Guide to Cleaning of RO System

I Brief Introduction of Fouling of Membrane Element

The membrane element can be possibly contaminated by the suspended substances, colloids, organic substances and microbes as well as salts deposited and separated out after concentration. The pretreatment of RO system can remove said contaminants to reduce the fouling on membrane and elongate the running time of system. However, since the pretreatment cannot completely remove said contaminants from the water, the membrane element always suffers fouling after a period of running, thus causing the decrease of system performance. The decrease of performance of RO system is featured by the decrease of permeate flow, the decrease of rejection rate (conductivity rising) and the increase of pressure difference between feedwater and concentrate.

II Judgement of Cleaning Time for RO System

Since the performance of RO system varies with the change of such factors as temperature, pressure, pH value, feedwater TDS, etc., (for example, the permeate flow is reduced by 10% for every temperature drop of 3℃, while the considerable variation of pH value has an influence on the conductivity of product water). Therefore, it was sometimes not the fouling of RO membrane that causes the change of performance of RO system. In order to exactly determine the proper time for cleaning of system, the operating data shall be put into standardized calculation by using the normalization software provided by the RO membrane manufacturer. In case of any of the following occurrences upon normalization of operating data, the RO system shall be put into chemical cleaning immediately:

- System permeate flow decreases by more than 15% comparing with the initial value after normalization of operating data.

- Salt passage increases by more than 10% comparing with the initial value after normalization of operating data.

- Pressure difference between feedwater and concentrate increases by more than 15% comparing with the initial value after normalization of operating data.

Chemical cleaning must be done immediately after the condition of chemical cleaning is met. In general case, the initial performance can be basically restored after chemical cleaning. In case the chemical cleaning is not performed in time, however, the RO system will suffer serious fouling, thus causing the chemical cleaning have little effect, and it's difficult to restore the performance of system.

III Steps of Cleaning of RO System

First Step: Low-pressure Flushing

It's better to use RO-filtered water to flush the system, or pretreated water can be used (in case the raw water contains special chemical substances that can possibly react with cleaning solution, such water cannot be used).

Step 2: Preparation of Cleaning Solution

Use the RO-filtered water for preparing the cleaning solution, accurately weigh the medicaments and mix them uniformly. Check the cleaning solution to make sure the pH value and temperature (not lower than 25℃), etc. meet the relevant requirements.

Step 3: Feed in the cleaning solution with low pressure and low flow rate, and then make it circulate in the system.

Feed the cleaning solution into the RO system with 1/3 of regular cleaning flow rate (see Table 1) under the pressure of 20~40psi, discard the backwater at the beginning to avoid the dilution of cleaning solution. Keep the cleaning solution circulating in the pipe for 5~10 minutes. Observe the turbidity and pH value of the backflow solution. If the cleaning solution become obviously turbid or the pH value varies by more than 0.5, it is advisable to add proper dosage of medicaments or to prepare a new solution and then to repeat the steps mentioned above.

Table 1: Recommended Cleaning Flow Rate for RO Membrane Elements

Washing Flow Rate	
Dia. of Membrane Element (in)	Flow Rate of Individual gpm(m^3/h)
2.5	5（1.2）
4	10（2.3）
8	40（9.1）

Step 4: Soaking and Intermittent Circulation

Stop the circulation of cleaning pump to prevent the cleaning solution from flowing out of the pressure vessel. It is advisable to close the cleaning solution feeding pump, the permeated cleaning solution return valve and the rejected cleaning solution return valve. The complete membrane module shall be soaked in the cleaning solution for about 1 hour or longer (10~15 hours or overnight), depending on the fouling situation of membrane module, during which period the circulating pump can be intermittently started to maintain constant temperature of cleaning solution (25～30℃).

Step 5:Large Flowrate Circulation

Increase the flow rate of cleaning solution to 1.5 times regular flow rate and then start cleaning. Circulate the cleaning for 30~60 minutes. The pressure shall not be too high at this moment, as limited to the extent that there is no or little filtered water produced. Be careful that the pressure difference among membrane elements and that among pressure vessels cannot exceed the limits.

Step 6: Flushing

Firstly use the product water to flush the system for around 5 minutes (with minimum temperature at 20℃), then use the suitably pretreated water to flush the system for 20~30 minutes. In order to avoid precipitation, the temperature for flushing shall be 20℃ at least, and the cleaning solution shall be completely flushed out, without any residual remained. Start the system and run it. Inspect the cleaning effect and discard the product water. If the system is scheduled for shutdown, the membrane modules shall be preserved properly in accordance with relevant procedures.

IV Fouling Symptoms of RO System and Cleaning Method

The routine running records of RO system are the major basis for determining whether fouling will occur with the system and what reasonable cleaning method shall be taken after fouling. Special importance must be attached to the recording of data in the management of RO system.

