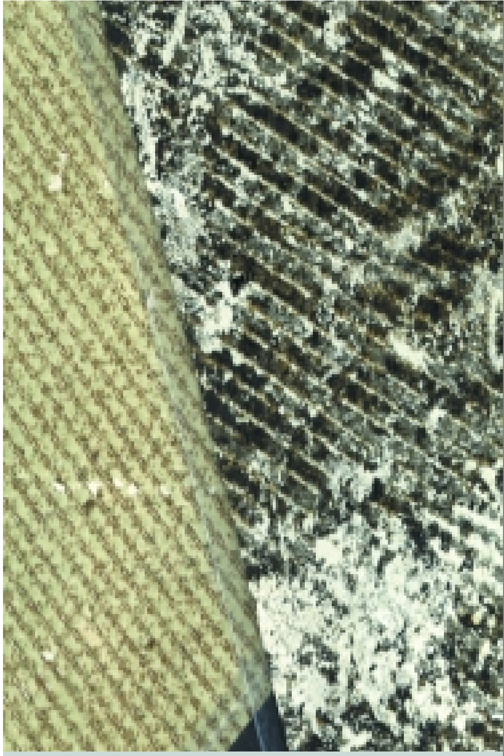

Membrane Biofouling and BIOCIDE use for Control

Inside this Bulletin:

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INTRODUCTION

Polyamide reverse osmosis (RO) membranes have become the industry's most commonly used. This is due primarily to the many advantages polyamide technology has over the older cellulose acetate membranes including:

- improved salt rejection
- resistance to hydrolysis
- resistance to bacterial degradation
- tolerance to cleaning formulations

The main disadvantage of polyamide membranes is their intolerance to chlorine and other oxidants. Without some form of disinfection, microorganisms may quickly colonize and biofoul membrane surfaces and plug element feed passages.

If left unchecked, the effects of biological fouling become irreversible, and the increase in element differential pressure may result in secondary mechanical deformation of the individual RO elements.

The cumulative effects of biofouling include; increased cleaning and maintenance costs of the RO system, a noticeable deterioration of product water quality, and significantly reduced element life.

Figure 1 illustrates the effect of severe biofouling on RO system flow. Following an initial decline phase, flow stabilizes at some reduced equilibrium value, a pattern similar to that seen with colloidal fouling. (See the Avista Technologies technical bulletin, *The Role of Coagulants in Reducing Colloidal Fouling.*)

FOULING MECHANISMS

Bacteria are brought into contact with membrane surfaces through permeate flow convection. Many bacteria adhere irreversibly to the membrane surfaces where they begin to multiply and exude membrane foulants.

Ridgeway[1] reports that the adhesion process is very rapid and follows closely the Langmuir adsorption isotherm equation, a mathematical expression that describes the adsorption of soluble or suspended material at an interface. He further concluded that RO membrane surfaces possess a finite number of bacterial

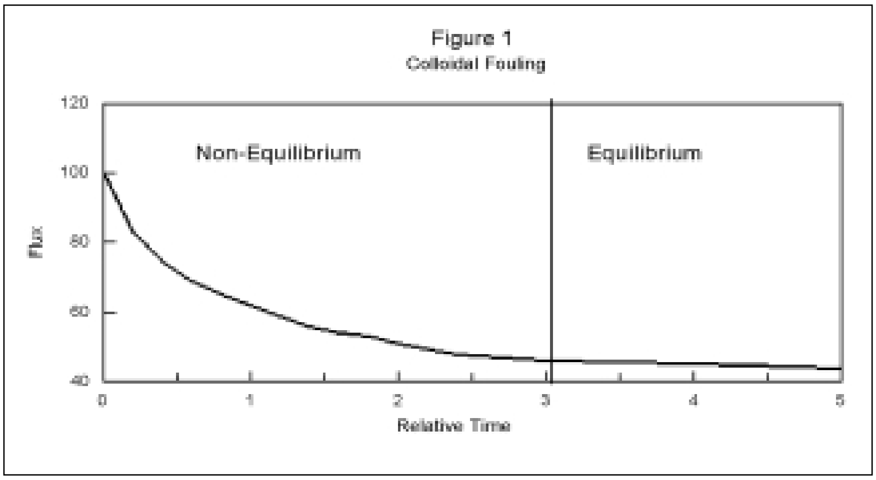

Figure 1 Effects of severe biofouling on RO System Flow

attachment sites which, when completely filled, become unavailable for further adhesion.
The molecular basis for microbial adhesion to RO membrane surfaces has not yet been studied or reported in any detail, although Ridgeway presented experimental evidence suggesting the involvement of hydrophobic interactions between mycobacterial cell surfaces and the surfaces of cellulose acetate membranes.[2,3]

Many species of bacteria, filamentous fungi, and yeast have been associated with biofouling.

