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European Journal of Advances in Engineering and Technology, 2017, 4(9): 707-710

Research Article ISSN: 2394 - 658X

# Evaluation of Biological Fouling of RO/MF Membrane and Methods to Prevent It

**Maliheh Torki[1], Nima Nazari[1] and Toraj Mohammadi[2]**

*[1]Department of Chemical Engineering, Islamic Azad University- Farahan Branch, Markazi, Iran*
*[2]Department of Chemical Engineering, Iran University of Science & Technology, Tehran, Iran*
*N.Nazari66@yahoo.com*

**ABSTRACT**

*All of the raw water in the world has micro-organisms such as bacteria, algae, funguses, and so on. These micro-organisms can be considered as colloidal materials and separated and removed by pre-treatment. Of course, the removal of all micro-organisms by the pre-treatment operation is very difficult, and some of them may escape from the pre-treatment process to reproduce and formed biofilm films. Microfiltration membranes (MF) and Reverse Osmosis Membranes (RO) can prevent many micro-organisms. However, some micro-organisms escape through the pores of the membrane and reach the reverse osmosis membrane, which can cause biological fouling in the membrane. The signs of reverse osmosis membrane fouling include the increase in differential pressure and the melt flux It should be noted that the potential of biological fouling in surface waters is much higher than that of wells water; the concentration of bacteria in water is also directly related to the potential for biological fouling. In this study, the causes of fouling of MF and RO membranes have been investigated and ways of preventing it have been presented*

**Keywords:** Membranes, Biofouling, Reverse Osmosis Membrane, Micro Filtration Membrane, Micro-Organisms, Prevent

## INTRODUCTION

Biological closure is the most complicated type of membrane fouling. Due to the formation of a sticky layer on the surface of the membrane and the growth and proliferation of various microbial species such as funguses, bacteria and yeast cells [1]. In other words, the production of a live layer and the unacceptable pressure drop in the membrane are called biological fouling, which itself exacerbates other fouling. The biological name assigned to this type of fouling is due to the presence of these living species in it. Biological fouling is dependent on the composition of the membrane material. Cellulose acetate membranes are the suitable nitrate-rich area for bacterial growth. For this reason, these membranes are completely degraded in the presence of low amount of bacteria. Polyamide membranes are also susceptible to biofouling and are quickly attacked by bacteria, while compound membranes are relatively resistant to bacteria. By applying methods such as disinfection of the intake or periodic washing of the membranes. Fouling is prevented [1-2].

### The Stages of the Occurrence of Biofouling

The stages of creating the biofouling phenomenon are: [1-3]

- Formation of thin film on the surface of the body, whose process is not completely clear and occurs quickly within a few minutes. This polysaccharide layer has a suitable substrate for absorbing microbial materials.
- At this stage, microbial materials are separated from the liquid phase and stick on the layer's surface.
- At this stage, the production and growth of microbial colonies occurs on surface of the membrane. In other words, biopolymer production begins at this stage, and the nutrients present in the lithium phase are also absorbed into the layer and the environment suitable for the growth and propagation of microbial species.
- At this stage, the secondary bonding process occurs. This process creates new microbial layers over several days to several weeks.
- The fifth stage involves dying and decomposing the underlying cellular material, which occurs due to the reduced access of cells to oxygen and nutrients.

**The Conditions for the Occurrence of Biological Fouling**

The main causes of the occurrence of biological fouling in the membranes are: [2-3]

- Presence of microbial substances, especially those with a higher growth factor in the membrane environment.
- Presence of nutrients such as: carbon, oxygen, nitrogen, phosphorus and other micro-nutrients necessary for the growth of microbial species.
- Suitable environmental conditions such as temperature, light, PH.

**Methods of identifying types of fouling in the membranes**

There are many methods for identifying types of fouling on the membrane surface. The below table, lists some of the methods with its advantages and disadvantages [4].

