



# FILMTEC Membranes

## Colloidal Fouling Prevention

### Introduction

Colloidal fouling of reverse osmosis elements can seriously impair performance by lowering productivity and sometimes salt rejection. An early sign of colloidal fouling is often an increased pressure differential across the system.

The source of silt or colloids in reverse osmosis feed waters is varied and often includes bacteria, clay, colloidal silica and iron corrosion products. Pretreatment chemicals used in a clarifier such as alum, ferric chloride, or cationic polyelectrolytes can also cause colloidal fouling if not removed in the clarifier or through proper media filtration. In addition, cationic polymers may coprecipitate with negatively charged antiscalants and foul the membrane.

The best available technology for determining the colloidal fouling potential of reverse osmosis feed water is the measurement of the Silt Density Index (SDI), sometimes referred to as the Fouling Index (FI). This is an important measurement to be carried out prior to designing an RO pretreatment system and on a regular basis during RO operation (three times a day is a recommended frequency for surface waters).

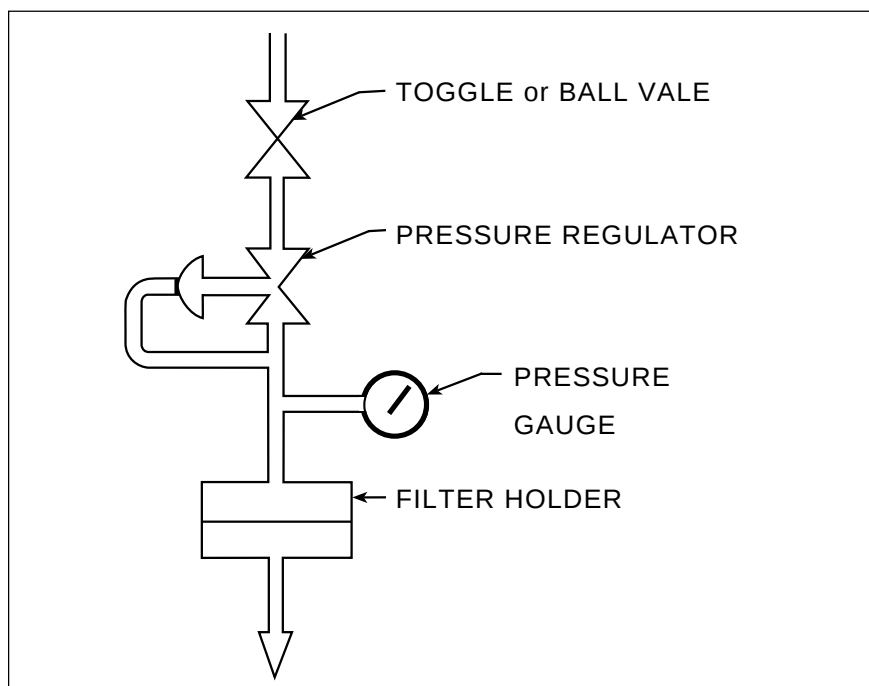
The Standard Test Method has been described in ASTM test D 4189-82.

### Equipment

(Available from Millipore Corporation)

- 47 mm diameter membrane filter support
- 47 mm diameter membrane filters (0.45  $\mu\text{m}$  pore size)
- 1 to 5 bar (10-70 PSI) manometer
- needle valve for pressure adjustment

Figure 1 shows the equipment needed to measure SDI.



**Figure 1: Apparatus for Measuring the Silt Density Index**

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## Procedure

- Place the membrane filter on its support, bleed water pressure on carefully, tighten the O-ring seal and fix the support vertically.
- Adjust feed pressure to 2.1 bar (30 PSI) and measure initial time,  $t_0$ , necessary to filter 500 ml of sample water (feed pressure to be kept constant by continuous adjustment).
- Keep filter in operation for 15 minutes under 2.1 bar (30 PSI) feed pressure.
- After 15 minutes measure again time,  $t_1$ , necessary to filter 500 ml. Membrane filter should be kept for further analysis.
- Calculation:

$$SDI = \left[ 1 - \frac{t_0}{t_1} \right] \times \frac{100}{15}$$

When  $t_1$  is four times as long as  $t_0$ , the resulting SDI is 5. A water sample that totally blocks the membrane filter has an SDI value of 6.7.

