Introduction to Iron and Manganese Removal

In order to produce good drinking water, many impurities should be removed during a treatment process. Two of these impurities which can cause problems to consumers are the metals – iron and manganese. They are found naturally in the soils and rocks that make up the earth. Iron is probably a little more common than manganese.

Groundwater often contains a number of substances that are dissolved in the water as it passes through soils, sands, gravels and rocks. Iron and manganese can also be dissolved and go into solution in groundwater. Saskatchewan has a lot of groundwater and much of the groundwater used for municipal supplies contains iron and manganese. In fact, there are over 200 municipal water systems that remove iron and/or manganese.

The iron and manganese that are dissolved in the water are said to be in solution or in a reduced form. In this form, they are often tied up with other dissolved salts such as bicarbonates, sulphates or hydroxides; or they may be linked to certain organic materials. In their soluble, or reduced state, iron and manganese are normally colourless and you cannot tell by the appearance of the water if they are present. However, once they become exposed to air or certain other chemicals, they change from a soluble to an insoluble form and yield the rusty colour or sediment which most people are familiar with.

Iron and manganese in drinking water are normally not considered to be a health concern. However, there are a number of problems which can occur if too much iron and manganese are present in the water. These include:

- staining of laundry and plumbing fixtures;
- discolouration of the water;
- taste to the water;
- growth of iron bacteria is encouraged;
- formation of deposits in distribution systems and plumbing;
- interference with treatment processes such as disinfection; and
- fouling of water softeners.

In order to avoid the above problems, objectives for the concentration of iron and manganese in water for human consumptive or hygienic use have been established. They are outlined in the *Saskatchewan Drinking Water Quality Standards and Objectives 2002* published by Saskatchewan Environment. These objectives are as follows:

- iron – 0.3 mg/L maximum; and
- manganese – 0.05 mg/L maximum.

The concentration is measured in units of milligrams per litre (mg/L) which is the same as the parts per million many people used to use. *Note*: The recommended maximum amount of manganese to avoid problems is very small.

EPB 223 03/2003

Saskatchewan Environment

Environmental Protection Branch

Remember:
Treated water should have less than 0.3 mg/L iron and less than 0.05 mg/L manganese.

One of the problems associated with excessive levels of iron and manganese is the discolouration and staining of laundry and plumbing. This happens when the dissolved iron and manganese become exposed to air or chemicals such as household bleach that converts the dissolved forms into precipitate or insoluble forms of iron and manganese. These soluble forms for iron are called ferrous iron and for manganese are called manganous manganese. When they change in form, they become ferric iron and manganic manganese, which can be filtered out. The procedure that often causes problems with these two metals is also one that is suitable for their removal.

The basic treatment approach to remove iron and manganese is to convert the soluble or dissolved forms of iron and manganese into insoluble or precipitate forms so that they can be filtered out.

The change of reduced soluble forms by the addition of air (oxygen) or certain chemicals to an insoluble form is called oxidation. For iron, ferrous iron is oxidized to ferric iron or a form that can be readily filtered. As well, manganous manganese is oxidized to the insoluble manganic manganese that can be filtered. The oxidation of iron and manganese is accomplished by adding air (oxygen) or certain oxidizing chemicals, such as chlorine in its various forms and potassium permanganate.

Water Treatment Processes

The general treatment process for iron and manganese removal is basically accomplished by the addition of air or an oxidizing chemical to convert the dissolved ferrous iron and manganous manganese to an insoluble form of ferric iron and manganic manganese and then filtering. The specific treatment that is required for iron and manganese removal depends on what the iron and manganese may be associated with in the raw water and also on the levels that are present. As well, the ease of oxidizing iron and manganese is different. Manganese is much more difficult to change than iron. It is more slowly oxidized and often requires high pH (measure of acid or base) levels. For manganese removal, special treatment processes are employed. Exact treatment can only be determined experimentally.

Consider two example processes for iron and manganese removal. One involves high iron above 5-7 mg/L and no manganese in the raw water and the other involves an iron concentration of less than 5-7 mg/L and 0.15 mg/L manganese in the raw water.

Iron = 5 – 7mg/L Manganese = 0	So: always oxidize with the cheapest method first—aeration to provide oxygen, next use chlorine
High iron can generally be removed by oxidation to form an insoluble heavy substance that can be settled out and filtered. Pilot testing is the best way to determine treatment methods.	Then: allow insoluble form of iron to settle out; Then: filter either in a single media pressure or gravity filter; and Then: disinfect the filtrate before storage.

Iron = less than 5 – 7 mg/L Manganese = 0.15 mg/L	So: oxidize the iron first, again using the cheapest method first—aeration and chlorine:
Relatively high iron can be removed by oxidation as in Case #1, but manganese requires the use of potassium permanganate and manganese greensand for removal.	Then: allow insoluble form of iron to settle out; Then: add potassium permanganate ahead of the filter; Then: filter in a manganese greensand pressure or gravity filter with an anthracite cap, which filters out any insoluble iron to avoid fouling the rather expensive greensand; and Then: disinfect the filtrate before storage.