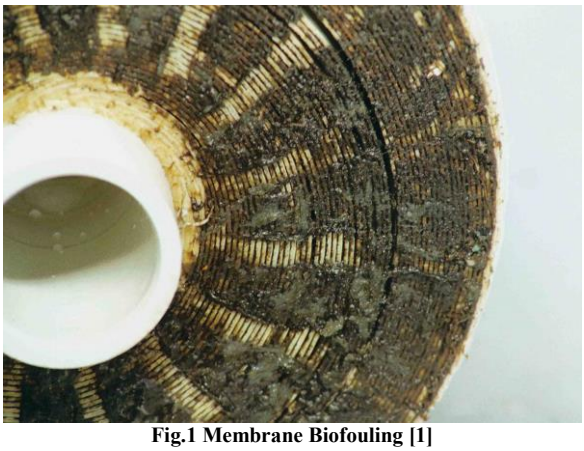

**Fig.1 Membrane Biofouling [1]**

**Table -1 Methods of Identifying Types of Fouling [4]**

| Technique | Information | Advantages | Disadvantages |
|---|---|---|---|
| Optical Microscopy | Morphology | Cost , Time | Limited Information |
| Scanning Electron Micros-copy | Morphology | Time , Sample size | Cost. Sample must be dry |
| X-ray Fluorescence | Elemental | Lower Detectable Limit | Sample size , Time |
| Atomic Absorption | Elemental | Lower Detectable Limit , Sample size | Sample preparation , Time |
| Infrared Microscopy | Composition | Lower Detectable Limit , Time , Cost | Interpretation |
| Transmission | Composition | Lower Detectable Limit , Sample size , Time | Sample should be Homogeneous |
| Reflection | Composition | Time , Sample preparation | Surface should be flat, smooth and ho-mogeneous |
| Energy-dipresives X-ray | Elemental | Time, Sample size | Lower Detectable Limit , Sample must be dry |
| Auger | Elemental , Composition | Surface sensitivity , Lower Detectable Limit | Cost , Interpretation |

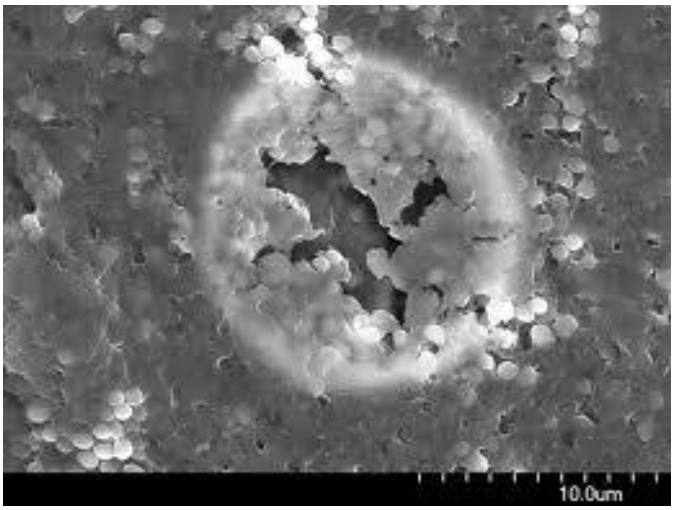


**Fig.2 Bacteria [4]**

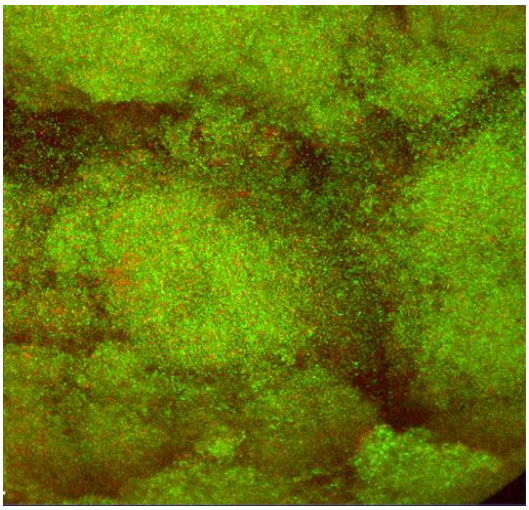

**Fig.3 Funguses [4]**

## FACTORS OF CREATING THE BIOLOGICAL FOULING IN RO/MF MEMBRANES

The source of biological fouling in RO/MF membranes is living species such as: bacteria, funguses and algae. Now the factors causing of biological fouling are examined separately: [4]