1. Fouling by Inorganic Salt Scaling and Its Cleaning

Symptom of Fouling by Inorganic Salt Scaling

At the beginning, the conductivity of product water from the second stage of RO system becomes abnormal (the conductivity rises), the permeate flow decreases obviously, the pressure becomes higher gradually, and the pressure difference in the second stage also increases gradually. The most obvious symptom is that the permeate flow decreases obviously.

The fouling of RO system most frequently seen involves in scaling by calcium carbonate and calcium sulphate. The situation that the permeate flow of RO system decreases by a large margin within several hours or several days relates mostly to said fouling.

Scaling by inorganic salt is generally caused by such reasons as excessively high recovery rate, insufficient dosing of antiscalant and untimely regeneration of ionic exchange softening resin, etc.

Cleaning of Carbonate Scaling

The carbonate scaling can be cleaned out by using the following formula:

Major Contaminants	Cleaning Solution Recommended	Remarks
Precipitation of Carbonate	0.2% hydrochloric acid / (HCl)	Preferential choice. Maximum temperature at 45℃, and pH = 2
	2.0% Citric Acid ($C_6H_8O_7$)	Acceptable choice. Maximum temperature at 45℃, and pH > 2

Cleaning shall be implemented as per the aforesaid steps.

Cleaning of Sulphate Scaling

Of the inorganic salt scaling, the sulphate scaling is the one that is comparatively difficult to clean out. The sulphate scaling shall be cleaned as early as possible, otherwise the performance of RO system will be unlikely restored after cleaning in case the scaling has been formed for more than one week. Therefore, high level pretreatment is required for the water source featured by high sulphate content. Special attention shall be paid to monitoring the system, and the system shall be cleaned properly soon after there is any sulphate scaling.

The sulphate scaling can be cleaned out by using the following formula:

Major Contaminants	Cleaning Solution Recommended	Remarks
Sulphate Scaling	0.1% Sodium Hydroxide; 1.0% EDTA tetrasodium	NaOH EDTA tetrasodium，pH=12， Maximum temperature at 30℃

Cleaning shall be implemented as per the aforesaid steps.

2. Symptom of Colloidal Fouling and Its Cleaning

The colloids in RO feedwater may include sludge, inorganic colloid, colloidal silica and a number of organic substances, etc., which can be removed generally by using flocculation filtration, activated carbon adsorption, etc.

Symptom of Inorganic Colloidal Fouling:

In a RO system, the symptom of inorganic colloidal fouling first appears in the first stage, where the permeate flow decreases gradually, the pressure difference becomes higher gradually, and the conductivity of

product water rises slightly. The most frequently seen symptoms of colloidal fouling are the gradual variation of permeate flow and pressure difference.

The inorganic colloidal fouling can be cleaned out by using the following formula:

Major Contaminants	Cleaning Solution Recommended	Remarks
Inorganic Colloid	0.1% sodium hydroxide ＋ 0.025% (SDBS)	NaOH ＋ Na-DDBS，pH=12, With maximum temperature at 30℃
	2.0%Citric Acid($C_6H_8O_7$)	Acceptable choice.Maximum temperature at 45℃， and pH＞2s

Cleaning shall be implemented as per the aforesaid steps.

3. Symptom of Fouling by Organic Substances and Their Cleaning

The RO system with surface water, wastewater or seawater, etc. as water source is possibly subject to the risk of fouling by organic substances, and the compositions of said organic substances mainly include humus, organic acid, etc.

The most frequently seen symptoms of fouling by organic substances are the drastic drop of permeate flow while the rejection rate remains substantially unchanged. In case of fouling by organic substances, the following formula can be used for cleaning:

Major Contaminants	Cleaning Solution Recommended	Remarks
Organic Substance	0.1% sodium hydroxide ＋ 0.025% (SDBS) 0.2% hydrochloric acid	First use NaOH and Na-DDBS solution for cleaning, with pH = 12 and maximum temperature at 30℃, then clean it by using HCl solution, with pH = 2 and maximum temperature at 45℃.
	2.0% sodium tripolyphosphate(STPP) +0.025% sodium dodecyl benzene sulfonate (SDBS)	Acceptable choice.Use $Na_5P_3O_{10}$ and Na-DDBS solution for cleaning,with pH=10 and maximumtemperatureat30℃

Cleaning shall be implemented as per the aforesaid steps.

4. Symptoms of Fouling by Microbes and its Cleaning

Microbe fouling usually comes into being during the downtime of RO system or in the RO system with surface water, recycled water (Grade-III wastewater) or seawater as the feedwater source, and is concurrent with fouling by organic substances. The biological fouling shall be cleaned out immediately at the beginning, otherwise it will become the biological film which is very difficult to clean and the membrane element has to be replaced.

It is recommended that the HOR (high oxidation resistant) membrane elements be selected for those RO systems apt to microbial fouling, where such germicides as NaCLO can be dosed online into the feedwater of membrane elements to build a germ-free system thus preventing the occurrence of microbial fouling.