The guideline is to maintain SDI at less than or equal to 5. A number of pretreatment technologies have proven effective in SDI reduction including media filtration (such as sand/anthracite), ultrafiltration, cross flow microfiltration. Polyelectrolyte addition ahead of filtration sometimes improves SDI reduction.

Methods to prevent colloidal fouling are outlined in the following sections.

## Media Filtration

The removal of suspended and colloidal particles by media filtration is based on their deposition on the surface of filter grains, while the water flows through a bed of these grains (filter media). The quality of the filtrate depends on the size, surface charge and geometry of both suspended solids and filter media, as well as on the water analysis and operational parameters. With a well designed and operated filter, a  $SDI < 5$  can usually be achieved.

The most common filter media in water treatment are sand and anthracite. The effective grain size for fine sand filter is in the range of 0.35 to 0.5 mm, and 0.7 to 0.8 mm for anthracite filter. In comparison to single sand filter media, dual filter media with anthracite over sand permit more penetration of the suspended matter into the filter bed, thus resulting in more efficient filtration and longer runs between cleaning. The design depth of the filter media is normally about 0.8 m (31 inches) minimum. In the dual filter media, the filters are usually filled with 0.5 m (20 inches) of sand covered with 0.3 m (12 inches) of anthracite.

There are two types of filters employed, gravity and pressure filters. As the filter vessel for pressure filtration is designed for pressurization, a higher pressure drop can be applied for higher filter beds and/or smaller filter grains and/or higher filtration velocities. The design filtration flow rates are usually 10-20 m/h, and the back-wash rates are in the range of 40-50 m/h. For feedwaters with a high fouling potential, flow rates of less than 10m/h and/or second pass media filtration is preferred. The available pressure is usually about 5 m of head for gravity filters, and 2 bar (30 PSI) to more than 4 bar (60 PSI) for pressure filters.

During operation, influent water to be filtered enters at the top of the filter, percolates through the filter bed, and is drawn off through the collector system at the bottom. Periodically, when the differential pressure increase between the inlet and outlet of the filter is 0.3 to 0.6 bar (4 to 9 PSI) for the pressure filter, and about 1.4 m for the gravity filter, the filter is back-washed and rinsed to carry away the deposited matter. Backwash time is normally about 10 min.

Frequent shut-downs and start-ups should be avoided, because each filter velocity increase will release previously deposited particulate matter. Design and operational details of media filtration are available in the literature.

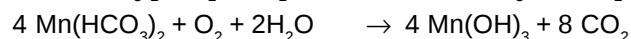
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### Oxidation Filtration

Some well waters, usually brackish waters, are in a reduced state. Typical for these waters is the absence of oxygen and the presence of divalent iron and manganese, sometimes also of hydrogen sulfide and ammonium.

If such a water has been chlorinated and then dechlorinated, or has taken up more than 5 mg/l of oxygen,  $\text{Fe}^{2+}$  is converted into  $\text{Fe}^{3+}$ , which forms insoluble colloidal hydroxide particles. The oxidation of iron and manganese is given by:



Iron fouling occurs more frequently than manganese fouling, since the oxidation of iron occurs at a much lower pH. Thus a fouling problem can be created even if the SDI is below 5, and the level of iron in the RO feed water is below 0.1 mg/l. Waters with low alkalinity usually have higher iron concentrations than waters with high alkalinity, because the  $\text{Fe}^{2+}$  concentration is usually limited by the solubility of  $\text{FeCO}_3$ .

One method of handling such waters is to prevent the exposure to air or to any oxidizing agent, e.g. chlorine, through the whole RO process. A low pH is favorable to retard  $\text{Fe}^{2+}$  oxidation. At  $\text{pH} < 6$  and oxygen  $< 0.5$  mg/l, the maximum permissible  $\text{Fe}^{2+}$  concentration is 4 mg/l. The other way is to deliberately oxidize iron and manganese by air,  $\text{Cl}_2$  or  $\text{KMnO}_4$ . The formed hydroxides can then be removed by media filtration. Colloidal sulfur as formed from hydrogen sulfide however, may be difficult to remove. Oxidation and filtration can be accomplished in one step by using a filter media with the ability to oxidize  $\text{Fe}^{2+}$  by electron transfer.

