3-6. Colloidal Fouling Control

The removal of suspended and colloidal particles can be done by media filtration, crossflow microfiltration and cartridge microfiltration only for the raw waters with an SDI slightly above 5. For raw waters containing high concentrations of colloidal matter showing SDI well above 5, the coagulation and flocculation process is necessary before media filtration.

Ferric sulfate or ferric chloride is usually used as a coagulant to destabilize the negative surface charge of the colloids to result in coagulation and further to entrap them into the freshly formed ferric hydroxide microflocs. Aluminum coagulants are also effective, but not recommended because of possible fouling problems with residual aluminum. Cationic polymers may be used as both coagulants and flocculants.

To further agglomerate the hydroxide microflocs for better filterability, flocculants can be used in combination with coagulants. Flocculants are soluble high molecular weight polymers such as polyacrylamides which may contain cationic, anionic, or neutral active groups.

The hydroxide flocs are allowed to grow and to settle in specifically designed reaction chambers or clarifiers. The hydroxide sludge is removed, and the supernatant water is further treated by media filtration.

Care must be taken not to allow coagulants and flocculants or the hydroxide flocs to escape from media filters to reach the RO membranes. Furthermore, reaction of the residual coagulants and flocculants with a scale inhibitor added after the media filter can cause a precipitate to form, which is very hard to be cleaned. Several RO plants have been heavily fouled by a gel formed from cationic polyelectrolytes and scale inhibitors.

3-6-1. Media filtration

Media filters use a filtration bed consisting of one or more layers of media granules which are sand and anthracite. The grain size for fine sand filter is in the range of 0.35 to 0.5 mm or 8 X 12 mesh to 60 mesh and for anthracite filter 0.6 to 0.9 mm.

A multimedia filter is designed to make better use of the bed depth in the removal of a greater volume of suspended solids. This is achieved by loading larger (irregular shaped) media granules of lower density such as anthracite over smaller media granules of higher density such as sand. The larger granules at the top remove the larger suspended particles, leaving the smaller particles to be filtered by the finer media, thus to result 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 with a 50%

freeboard for the media expansion during backwashing. The multimedia filters are usually filled with 0.5m (20 inches) of sand covered with 0.3 m (12 inches) of anthracite.

The multimedia filters can be operated by either gravity or a pressure. A higher pressure drop can be applied for higher filter beds or smaller filter grains or higher filtration velocities. The design filtration flow rates are usually 10-20 m/h, and the backwash rates are in the range of 40-50 m/h.

For feed waters with a high fouling potential, flow rates of less than 10 m/h and/or second pass media filtration is preferred.

The available pressure is usually about 5 m of head for gravity filter and 2 bar (30 psig) to 4 bar (60 psig) for pressure filters. Periodically, the filter is backwashed and rinsed to remove the deposited matter, when the differential pressure increase between the inlet and outlet of the filter is 0.3 to 0.6 bar (4 to 9 psig) for the pressure filter and about 1.4 m for the gravity filter. Backwash time is normally about 10 min.

Frequent shut-downs and start-ups should be avoided, because a velocity shock will release previously deposited particulate matter.

3-6-2. Oxidation Filtration

Some well waters, usually brackish waters, contain divalent iron (Fe^{2+}), manganese (Mn^2+) and sometimes sulfide in the absence of oxygen. If such a water is exposed to air or is chlorinated, Fe^{2+}, Mn^{2+} and sulfide are oxydized to Fe^{3+}, Mn^{3+} and elemental sulfur, respectively, which form insoluble colloidal hydroxides and elemental sulfur as shown in the following equations :

$$4Fe(HCO_3)_2 + O_2 + 2H_2O \rightarrow 4Fe(OH)_3 + 8CO_2$$

$$4Mn(HCO_3)_2 + O_2 + 2H_2O \rightarrow 4Mn(OH)_3 + 8CO_2$$

$$2H_2S + O_2 \rightarrow 2S + 2H_2O$$

Iron fouling occurs more frequently than manganese fouling, since iron is present in the raw waters more abundantly than manganese and the oxidation of iron occurs at a much lower pH. Thus iron fouling is still possible even if the SDI is below 5 and the level of iron in the RO feed water is below 0.1mg/L.

An RO system can treat the well water containing iron (Fe^{2+}) in a closed system without an exposure to air or to any oxidizing agent, e.g. chlorine. A low pH is favorable to retard Fe^{2+} oxidation. At pH<6 and oxygen<0.5mg/L, the maximum permissible Fe^{2+} concentration is 4mg/L.

Oxidation and filtration can be done in one step by using a filter media greensand coated with MnO_2 to oxidize Fe^{2+}. Greensand is a green (when dry) mineral glauconite and can be regenerated with $KMnO_4$ when its oxidizing capability is exhausted. After the regeneration, the residual $KMnO_4$ has to be thoroughly rinsed out in order to avoid an oxidation damage of the membranes. This technique is used when Fe^{2+} is present in the raw water in less than 2 mg/mL.

An alternative to the greensand is a product called Birm(a registered trademark of Clack Corporation) which is a light silica coated with manganese dioxide. It catalyzes the oxidation of iron and manganese by dissolved oxygen. It does not lose the catalytic activity and thus does not need to be regenerated using $KMnO_4$. However, Birm requires a certain concentration of dissolved oxygen in the feed water at an alkaline pH. The alkaline condition may increase a possibility of $CaCO_3$ precipitation. Birm is less expensive than greensand.

3-6-3. Crossflow Microfiltration and Ultrafiltration

Crossflow microfiltration can effectively remove most suspended matter, depending on the pore size of the membranes. Normally microfiltration MF membranes with a pore size in the range of 1 to 10 μm are used, depending on the feed water quality. When the silica concentration in the concentrate stream exceeds the calculated solubility, MF membranes with 1 μm pore size are recommended to minimize the interaction with other colloids such as iron and aluminum colloids.

Now the fouling problem due to colloid deposit is transferred from the RO membrane to the MF membrane. In fact, the fouling of MF membranes is more severe and more often than RO membranes because of a high specific permeate flow. However, it is easier to clean a fouled MF membrane than an RO membrane, using periodic backflush cleanings which have been proven very effective for cleaning MF membranes, not for RO membranes. Chlorine can be added to the wash water in order to prevent biological fouling. Continuous microfiltration membranes (CMF) equipped with an automated backflush washing mechanism are available in the market (US Filter). It is usually economical to employ multimedia filters prior to MF membranes since the cheaper media filters will take a majority of suspended matter to reduce the costly cleaning frequency of MF membranes and thus to extend the membrane life time.

Cheaper disposable cartridge filters may be an alternative to the MF membranes and replaced before the pressure drop has increased to the permitted limit, but latest after 3 months. Replacing cartridge filters more often than every 1 to 3 months usually indicates a problem with the pretreatment. If it is desirable to remove soluble organic or inorganic polymers, then ultrafiltration (UF) membranes could be used.