**Bacteria**
Bacteria are single-cell micro-organisms that are not well-suited to both of plant species and animal species. They have a cell wall, without seed. They have a region called nucleotide that contains a single-branched Deoxyribonucleic acid (DNA). This is part of the genetic material of the bacterium that determines its characteristics [4]. The bacteria in the water usually have length of about 1 micron. Some of them may be so small, that they pass through pores. They are either bar-shaped or spiral-shaped. Bacteria often produce a layer of glycoprotein around the cell wall, which has the sugar-based and is called polysaccharide. This material, which has the sticky nature, interconnects the bacteria and also adheres them to the surfaces, which causes the formation of fouling in the membrane [4].

**Funguses**
Under appropriate conditions, funguses are rapidly propagating in a system and lead to folding. They are propagated by the use of spores containing proteolysis surrounded by walls. These hogs can be multiplied in millions. Fungal spores can be expanded by air. If they enter the humid environment combined with atmospheric oxygen and an organic power supply, they grow and reproduce rapidly. Yeasts are sample of single-cell funguses and mushrooms are examples of multicellular funguses [4]. Parasitic funguses and mildew are examples of fungi. Mildew is usually white and parasitic fungus can be any colour. They have the similar network growth in mushroom-friendly environments. Fungal common problems for membrane systems are that use high-concentration organic water sources (like those that use juice processing). If such a system allows stopping and evacuation, fungal spores will be pulled out with the oxygen they need to grow. Funguses can be replicated rapidly and they will have a folding system within just a few hours [4].

**Algae**
Algae contains variety of simple structure plants. They may be microorganisms They can use sunlight like plants to convert carbon dioxide and water to sugars in the process of photosynthesis [4]. Because light is required for photosynthesis, algae do not grow in membrane packed systems. Although they can grow in transparent tubes and waterways, or even upstream levels (if outdoors). Algae generally adhere to the surface. The factor causing organic matter in algae called algal blossom. In some water sources there is a kind of single-cell algae called diatoms, which, if introduced through the pre-treatment system into the membrane system, will be problematic. These algae have cell walls including silica. Solving and removing this silica from the reverse osmosis system is very difficult. Fortunately, because of the large size of the diatoms (about 5 microns), they can be removed by special filters before entering the reverse osmosis system [4].

## EVALUATION OF METHODS TO PREVENT BIOLOGICAL FOULING OF RO/MF MEMBRANES

All of the raw water in the world have micro-organisms such as bacteria, algae, funguses, and so on. These micro-organisms can be considered as colloidal materials and separated and removed by pre-treatment. Of course, the removal of all micro-organisms by the pre-treatment operation is very difficult, and some of them may escape from the pre-treatment process to reproduce and form biofilm films [5]. Microfiltration membranes (MF) can prevent many micro-organisms. However, some micro-organisms escape through pores of the membrane and reach the reverse osmosis membrane, which can cause biological fouling in the membrane. The symptoms of reverse osmosis membrane fouling include the increase in differential pressure and the melt flux [6]. It should be noted that the potential of biological fouling in surface waters is much higher than that of wells; the concentration of bacteria in water is also directly related to the potential for biological obstruction [5].

In the following, methods for preventing and controlling the phenomenon of biological fouling in reverse osmosis/micro filtration membrane systems are presented.

