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EFFICIENT MANAGEMENT OF REVERSE OSMOSIS SYSTEM IN WATER TREATMENT PLANT

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ABSTRACT

Reverse osmosis system has emerged as most efficient treatment system worldwide for treating water of high conductivity. Reverse osmosis is a multipurpose system, which is used to remove dissolved solids, heavy metals and bacteria and viruses. Due to the lack of implementation of a number of factors, performance of reverse osmosis system is severely affected leading to frequent breakdown, unsatisfactory treatment of feedwater and wastage of resources. This paper undertakes a study to find out the best possible steps for efficient reverse osmosis management in water treatment process. It was found that the life of membranes in reverse osmosis can be extended and satisfactory treatment of feedwater can be done leading to cost-effectiveness in operation .

Key words: Permeates, Membranes, Ultrafiltration, Sanitation

INTRODUCTION

Reverse osmosis (RO) is a high pressure driven system, which consists reverse osmosis membrane capable for removing even dissolved impurities[1-3]. The number of membranes installed depends upon conductivity of the feed water to be treated, the volume of water desired and the permeate water quality supposed to be meeting specifications of regulating authorities like Bureau of Indian Standards, Central Pollution Control Boards, State Pollution Control Boards etc. Inappropriate handling of reverse osmosis membranes results in reduced performance, severe flux decline, high energy consumption and frequent membrane cleaning or replacement[4].

EXPERIMENTAL

The study is based upon performance of various reverse osmosis systems working under different feedwater characteristics.

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Design and installation of RO

The first task is to select right type of membranes and modules before installation[10, 11], Membrane materials and properties are important factors that affect RO performance. Properties include hydrophobicity, surface charge, pore size and roughness. Membranes are manufactured in a wide variety of materials, which include sintered metals, ceramics and polymers. The manufacturing processes result in a number of different membranes like asymmetric and composite[12]**.** Membranes are assembled as modules that are easily integrated into systems containing hydraulic components. Membrane should be selected based on the specific application objective. The end- use also defines membranes for industries such as potable water, effluent treatment, desalination, water supply or pharmaceutical manufacturing.

RO uses a semipermeable membrane such as polyamide to effect physical removal of dissolved solids from water flowing through the membrane under pressure. The membranes are housed in a module, which could have several configuration like spiral wound (SW), hollow fine fibre, etc. However, these conventional module requires stringent pretreatment and are easily prone to scaling/fouling. These are the major limitations in the application of this technology for wastewater treatment and have now been overcome through the development of the Disc and Tube (DT) membrane module technology. The DT module eliminates the concentration polarization, consequently minimizing scaling and fouling. DT module configuration have distinct constructional advantage over the other membrane configuration such as open channel feed flow path and short flow path. On operational aspects, DT module plants are far superior to operate due to absence of extensive pretreatment of raw water.

Accessory maintenance and operator training

A periodical check should be undertaken for observing and rectifying various mechanical problems that are associated with RO system. Special attention should be given to O-rings, which might be in a position to become loose or in a position to be replaced. O-rings are an important accessory in RO, which binds membranes tightly. A minor leakage of O-rings may result in increase in permeate conductivity irrespective of the efficient functioning of RO membranes. O-rings should be checked periodically for couplers, adopters and end-plugs for correct installation and aging conditions[13]. Old O-rings may be replaced as it may leak after exposure to certain chemicals, or to mechanical stress.

