3-7. Biological Fouling Prevention

All raw waters contain microorganisms such as bacteria, algae, fungi, viruses and higher organisms. Microorganisms can be regarded as colloidal matter and removed by the pretreatment. However, it is very difficult to remove all the microorganisms and a few of them may escape the pretreatment to reproduce and form a biofilm downstream. MF membranes could stop most of the microorganisms, but still some will escape through the pores or defects of the membranes to reach the RO membranes. The symptoms of the biologically fouled RO system are an increase of the differential pressure and a membrane flux decline.

The potential for biological fouling is higher with surface water than well water. The concentration of bacteria in water is directly related to the biological fouling potential.

Total Bacteria Count (TBC) is a method to determine the total number of viable microorganisms in a water sample according to ASTM F60 by filtering a measured quantity of water through a membrane filter. Subsequently, the organisms retained on the filter surface are cultured on the proper nutrient medium for several days to develop colonies, which are then observed and counted at low power magnification.

This culture technique can be applied to monitor the microbial activity from the intake through the subsequent treatment steps up to the concentrate stream and the permeate.

Direct Bacteria Count (DBC) techniques employ filtration of the water sample and counting the retained microorganisms on the filter plate directly under a fluorescent microscope after they are stained with acridine orange or INT stain. INT stain can tell the difference between living cells and dead cells.

The germicidal efficiency of free residual chlorine is directly related to the concentration of undissociated HOCl which is 100 times more effective than the hypochlorite ion OCl^-.

The fraction of undissociated HOCl increases with decreasing pH and temparture.

At pH = 7.5 (25 ℃), 50% HOCl

At pH = 6.5 (25 ℃), 90% HOCl

At pH = 7.5 (5 ℃), 62% HOCl

In high salinity waters, less HOCl is present (30% at pH 7.5, 25℃, 40,000 mg/L TDS)

Chlorine can react with ammonia to give various chloramines in a series of stepwise reactions :

$$HOCl + NH_3 \rightarrow NH_2Cl + H_2O$$
$$HOCl + NH_2Cl \rightarrow NHCl_2 + H_2O$$
$$HOCl + NHCl_2 \rightarrow NCl_3 + H_2O$$

Chloramines also have a germicidal effect, albeit lower than that of chlorine. One advantage with the chloramines is that they do not oxidize the RO membranes. However, there will be always some residual unreacted HOCl which can still oxidize the membranes and thus care must still be taken when chloramines are used as a disinfectant.

To determine the optimum chlorine dosage, best point of injection, pH and contact time to prevent biofouling, the ASTM D1291, Standard Practice for Determining Chlorine Requirement of water should be applied to a representative water sample.

Dechlorination

The residual chlorine has to be dechlorinated before it reaches the RO membrane. CSM RO membrane has some chlorine tolerance, but eventual degradation may occur after 200-1000 hours of exposure to 1 mg/L of free chlorine, depending on the pH, temperature and residual transition metals such as iron in the feed water. Under alkaline pH conditions, chlorine degrades the membrane faster than at neutral or acidic pH. At an acidic pH, chlorine becomes more effective as a disinfectant.

Activated carbon(AC) bed is very effective in dechlorination of the residual chlorine in RO feed water according to the following reaction :

$$C + 2HOCl \rightarrow CO_2 + 2HCl$$

Sodium Metabisulfite (SMBS) or sodium Bisulfite(SBS) is most commonly used for removal of free chlorine and as a biostatic, as shown in the following reaction.

$$Na_2S2O_5 + H_2O \rightarrow 2NaHSO_3$$
$$NaHSO_3 + HOCl \rightarrow HCl + NaHSO_4$$

Stoichiometrically, 1.34 mg of sodium metabisulfite will react with 1.0 mg of free chlorine. In practice 3.0 mg of sodium metabisulfite is normally used to remove 1.0 mg of chlorine to make sure that all the chlorine is reduced.

The injection point of the SMBS solution is preferably upstream of the cartridge filters in order to keep the residual chlorine up to the filters to prevent microbial growth in the filters.

The SMBS solution should be filtered through a separate cartridge and injected through static mixers for good mixing into the RO feed line. The absence of chlorine should be monitored using an oxidation - reduction potential (ORP) electrode down stream of the mixing line.

Disinfection by Ultraviolet(UV) Irradiation

UV at 254㎚ is known to have a germicidal effect and has been used especially for small-scale plants. No chemicals are added and the equipment needs little attention other than periodic cleanings or replacement of the mercury lamps. However, UV treatment is limited to relatively clean waters, because colloids and organic matter interfere with the penetration of UV into depth of the turbid water.

Biological Activity Control by Sodium Bisulfite

Sodium bisulfite (SBS) concentrations in the range of up to 50mg/L in the feed stream of sea water RO plants have proven effective to control biological fouling. Colloidal fouling has also been reduced by the method. SBS is also helpful in controlling calcium carbonate scaling by supplying protonium(H^+) ions as shown below.

$$2NaHSO_3 + CaCO_3 \rightarrow Na_2SO_3 + Ca^{2+} + HCO_3^- + HSO_3^-$$