As noted in the second example, for the removal of manganese, potassium permanganate is used as the oxidizing agent and further that the water is then filtered through a manganese greensand filter. The potassium permanganate is particularly useful for manganese removal because it not only assists the oxidation of manganese but also regenerates the manganese greensand. Manganese greensand is a specially treated mineral (zeolite) that is mined in the eastern United States. It is treated so that it has particular capabilities for oxidation. With these capabilities, it acts not only as a filter but as a further oxidation agent for the manganese. It also assists to oxidize and filter iron. In order to maintain this oxidation property, manganese greensand has to be regenerated through the application of potassium permanganate.

One of the major differences with processes relates to the iron and concentration. It is desirable to avoid overloading the filter with high amounts of iron sediment. Where the raw water iron levels are high, it is normally useful to have a sedimentation basin ahead of the filters, such as in the first two examples.

Two other examples:

Iron = 1.2mg/L Manganese = 0	So: always oxidize with the cheapest method first—aeration to provide oxygen, next use enough chlorine to oxidize the iron and to carry a chlorine residual into the distribution system;
Low levels of iron can generally be removed by oxidation to form an insoluble heavy substance that can be filtered. Pilot testing is the best way to determine treatment methods.	Then: filter either in a single media pressure or gravity filter; and Then: the filtrate goes to storage.

Iron = 1.2 mg/L Manganese = 0.8 mg/L	So: always oxidize with the cheapest method first—possibly aeration and if not, use enough chlorine to carry a chlorine residual into the distribution system;
Low levels of iron can generally be removed by oxidation to form an insoluble heavy substance that can be filtered. Low levels of manganese can be removed with a manganese greensand filter. Pilot testing is the best way to determine treatment methods.	Then: filter either in a pressure or gravity filter with manganese greensand and an anthracite cap; and Then: the filtrate goes to storage.

Pretreatment Processes

To assist in iron and manganese removal, there are a number of oxidation or other approaches that can be used. These include the following:

Aeration: This is frequently useful for the conversion or oxidation of iron. Aeration is normally too slow to be used with successful manganese oxidation unless the water's pH is very high. Aeration is generally used before other chemical treatment, since it is relatively inexpensive to operate and it can reduce the amount of chemicals that might subsequently be used.

The common types of aeration equipment are either pressure aerators or forced draft aerators:

- in the <u>pressure</u> type, compressed air is diffused into the water in very fine bubbles and the oxygen from the air converts the ferrous iron to ferric iron. This type of aeration treatment is used to avoid double pumping; and
- in the <u>forced draft aerator</u>, the raw water is introduced into the top of a rectangular or circular tank and the water falls over trays breaking up into droplets as it goes to the bottom. Air is added from the bottom by a blower and is blown out through the top. This way there is a good mixing effect between the water droplets and the air so that the iron is easily converted to the ferric type.

Chlorination: Chlorine is a good oxidizing agent particularly for a lot of the ferrous ions. Chlorine is normally not that effective for manganese removal or conversion. Chlorine can be applied as a hypochlorite solution – either calcium hypochlorite (65% available chlorine) or sodium hypochlorite (12% available chlorine) – or as chlorine gas. The use of chlorine also provides disinfection of the water. If chlorine or chlorine solution is used for the pretreatment, it is important that it be used in the right dosages and constantly to avoid problems with the filter. Obviously, if the right amount of chlorine is not added, the iron will not be converted and it will pass right through the sand filters.

Remember:
Keep Chemical Feeders Working Have Backup Equipment or Parts on Hand

Potassium Permanganate: This purple chemical has to be used when manganese greensand filters are used. Potassium permanganate in dilute solution is a pink colour. When it reacts with iron or manganese, the colour is yellow to orange unless extra permanganate is available. The normal operation is to feed potassium permanganate in solution form ahead of a manganese greensand filter in such dosages that the water is slightly pink as it goes onto the filter. The presence of the pink colour tells you there is enough of the chemical being added. Potassium permanganate is normally fed in a pretreatment process following the application of other oxidizing agents such as air or chlorine. It is important that enough mixing time or reaction time be provided to oxidize as much as possible the manganese in solution. The time required depends on the pH – the higher the pH, the shorter the time that is necessary.