Once the system is in place and running smooth, it is very important that the RO plant be operated and maintained with utmost care. For this, the plant operators should be trained not only in plant operation but also in the basics of membrane technologies. Since RO is a pressure driven technology, in-depth knowledge of maintaining appropriate pressure at different locations of membrane arrays is useful in detecting problems in RO. An increase in pressure indicates the condition of pore blockage and a sudden decrease in membrane pressure indicates membrane is torn. An in-depth knowledge of pressure change in RO can provide certain indications regarding various precipitations in membranes. The nature and rapidity of fouling depends on the condition of the feed water. Fouling is progressive, and, if not controlled early will impair the RO membrane element performance in a relatively short time. Probing is an important device in RO technology, which should be known to RO operators to locate membrane leakage in array consisting multiple membranes. They should also be well trained in troubleshooting of high pressure pumps as sometimes due to misalignment of the pump shaft; the impellers get deteriorate and throw-off small plastic shavings[14]. The shavings can enter and physically plug the lead –end RO elements.

The operators should also be trained for those type of problems, which is although not very common but still found in RO operation like hydraulic shock to the membrane element at initial start-up / restart –up. This is due to the fact that in starting-up a partially empty RO system, the pump may behave as if it had little or no back pressure. It will suck water at great velocity; thus, hammering the elements. To avoid hydraulic shock to the membranes, the operator should ensure that the pressure vessels are not under vaccum when the plant is shut down.

Quality control monitoring

Complete chemical and microbiological analysis of feed water and permeate water should be undertaken initially and the same should be followed up monthly. On daily basis, the following practices should be adopted:

Conductivity monitoring

In wastewater treatment, RO is designed for treatment based on feed water quality. If feed water quality remains the same and there is a sudden increase in conductivity, membrane of RO should be checked for possible leakage. Moderate increase in conductivity of permeate is acceptable but if it goes above 10 %, there might be leakage in membranes. Conductivity of the permeate can be controlled to some extent by adjusting recirculation flow.

pH monitoring

The pH of the permeate water goes down after RO treatment. It was observed that if feed water pH is 7.4, the resultant pH coming out from RO will be approximately 5.5 - 5.7. For packaged drinking water, the BIS specification for packaged drinking water is 6.5 to 8.5. Hence, if the feed water pH is lower than 7.4, the resultant pH will be much lower and it will require pH boosting to meet the specification. A continuous pH monitoring helps in better RO management.

Stagewise pH and TDS monitoring

If RO system consists multiple membranes in different arrays; then instead of depending upon pH and conductivity of the permeate only, pH and conductivity of the permeate of each arrays of RO membranes should be checked. We found that the conductivity of the permeate of 1^{st} array is always lowest but as the number of arrays increases, the conductivity also increases progressively. This is due to the fact that recirculated water is passed through other arrays, the conductivity of which is always higher than the feedwater. In some cases, online pH and conductivity meter is installed but these are installed generally only at inlet and outlet. checking pH in each arrays help in quick finding of problems. The conductivity of RO reject should also be monitored daily in order to know the variations in effluent quality.

System pressure monitoring

Reverse osmosis units are designed to withstand specific pressure. Recommended pressure should be maintained for feed, recirculation and permeate flow. An in-depth knowledge of pressure change in RO can provide certain indications regarding various precipitations in membranes. The increase or decrease in RO pressure may be of several types: marked increase/gradual increase /sudden increase, each depending upon types of depositions, which can be of calcium bicarbonate, calcium sulphate, metal hydroxides, SDI and bacteria /viruses. A pressure more than recommended can damage membranes and may also result in accident.

Hardness monitoring

Any type of hardness is undesirable for RO membranes as it may irreversibly damage the membranes, if not controlled in time. Hardness is primarily due to calcium and magnesium salts. Feed water to RO should have less than 5 ppm hardness as $CaCO_3$. If softener is not installed for hardness removal in feed water, then antiscalant may be used.

However, using antiscalant is not a preferred option over softener installation. If a softener is provided upstream, then it should not be over exhausted otherwise unacceptably high amount of hardness could form scale on membranes and ultimately pore blockage may occur.

Pretreatment of feed water to RO unit

While reverse osmosis effectively removes inorganic constituents from feed water, contaminants like colloidal silica and TOC may not removed and may slipped through the ion excange beds [15]. The UF based membrane process has proved the best technology for effective and consistent removal of colloidal particles and silica required values.