Greensand is such a granular medium, which is a green (when dry) mineral glauconite. It can be regenerated with  $\text{KMnO}_4$  when its oxidizing capability is exhausted. After the regeneration, the residual  $\text{KMnO}_4$  has to be thoroughly rinsed out in order to avoid an oxidation damage of the membranes. This technique is used when  $< 2$  mg/l  $\text{Fe}^{2+}$  is present in the raw water. For higher  $\text{Fe}^{2+}$  concentrations,  $\text{KMnO}_4$  can be continuously dosed into the inlet stream of the filter. In this case however, measures have to be taken to assure that no permanganate can reach the membranes, for example by installation of a carbon filter.

Birm filtration has also been used effectively for  $\text{Fe}^{2+}$  removal from RO feed water. Since with birm a pH increase and consequently a shift in the LSI value might occur, care should be taken to avoid  $\text{CaCO}_3$  precipitation in the filter and in the RO system.

### In-Line Filtration

The efficiency of media filtration to reduce the SDI value can be markedly improved if the colloids in the raw water are coagulated and/or flocculated prior to filtration. In-line filtration can be applied to raw waters with an SDI only slightly above 5. The method, also named in-line coagulation or in-line coagulation-flocculation, is described in ASTM Standard D 4188. A coagulant is injected into the raw water stream, effectively mixed, and the formed microflocs are immediately removed by media filtration.

Ferric sulfate and ferric chloride are used to destabilize the negative surface charge of the colloids and to entrap them into the freshly formed ferric hydroxide microflocs. Aluminium coagulants are also effective, but not recommended because of possible fouling problems with residual aluminium.

Rapid dispersion and mixing of the coagulant is extremely important. An in-line static mixer or injection on the suction side of a booster pump is recommended. The optimum dosage is usually in the range of 10 to 30 mg/l, but should be determined case by case.

To strengthen the hydroxide microflocs and thereby improving their filterability, and/or to bridge the colloidal particles together, flocculants can be used in combination with coagulants or alone. Flocculants are soluble high molecular mass organic compounds, e.g. linear polyacrylamides. Through different active groups, they may be positively charged (cationic), negatively charged (anionic), or close to neutral (non-ionic).

Coagulants and flocculants may interfere with an RO membrane directly or indirectly. Indirect interference occurs when the compound forms a precipitate which is deposited on the membrane. For example, channelling of the media filter may enable flocs to pass through and deposit on the membrane. A precipitate can also be formed when concentrating the treated feedwater, such as when aluminium or ferric coagulants are added without subsequently lowering pH to avoid supersaturation in the RO stage. Furthermore, reaction with a compound

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added after the media filter can cause a precipitate to form. This is most noticeable with antiscalants. Nearly all antiscalants are negatively charged and will react with cationic coagulants or flocculants present in the water. Several RO plants have been heavily fouled by a gel formed by reaction between cationic polyelectrolytes and antiscalants.

Direct interference occurs when the compound itself affects the membrane resulting in a flux loss. The ionic strength of the water may have an effect on the interference of the coagulant or flocculant with the membrane. If so, the result at brackish water conditions could be different from that at sea water conditions. To minimise the risk of direct or indirect interference with the RO membrane, anionic or nonionic flocculants are preferred rather than cationic ones. Overdosing must be avoided.

### **Coagulation – Flocculation**

For raw waters containing high concentrations of suspended matter resulting in a high SDI, the classic coagulation – flocculation process is preferred. The hydroxide flocs are allowed to grow and to settle in specifically designed reaction chambers. The hydroxide sludge is removed, and the supernatant water is further treated by media filtration.

For the coagulation – flocculation process, either a solids-contact type clarifier or a compact coagulation – flocculation reactor may be used. For details, please refer to the general water treatment textbooks.