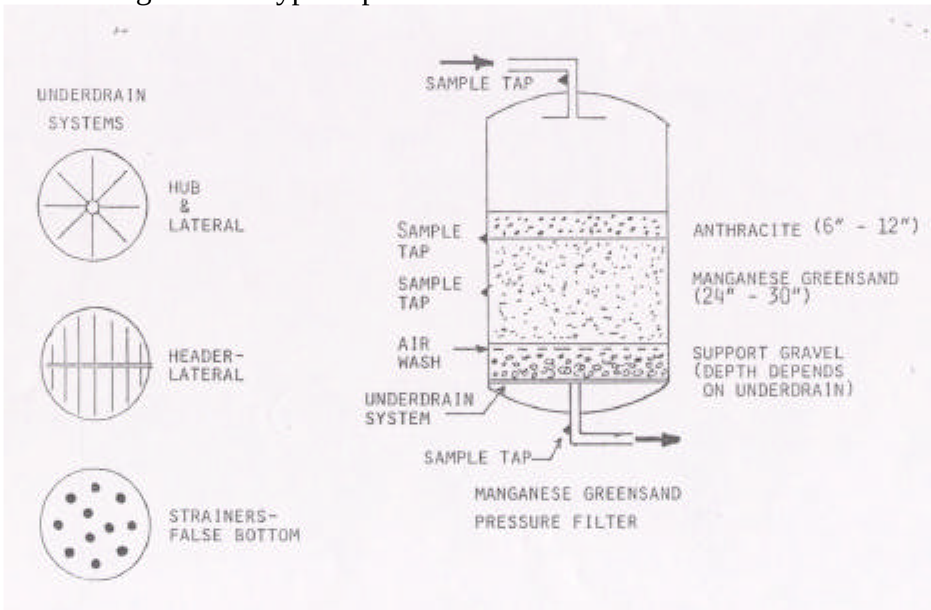
Miscellaneous Processes: One way which can assist in the conversion of iron and manganese is the control of the water's pH (measure of acidic or basic properties). Iron and manganese (particularly manganese) are more readily converted to the sediment forms at a high pH (basis). Chemicals often used for raising the pH in the water include soda ash, lime and caustic soda. Polyelectrolytes also have been used to assist in iron and manganese removal. Their main function is to assist making larger particles that are more readily removed during a filtration step.

Filtration

The filtration step involves the final removal of iron and manganese from the water. It therefore is a critical link in the process. There are two basic types of filters that are used; gravity high rate filters and pressure filters. Basically, they include a means of introducing the water, the filter media and a collection system for the filtered water. The collection system also serves as a distribution system for the backwash water used to clean the filters. Since pressure filters are used in the vast majority of iron and manganese removal plants in Saskatchewan, the operation of pressure filters will be stressed. *Note* that the selection of filtration media and operational cycle of a gravity filter is somewhat similar to that of a pressure filter.

The media for the filters can include anthracite filter material, sands and manganese greensand together with the support sands and gravels. If manganese removal is not required, then the filter can be anthracite and sand, sand only or anthracite only. On the other hand, if manganese removal is required, then normally manganese greensand is used. If there are any significant iron levels present, it is beneficial to have an anthracite cap on top of the manganese greensand to protect it from a lot of iron sediment.

Filter Option: A diagram of a typical pressure filter and underdrains is shown below.



There are two basic operations associated with filtration. They are:

1. The **filtration** step includes application of water uniformly to the top of the filter. Often the rate of water application is described in relation to the area of the filter surface. The application rate can be expressed in cubic metres per hour of water per square meter of area (metres per hour) or gallons per minute per square foot. The rates that can be appropriately used will depend on the raw water quality, the pretreatment provided and the media used in the filter. A typical rate for filtration would be 6 metres per hour (m/hr) or 2 gallons per minute per square foot (2 gpm/ft^2) although some filters have been designed for higher rates. Normally, the lower rate will permit a better operation and subsequently less treatment and filter problems. The underdrain system is designed so that the water is collected evenly from the filter. This type of system can be either a hub and lateral system which has a spoke type configuration or it could be a system of evenly spaced nozzles or collectors on a false bottom. The use of fine porous plates is normally not recommended for iron and manganese removal since the small pore size is susceptible to clogging.