The objective of pretreatment of feed water to RO system is to eliminate scaling of membrane and minimize fouling of membranes by colloidal impurities and bacteria. Adequate pretreatment of water is essential in order to ensure trouble free performance from the reverse osmosis unit. Conventional pretreatment normally involves chlorination for disinfection, filtration through granular media like sand and anthracite for removal of suspended solids and turbidity and filtration through activated carbon for removal of free residual chlorine (FRC). Alternatively, sodium bisulphate can be added for the removal of FRC. Softening of feed water is done to prevent scaling of membranes. Alternatively, antiscalant can be added. Another way of eliminating scale is to add acid to convert carbonate hardness into noncarbonate hardness. Filtration through micron cartridge filter is ensured for removal of colloidal impurities. Followings are feed water limitations for RO:

TDS/Conductivity: Not to exceed the specified value as per RO design

pH: 7.0 – 9.0

Free chlorine: Nil

Iron and heavy metals: < 0.1 ppm

Turbidity: < 1NTU

Organics: Absent

Total hardness: < 5 ppm as $CaCO_3$

SDI: < 4

Microfiltration or ultrafiltration as a pretreatment step in place of the conventional methods is more beneficial.The use of microfiltration or ultrafiltration has following advantages inspite of marginally higher capital cost:

- Elimination of colloidal fouling
- Elimination of biofouling
- Reduction in organic matter (TOC)
- High flux rate of RO membrane
- Infrequent chemical cleaning
- Enhanced membrane life

Effective sanitation

Though every care is taken during RO plant operation, RO membranes might be scaled or fouled due to change in raw water chemistry / improper plant operation, poor quality of dosing chemicals (or impurities in it). RO system should be sanitized periodically. The time taken for successive sanitation depends upon many factors and hence, stipulated time to take sanitation can not be specified. The sanitation should be undertaken considering following factors:

- Running hour of RO system at a stretch
- Quality of the permeate water
- Bacteriological quality of the permeate
- Feed water quality

Foulant removal is required, when any of the following conditions occur:

(i) Permeate flow is dropped to 10-15 percent below rated flow at normal pressure.

(ii) Product water quality is decreased 10-15 percent, salt passage has increased 10-15 percent.

(iii) Applied pressure is increased about 10-15 percent.

(iv) The differential pressure across RO stage is increased noticeably.

Sanitation schedule should be made by quality control professionals. Utmost care should be undertaken while selecting chemicals to sanitize RO membranes since a wrong chemical may irreversibly destroy the membranes resulting in huge loss for the company or it may result in ineffective sanitation.. If the membranes are made of polyamide/cellulose acetate, hypochlorite solution should not be used for RO sanitation. Since hypochlorite solution is used widely for disinfection in many water treatment units like UF and various water storage tanks, chances are that hypochlorite solution may enter in RO membranes. If hypochlorite solution is suspected in RO or it is detected in RO, it should be neutralized with sodium busulfite. Only recommended chemicals should be selected. Among other available chemicals, citric acid and hydrogen peroxide are most widely used chemicals for RO sanitation. Great care should be excercised, if membranes are opened to see the physical condition of membranes as they might be contaminated microbiologically. Sanitation may take long time depending upon RO situation. An effective sanitation schedule should provide enough contact time. Effective sanitation depends on many factors such as, the concentration of the chemicals selected, contact time in static / recirculation and chemical/microbiological quality of the feed water.

Indepth knowledge of foulants

In RO membranes, the rate and extent of fouling is exacerbated by conditions of low pH, high ionic strength and particle concentration. When no pore blockage occurs, fouling is reversible and is attributed solely to the deposition of particles at the membrane . Pore clogging may occur because of cell debris and colloidal[16] particles found in mixed liquor, the size of which are similar to the membrane pore. During permeation, these fine particles can become entrapped in the pores and thus, reduce the surface area for filtration. Pore clogging decreases the flow area of the permeate resulting in a greater TMP to achieve the same flux. Backwashing and chemical cleaning are primarily the ways to reduce membrane pore clogging[17].