Acremonium
Aspergillis
Alternaria
Aureobasidium
Candida

Bacterial generally identified include:

Lactobacillus
Pseudomonas[4]
Micrococcus

Biofouling of RO membrane surfaces is invariably accompanied by some degree of mineral deposition, including scale. Inorganic ions identified in biofilms are generally of the more insoluble type such as calcium, aluminum, iron, sulfur, phosphorus, and silicon.

The deposition of inorganic salts may be related to a disruption of flow across the membrane surfaces that increase the concentration polarization effect. However, it is also possible that certain microorganisms either directly or indirectly cause the precipitation of inorganic ions.

Biofilms consist of a complex mixture of microorganisms, the by-products of microbial metabolism, and inorganic salts. Table 1 summarizes chemical analyses conducted on biofilm scrapings[5]. The range of values reflects where the samples were taken. Second stage elements generally contained greater quantities of biofoulants than did first stage elements.
Figure 2 is an SEM photograph of a biofilm surface and Figure 3 is an SEM photo of a biofilm cross-section[6].

BIOFOULING CONTROL

Biofouling is controlled by the injection of non-oxidizing biocides into RO feedstreams, either continually or intermittently.

Some biocides are poorly rejected by RO membranes, so if the presence of these substances cannot be tolerated in the product, then a choice must be made. The options include biocides that are completely rejected by the RO membrane or those that kill microorganisms quickly enough that they can be injected while the system is off-line.

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CONSTITUENT	UNIT	RANGE
Total quantity	mg/cm2	8.2 - 12.6
Total organic fraction	% dry weight	87.3 - 92.6
Total inorganic fraction	% dry weight	7.4 - 12.7
Protein	% dry weight	15.0 - 30.1
Carbohydrates	% dry weight	13.2 - 17.6

Table 1 Biofilm Composition

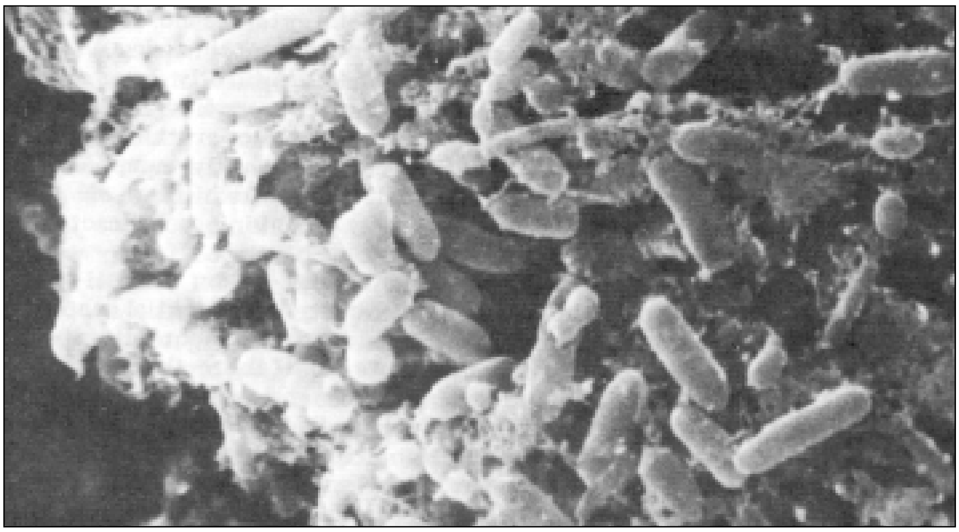

Figure 2 Biofilm Surface

EVALUATING BIOCIDES

The choice of which biocide to use depends upon customer requirements and the type and number of bacteria present in the RO system.

Avista Technologies offers laboratory screening tests of its biocide formulations. All that is necessary is for the customer to collect a system concentrate sample in a sterile container and to send that sample to Avista in an insulated container for analysis. Avista provides both sterile and insulated containers.

Details of the system must also be provided to ensure that a biocide is selected within the environmental and legislative restrictions in force in that location or application.

After the biocide formulation is chosen, the usual practice is to begin the biocide treatment in the system at a relatively high dosage. As biofouling control is achieved, the dosage is gradually reduced.

Control of biofouling is associated with a marked decrease in the rate of flux decline and differential pressure increase. Control may be predicted by bacterial counts. When the numbers of bacteria present in the concentrate stream equal those of the feed, taking concentration factor into account, control is achieved, and biocide dosage is reduced.

A convenient method of making bacterial counts is the Petri Film technique.