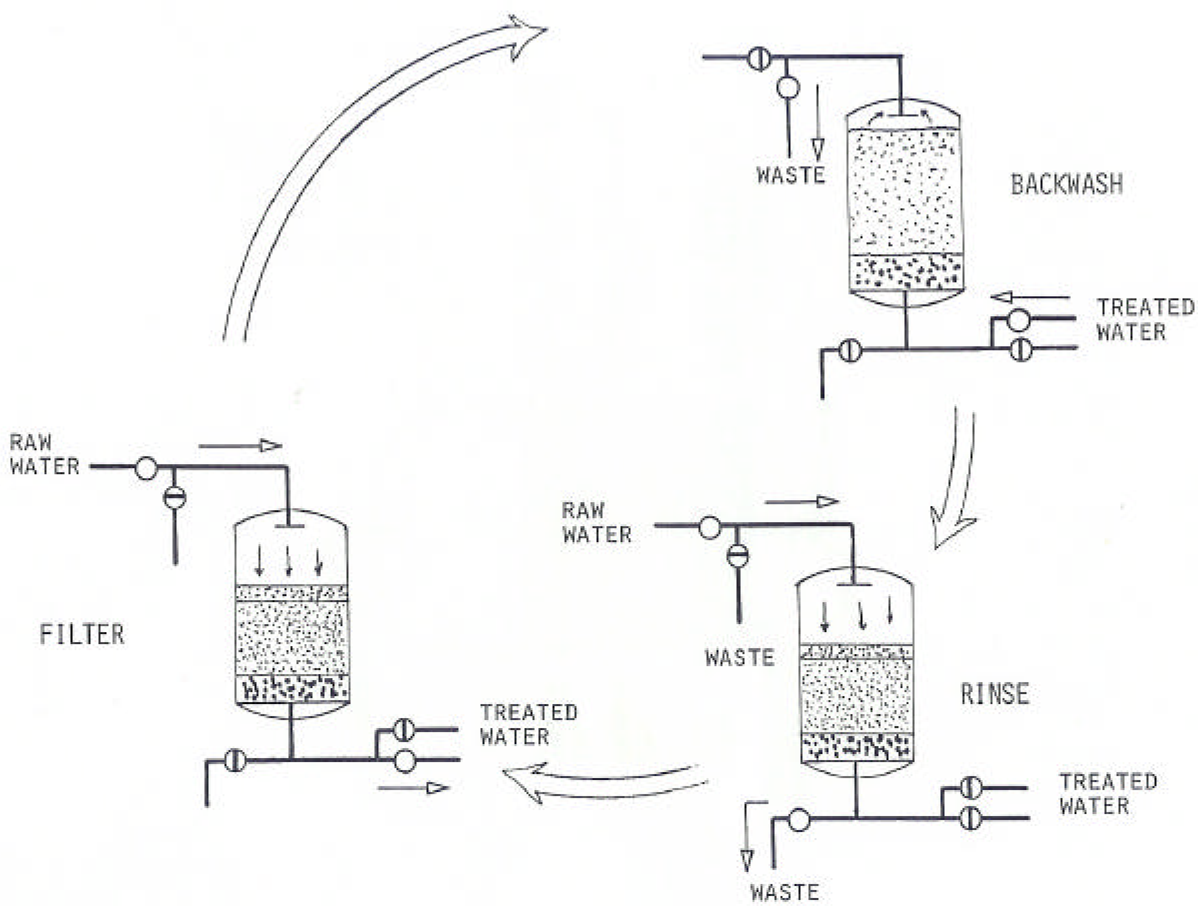
2. The **cleaning or backwashing** of a filter is one of the most important aspects of filter operation. The process is to reverse the flow upwards from the underdrain or distribution system up through the filter and waste that water. The cleaning action arises from the expansion of the bed and the rubbing of the filter particles so that all of the deposits become free and pass out in the wastewater. For effective backwashing, it is important that the rate of water applied be sufficiently large to permit a good expansion of the bed. This rate is also expressed as a water flow per unit area of filter. Typical backwash rates would be in the order of 60 to 70 metres per hour or 10 to 12 gallons per minute per square foot. It is important the distribution water be uniformly applied so that the entire filter bed is expanded evenly. Backwashing is normally carried out until the wastewater turns clear. The backwash water is then stopped and the filter is rinsed to waste before placing it into service. For manganese greensand, an air scour or air wash system is also useful to ensure the media becomes clean. This air wash is normally used during the backwash cycle after the filter has been initially flushed.

It is also important that treated water is used to backwash and clean the filter media, particularly in the case of manganese greensand.

The Filtration Cycle

The diagram on this page shows the filtration cycle beginning with the filter in normal ***Filter Mode*** on the left hand corner. The arrow indicates the raw water entering the filter at the top, passing through the media and exiting to the treated water reservoir. Open and closed valves are indicated. Next, in the ***Backwash Mode,*** treated water travels through the filter in reverse, up through the media loosening the trapped dirt and carrying it to waste. An air wash can be used in the backwash to enhance cleaning of the filter media.

Finally in the ***Rinse Mode***, raw water enters the filter at the top, passes through the media and exits to waste. The rinse water must go to waste, otherwise any loosened particles and dirt still in the filter media after backwash will go the clear well and will reduce the quality of the treated water. Once the rinse is completed, the filter can be put back into service in the ***Filter Mode.***



If your treatment facility normally removes iron and/or manganese from the raw water, you should plan to attend an Iron and Manganese Removal Workshop. Please refer to the latest edition of SIAST's Water and Waste Training Centre Extension Workshop calendar or the SWWA newsletter "The Pipeline" for further information.