In RO membranes, natural organic matter (NOM) is considered to be a major foulant of membranes. Increasing electrolyte concentration, decreasing solution pH and addition a divalent cation Ca^{2+} results in increased fouling of humic acids.The effect of divalent cations has been attributed to a reduction in the electrostatic repulsion between humic acids, which are rich in carboxyl functional groups. Removal of free calcium and NOM-complexed calcium ions by ethelyenediamenetetraacetic acid (EDTA) reduces NOM fouling. Recent studies on NOM fouling during ultrafiltration indicate that an initial fouling layer of larger aggregates (> 300 kDa) can enhance fouling by lower molecular weight spices (10-100 kDa), resulting in irreversible fouling and pore blockage.

Biofouling is specially related to the interaction of biosolids with the membrane. This could consist of formation of biofilms or the accumulation of bioorganic material including Extracellular Polymeric Substances (EPS), on the membrane surface. Extracellular polymeric substances are a complex mixture of proteins, carbohydrates, acids, polysaccharides, DNA, lipids and humic substances that surround cells and form the matrix of microbial flocs and films. Because of the nature of wastewater and the contents of mixed liquor suspended solids (MLSS), composite fouling (i.e. a combination of biofouling and inorganic fouling) often occurs in RO membranes.

CONCLUSION

It is expected that implementation of the aforementioned steps in reverse osmosis plant will result in reduction of breakdown leading to cost-effectiveness, better treatment of feed water, resource conservation as well as extended life of membranes. However, more research needs to be undertaken in characterization of foulants using gas chromatography, mass spectrometry, FTIR (Fourier Transform Infrared Spectroscopy) and advanced microscopy like ESEM (Environmental Scanning Electron Microscopy) and TEM (Transmission Electron Microscopy).

REFERENCES

1. A. Popat, Everything about Water, (2005) p. 22.
2. N. Manimegalai, Beverage and Food World, (2005), p. 53.
3. T. H. Bae, S. S. Han and T. M. Tak, Process Biochemistry, (2003) p. 39.
4. Eisenberg, N. Talbert and E. Joe Middlebrooks, American Water Works Association Journal, **76**, 44 (1992).
5. Standard Method for Examination of Water and Wastewater - APHA, (1984)
6. M. H. Ansari and R. Shukla, Indian J. Environ. Prot., **21**, 110 (2001).
7. J. N. Cloutier, A. Leuduy and R. S. Ramalho, Canad. J. Chem. Engg., **63**, 250 (1990).
8. P. K. Pandey and Ramchandra, Indian J. Environ. Prot., **21**, 134 (2000).
9. M. Vasanthy and P. Lakshamanaperumalswamy, Poll. Res., **17**, 173 (1998).
10. Evangelista Franco, Ind. Eng. Chem. Res., **26**, 1109 (1987).
11. A. T. A. M. DeWaele, H. W. G. Hooijkas, P. P. Steijaert, A. A. J. Benschop and J. E. Nemeth, Desalination, **118**, 63 (1998).

12. S. Anandkumar, P. Amudhan, T. Arumuganthan, D. Balasubramaniam and S. Balasubramaniam, Beverage and Food World, (2005) p. 48.
13. Jacy Choi, Environ. Sci. Engg., **3**, 49 (2004).
14. Jacy Choi, Environ. Sci. Engg., **3**, 79 (2005).
15. D'Costa and Lois, Everything about Water, (2005) p. 42.
16. J. A. Brant and A. E. Childress, J. Membrane Sci., **241**, 235 (2004).
17. B. Q. Liao, D. M. Bagley, H. E. Kraemer, G. G. Leppard and S. Liss, Water Environ. Res., **76**, 7 (2004).

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