### **Crossflow Microfiltration/Ultrafiltration**

Crossflow filtration through a microfiltration (MF) or ultrafiltration (UF) membrane removes virtually all suspended matter and, in the case of ultrafiltration, also dissolved organic compounds depending on their molecular mass and on the molecular mass cutoff of the membrane. Hence, an  $SDI < 1$  can be achieved with a well designed and properly maintained microfiltration or ultrafiltration system. The fouling problem, now transferred from the RO membrane to the MF or UF membrane, has to be handled by this system. At the same time, a high MF/UF system recovery and a high specific permeate flow is requested for economic reasons. These objectives are usually achieved by periodic cleanings, either a forward flush or preferably a backflush. If a chlorine resistant membrane material is used, e.g. polysulfone or a ceramic membrane, chlorine can be added to the wash water in order to prevent biological fouling.

### **Cartridge Microfiltration**

A cartridge filter with a pore size of less than 10  $\mu m$  is the minimum pretreatment required for every RO system. It is a safety device to protect the membranes and the high pressure pump from suspended particles. Usually it is the last step of a pretreatment sequence. We recommend to use a pore size of 5  $\mu m$  or less. The better the prefiltration is, the less cleaning of the RO membranes is required. When the silica concentration in the concentrate stream exceeds the theoretical solubility, cartridge filtration with 1  $\mu m$  pore size is recommended in order to minimise the interaction with iron and aluminium colloids.

The filter should be sized on a flow rate according to the manufacturer's recommendation, and replaced before the pressure drop has increased to the permitted limit, but at the latest, after three months. Backflushable filters are not recommended because of their lower efficiency and higher biofouling risk.

The cartridge filter should be made of a synthetic nondegradable material; e.g. nylon or polypropylene and equipped with a pressure gauge to indicate the differential pressure drop and thereby indicating the extent of its fouling. Regular inspections of used cartridges provide useful information regarding fouling risks and cleaning requirements. If the differential pressure across the filter increases rapidly, it is an indication of possible problems in the raw water supply or in the pretreatment process. The filter provides some degree of short term protection for the membranes while corrective action is taking place.

Replacing cartridge filters more often than every 1 to 3 months usually indicates a problem with the pretreatment. However, the cartridge filter is not meant to be a major component for the removal of high amounts of filterable solids. This would not only be an inefficient use of rather expensive filters, but would probably lead to premature failure of the membrane system due to the high probability that some of the unwanted material will break through. It may be considered however, to use upstream a second cartridge with larger pore size.

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### Other Methods

Other methods to prevent colloidal fouling than those described in the previous chapters also exist.

**Lime Softening** is described in separate information on Scale Control as a method for silica removal. Removal of iron and colloidal matter are further benefits.

**Strong acid cation exchange resin softening** does not only remove hardness, but also lowers concentrations of iron and aluminium that otherwise could foul the membranes. Softened water is also known to exhibit a lower fouling tendency than unsoftened water, because multivalent cations promote the adhesion of naturally occurring colloids, which are usually negatively charged.

Backflushable fine filters may be used upstream of the cartridge filters to protect these. They are, however, no substitute for disposable cartridges.

### Design and Operational Considerations

The prevention of colloidal fouling is not only a matter of the proper pretreatment technique, but also of the system design and operation. As an extreme example, a surface water could be pretreated by coagulation – flocculation and ultrafiltration. The RO system could then operate with a high permeate flux, and almost no cleaning would be required. If the same water, however, would just be cartridge filtered, then the RO system would need much more membrane area, and the membranes would require frequent cleaning and maintenance. A poor pretreatment can be partially compensated by adding more membrane area and modifying the system, and by more frequent and/or harsh cleaning. On the other hand, improving the pretreatment means savings in membrane costs. In order to minimize the pretreatment effort and/or improve the feed water quality, the best available raw water quality should be used. The intake of surface water, including sea water is of paramount importance. A contamination of the raw water with waste water effluent may cause serious problems in the RO plant. A deep well close to the shore or the river is preferred. If an open intake is required, it should be located well away from the shore and some meters below the water surface.

New wells often release suspended matter in the first days of operation. Care must be taken that wells are properly rinsed out.

Fouling by iron oxide is also a common problem. It can be avoided by selecting non-corrosive materials.

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The technical information contained here is extracted from the **FILMTEC Membranes - Technical Manual**. References to other sections of the manual have been replaced with short references to additional but separate information available from our web site. The information in these extracts has been updated and supercedes that contained in the full manual.

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Published July 2002.



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Form No. 609-00307-702QRP