Prior to beginning biocide treatment, RO systems should be thoroughly cleaned to remove accumulated biofilm deposits on membrane surfaces and within element flow passages. Biofouling control is achieved much more quickly when this step is accomplished.

When feasible, clean and sanitize feed piping separately. If this is not done, large quantities of accumulated biofilm may slough from the piping walls and plug cartridge filters and feed-end RO elements when biocide treatment is initiated.

BIOCIDE APPLICATION

The requirement to control biofouling in membrane systems is universal, however, the methods of achieving this are particular to each site and are dependant on many factors such as:

- Local temperature
- Intake source and condition
- Upstream treatment processes

Various methods have been found to be effective including:

- Continuous biocide dosing
- Shock biocide dosing on-line
- Shock biocide dosing off-line

Close monitoring of plant operation will allow the optimisation of a biocide dosing regime. Typical regimes are described below.

Continuous Dosing On-line:

When systems are found to exhibit serious biofouling continuous dosing of a biocide is necessary to attain biostatic conditions. It should be noted that even when continuous dosing is undertaken periodic changes in the biocide applied should be considered to ensure that the bacteria in the system do not become resistant to the biocide. In addition, the biocide must be acceptable within the regulatory framework of the water treatment plant.

RoCide IS2 is an ideal biostat for continuous dosing.

Shock Dosing:

A programme of periodic dosing is sufficient to control biofouling in many cases. A regime of one hour shock dosing once or twice per week is normally suitable.

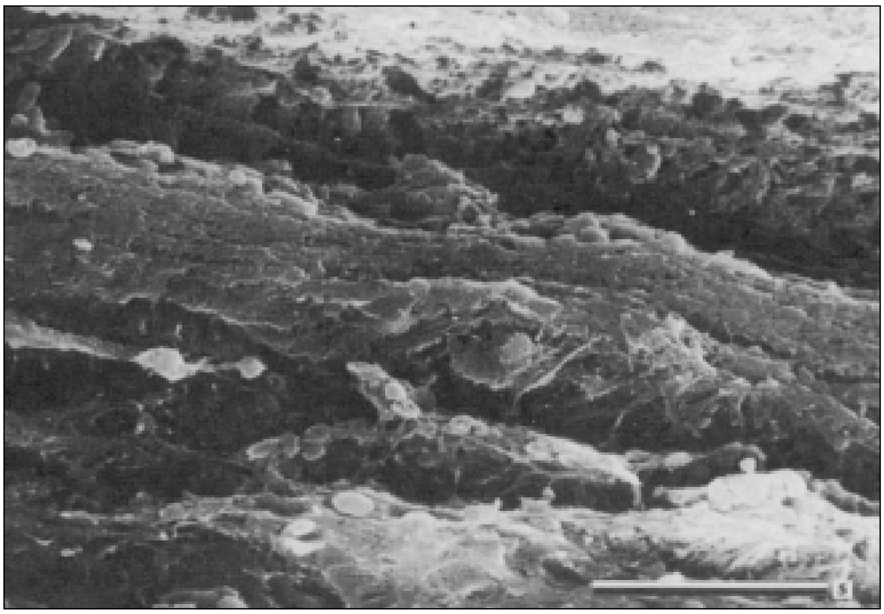

Figure 3 Biofilm Cross Section

In-frequent shock dosing can result in a rapid increase in differential pressure resulting from migration of biofilms from pipe linings to the feed spacer of membranes. This infrequent dosing should only be carried out if it is the first step of a chemical clean.

RoCide DB5 is a suitable choice for shock dosing, and is applied at 100-200ppm.

For Preservation:

Where a plant is to be shut down for a period of more than a week a biocide should be applied to ensure the system is sanitised and remains sterile during the period offline.

This is normally achieved by circulating a 2% solution of RoCide SC for an hour prior to 'locking in' the solution.

Avista Technologies are available to assist you in determining an effective biocide dosing regime for your installation.

REFERENCES

1. Ridgway, H.F. et. al.; Adhesion of a Mycobacterium sp. to Cellulose Diacetate Membranes used in Reverse Osmosis: Appl.. Environ. Microbiol,, 47,61 (1984).

2. Ibid; Bacterial Adhesion and Fouling of Reverse Osmosis Membranes; J. Amer. Water Works Assoc., 77, 97 (1985).

3. Ibid; Fouling of Reverse Osmosis Membranes: The mechanism of bacterial Adhesion; Proceedings of the Water Reuse Symposium III, Future of Water Reuse;Vol. 3, San Diego, CA (1984).

4. Parekh; Reverse Osmosis Technology; Marcel Dekker, Inc. (1988).

5. Ibid

6. Ibid

The picture on page 1 shows two membrane samples, one fouled by organics and the other by algae.

Figure 4: An example of heavy biofouling