There may be opportunities to use alternative energy supplies such as photo-voltaic and wind power.

Chemical Requirements

In applications where only iron is being removed, simple aeration is the only pre-treatment necessary. Post-filtration chlorination will be required. In many applications the only chemicals used for pre-treatment is sodium hypochlorite and in some circumstances chlorine dioxide. Sodium hypochlorite is very commonly used for chlorination of drinking water and is not considered a complicated or dangerous chemical to use. Recent advances in chlorine dioxide technology, specifically ease of chemical management and dispensing, safety and monitoring, are facilitating its use in municipal water treatment plants.

Wastewater Production

Wastewater production is typically less than one per cent of filtered water production compared to five or much more per cent for other iron and manganese removal technologies.

Water Conservation and Opportunity for Recycling

As noted very little wastewater is produced. It is practical to consider wastewater recycling as the concentration of iron and manganese in the wastewater is quite high allowing for rapid clarification. The clarified wastewater is returned to the contact tanks and production of small quantities of sludge for disposal. The ability to recycle is especially important if arsenic is also being removed.

Robustness and Simplicity of Construction and Operation

Treatment processes using the MPSF technology are very robust and easy to operate well. Typically, water treatment plants that use the MPSF technology can be successfully operated by staff certified at the lowest level of certification needed to operate water treatment plants. The plants require very little operator attention often less than two hours per day. The advantages are much lower operation costs and the opportunity to use locally available staff.

Water treatment plants which use the MPSF technology may be operated with minimal or no automation using commonly available construction elements. This allows ease of repair using local suppliers and contractors or treatment plant staff. However, they can be fully automated and remotely monitored and controlled with minimal local attention.

Portability

Water treatment plants that use MPSF technology may be constructed on mobile trailers that are moved from site to site – without the necessity for removing the media (though this may be advisable for safety purposes during transportation) . The construction must be robust enough to accommodate the physical abuse associated with transport. Because the filters are commissioned and cleaned using a backwash process they may be put into operation very easily and quickly once the necessary site utilities are made available.

Seasonal Use

The MPSF's may be operated on a seasonal basis. They may be completely drained, after a final backwash, and allowed to stand idle for as long as required. In cold environments where their use is not required during the winter months they may be allowed to freeze once all of the water has been drained from the system or replaced with a food grade anti-freeze.

Other Groundwater Treatment Applications

The MPSF technology may be used to remove a variety of particles and dissolved solids that may be found in groundwater either directly or with selected pre-treatment. These include:

- sand, silt and clay and organic particulate matter (suspended solids)
- TOC/DOC (NOM)
- arsenic
- heavy metals
- fluoride
- naturally occurring radioactive materials (NORM)
- elevated concentration of dissolved solids (high TDS)
- pathogens (GWUDI)

Inorganic and Organic Suspended Solids

While larger inorganic or organic particles including sand and silt can be removed directly, colloidal sized particles may require some form of pre-treatment.

Pre-treatment may consist of the addition of very small dosages of alum or other coagulant (such as PAC if the water is very cold) and a short mixing period in a contact tank to insure formation of micro-flocs (such as necessary for the removal of iron and manganese). Pilot testing is essential to determine chemical dosage rate and contact time.

TOC/DOC

Some of the TOC may be filtered directly but none of the DOC can be removed without pre-treatment. Pre-treatment might consist of the addition of a coagulant such as alum which helps capture particulate TOC and adsorb some of the dissolved organics prior to filtration or possibly the addition of powdered activated carbon (PAC) with the use of contact tanks to allow maximum opportunities for adsorption prior to filtration. The efficiency of these procedures is water specific and highly variable. Pilot testing is essential to determine chemical dosage rate and contact time. If large doses of coagulant are required the technique might not be compatible with the MPSF technology. However, most treatment processes that are able to effectively remove DOC (such as post-filtration use of granular activated carbon or membrane processes) will perform better (longer run times between cleaning or maintenance or media replacement) if the water is free of particulate material.

Arsenic

Arsenic removal using the MPSF technology relies on the same principles as associated with co-precipitation processes. The procedure includes the following steps:

- Adding an oxidant such as sodium hypochlorite or chlorine dioxide to insure conversion of arsenic three to arsenic five and insure the elimination of potential organic sequestration problems.
- Addition of small quantity of ferric chloride or ferric sulphate (alum may also be considered).
- Provide sufficient time for adsorption of arsenic to iron hydroxides and formation of micro-flocs using contact tanks
- Filter using MPSF technology

It is possible to recycle the backwash water resulting in almost zero liquid waste and a chemically stable sludge. Pilot testing is essential to determine chemical dosage rate and contact time.

Heavy Metals

The process is similar to that used for arsenic removal though other coagulants than iron salts may be used.

Fluoride

The process involves the addition of alum which will remove the fluoride ion by adsorption to the aluminum hydroxide. Significant alum dosages may be required along with the addition of other chemicals such as lime to meet alkalinity requirements. The process may include a clarification step followed by filtration to remove all residual micro-flocs. Pilot testing is essential to determine chemical dosage rate, need for clarification and effectiveness of filtration.

Naturally Occurring Radioactive Material

The process is similar to that used for arsenic removal though other coagulants than iron salts may be used.

High Concentration of Dissolved Solids

The MPSF technology is not capable of removing dissolved solids unless appropriate pre-treatment is available that allows the dissolved substance be adsorbed to or react with particulate matter that can itself be removed by the MPSF; or, by the addition of chemicals that will react selectively with the dissolved solid to form a precipitate that can be removed by the MPSF.

It is usually necessary to use technologies such as reverse osmosis or electrodialysis to remove dissolved solids. However, these technologies require pre-treatment for the removal of suspended particles to minimize cleaning and maintenance. The MPSF technology may economically provide the necessary pre-treatment.

Pathogens (GWUDI)

If the groundwater to be treated is considered to be GWUDI and the only concern is the presence of pathogens the MPSF may be replaced with the Manz Slow Sand Filter™ or MSSF to benefit from the ability of the slow sand filtration process to remove pathogens. The MSSF may be demand operated and also cleaned using a backwash process. See web site www.oasifilter.com for more information.

If the groundwater to be treated has other water treatment problems (iron, manganese, TOC/DOC, arsenic, heavy metals, fluoride or NORM) and is also considered GWUDI a variety of treatment processes before and after filtration using either the MPSF or MSSF technologies may be required.

Discussion

The utility of the MPSF technology to treat groundwater for removal of iron, manganese and SRB has been clearly demonstrated. Other opportunities to use the MPSF technology for groundwater treatment include removal of a variety of particulate material, arsenic, fluoride, heavy metals, DOC and naturally occurring radioactive materials as well as pre-treatment of water for GAC, membrane and electrodialysis. Treatment plants that will use the MPSF technology for arsenic and fluoride removal are in the preliminary design phase.

Groundwater treatment using the MPSF technology is proving effective, low cost, water efficient, environmentally friendly and sustainable.

The advantages of the MPSF technology for treatment of groundwater promises to make it the treatment process of choice for small to medium sized communities, particularly those with limited financial resources or in remote locations.