Symptoms of Microbial Fouling

The fouling occurs in all stages of the system, and pressure difference in the first stage and the second stage increases rapidly while the permeate flow decreases and the conductivity of product water remains unchanged substantially. The most common symptom is the increase of pressure difference.

The microbial fouling can be cleaned out by using the following formula:

Major Contaminant	Recommended Cleaning Solution	Remarks
Microbe	0.1%（NaOH）＋0.025％sodium dodecyl benzene sulfonate（SDBS）	Preferred. Use NaOH and Na-DDBS solution for cleaning, with pH = 12 and maximum temperature at 30℃.
	0.1%（NaOH）	Preferred. Use NaOH solution for cleaning, with pH = 12 and maximum temperature at 30℃.
	2.0% sodium tripolyphosphate(STPP) +0.025% sodium dodecyl benzene sulfonate (SDBS)	Acceptable. Use $Na_5P_3O_{10}$ and Na-DDBS solution for cleaning, with pH = 10 and maximum temperature at 30℃.

Cleaning shall be implemented in accordance with the aforesaid steps.

For the RO system with microbial fouling, the chemical cleaning shall be followed by disinfection of the system, and the pretreatment shall be improved in order to prevent the reoccurrence of microbial fouling.

5. Fouling of Metallic Compound

Fouling of metallic fouling involves mainly in metallic oxide or metallic hydroxide, etc, especially the ferrous fouling. The factors causing such fouling include mainly the defect of pretreatment and the rust of pipings, with the symptoms of decrease in both permeate flow and rejection rate and increase of pressure difference among membrane elements. The following formula can be used for cleaning:

Major Contaminants	Cleaning Solution Recommended	Remarks
Metallic Oxide	1.0% sodium pyrosulfite	$Na_2S_2O_5$，pH＝5， with maximum temperature at 30℃
	2.0% citric acid	$C_6H_8O_7$，pH>2， with maximum temperature at 45℃

Cleaning shall be implemented according to the aforesaid steps.

6. Calculation of Volume of Cleaning Solution

The total volume of cleaning solution includes the volume of pressure vessel, cleaning pipe, high-pressure pipe and filter plus 20% overmeasure. The calculation of cleaning solution volume includes two manners, i.e.

rough estimation and precise calculation.

Rough estimation of cleaning solution volume: Depending on the model of membrane elements and the degree of fouling.

For common fouling, each 4040-sized membrane element shall be furnished with 10 litres of cleaning solution, and each 8-inch membrane element shall be furnished with 40 liters of cleaning solution.

In case of serious fouling, each 4040-sized membrane element shall be furnished with 18 liters of cleaning solution, and each 8-inch element shall be furnished with 55 liters of cleaning solution.

Examples of precise calculation: Refer to Table 2 and Table 3 for rough estimate of volume of pressure vessel and cleaning pipe.

Table 2: Volume Fraction of Regular Pipe

Pipe Diameter (in)	Volume Fraction
2	0.16 Gallon / Foot 2.0 Liter / Meter
3	0.37Gallon / Foot 4.6 Liter / Meter
4	0.65 Gallon / Foot 8.1 Liter / Meter

Table 3: Volumetric Capacity of Pressure Vessel

Volumetric Capacity of Pressure Vessel	
Membrane Element Sizes	Volumetric Capacity of Each Element, in Gallon (Liter)
2540	0.8（3）
4040	2（8）
8040	8（32）

Taking 36 pieces of 8040-sized elements as example, following is the calculation:

The RO system is in a 4:2 array, with each pressure vessel containing 6 pieces of 8080 elements, and shall be cleaned stage by stage.

The cleaning pipe with 3 inches nominal diameter and 15 meters length amounts to a volumetric capacity of 69 liters (15x4.6), the safety filter can hold 60 liters of water, and the volumetric capacity of pressure vessel in the first stage is 768 liters (4x6x32=768), and thus the total volume of cleaning solution is 897 liters (69+60+768=897), i.e. 1076 liters (897+897x20%=1076) of cleaning solution shall be prepared for cleaning the first stage. Similarly, 615 liters of cleaning solution shall be prepared for cleaning the second stage.

Table 4: Total Volume of Cleaning Solution Required

Estimate of Total Volume of Cleaning Solution		
	Volume (Liter)	
	1st Stage	2nd Stage
Pressure Vessel	4×6×32=768	2×6×32=384
Cleaning Pipe	15×4.6=69	15×4.6=69
Safety Filter	60	60
20% Overmeasure	180	102
Total Volume	1076	615

Notes:

1. When in chemical cleaning, be sure to prevent the chemical medicaments from injuring the operating personnel. Especially certain chemical medicaments with strong corrosivity are used (fluorochemical possibly used for cleaning the silica fouling, for example), it is strongly recommended that the cleaning shall be implemented under the guidance of professionals.

2. The exampled calculation of cleaning solution volume is only for reference.