**Total Bacteria Count (TBC) Method**
TBC is a method for calculating the total number of live microorganisms in a water sample based on ASTM-F60 by filtering the measured amount of water through a membrane filter. The cultures maintained at the surface of filter are then cultivated for a few days in a suitable culture medium rich in nutrients to develop colonies. After this period, the observation materials and their number are counted [5]. This method is very interesting and can be used to monitor microbial activity at the dewatering input, the post-purification step to concentrate flow and penetration [5].

**Direct Bacteria Count (DBC) Method**
This method is used to sample water filtration and count the number of microorganisms present at the surface of the filter. The INT is capable of displaying the difference between living cells and dead cells [5]. The effect of the release

of free chlorine microbial fraction directly depends on the unbundled HOCL concentration. Which is 100 times more effective than the –OCL hypochlorite ion. The amount of HOCL not dissociated increases with decreasing temperature and PH [5].

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, a lower content of not separated HOCL, are available.30% at pH 7.5, 25℃, 40,000 mg/L TDS Chlorine can react with ammonia and lead to chloramine production in a series of step-by-step reactions. These reactions are as follows:

$$HOCL+NH_3 \rightarrow NH_2CL+H_2O$$
$$HOCL+NH_2CL \rightarrow NHCL_2+H_2O$$
$$HOCL+NHCL_2 \rightarrow NCL_3+H_2O$$

Chloramine also have the Eliminate microbial effect, but their effect is less than chlorine. One of the most important benefits of chloramines are that, they do not react with the reverse osmosis membrane and do not oxidize it. However, there are still remaining HOCLs that can oxidize the membranes. Therefore, care should be taken when using chloramine as an antiseptic agent and monitor the reactions. To determine the optimal dosage of chlorine, the best injection point, pH and contact time to prevent biological fouling, Standard requirements according to ASTM-D1291, which are used to determine the water requirement for chlorine, to be applied to the water sample tested and to analyse the results thoroughly [5].

**Chlorine Dosage Method**

The remaining chlorine must be eliminated before reaching the reverse osmosis membrane. The CSM reverse osmosis membrane resists chlorine from itself. However, the probability of destruction of the membrane after 200 to 1000 hours of exposure to free chlorine is 1 mg / lit and depending on the pH, temperature and residual intermediate metals (such as iron) may occur in the incoming water [5].

**Sterilize Using Ultraviolet (UV) Radiation Method**

UV radiation in the 254 nm spectrum range has a microbial degradation effect and is used specially in small plants. In this process, no chemicals are required. Equipment requires only a brief care which includes periodic cleaning and replacement of the mercury lamp [5]. In spite of all this, UV rays are limited to fairly clean water purification. Because in contaminated waters, the presence of colloids and organic matter prevents the penetration of ultraviolet radiation into the depths of water [5].

**Control of Biological Activity using Sodium Bisulphite Method**

Sodium bisulphite (SBS) at a concentration of 50 mg / L in the inflow of reverse osmosis units of seawater can improve the effect of control of biopsy cramps. Colloidal emesis can also be eliminated by this method [5]. Sodium bisulphite (SBS) can help control the calcium carbonate deposition of peritoneum ions (H+), which is as follows:

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

## CONCLUSION

Biological fouling of reverse osmosis and MF membranes is one of the most difficult and least known types of membrane fouling. Some cases of biological fouling have been observed in many aerobic systems (seawater, river water and sewage) and in some non-aerobic systems (saltwater wells). Because of the complex nature of microbial growth mechanisms and the harmful effects of biological fouling on system performance, which is often irreversible, practical and effective provision with appropriate design for stabilizing and improving the performance of reverse osmosis and MF systems is imperative. Surface water systems such as open canals, seawater, river water and saltwater lake, as well as industrial wastewaters, often have relatively high levels of biological activity. Many different types of bacteria, algae, funguses and other aquatic micro-organisms grow and develop in an optimal environment.

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