BIOLOGICAL FOULING OF ULTRAFILTRATION MEMBRANES DURING OPERATION

Derevjanko V.N., Nechitaylo N.P.
Pridneprovskaya State Academy of Civil Engineering and Architecture

INTRODUCTION

Membrane technologies are widely used for treatment of various water mediums and solutions, such as saline and brackish waters, wastewaters, yeast cream, liquids in milk and brewing productions etc. The subject matter of membrane using is filtration cycle duration, or operational period. In terms of economics membrane fouling is the main obstacle to using membrane filtration. To evaluate the applicability of membrane technologies a detailed analysis of treated water is performed, and in most cases experimental justification is required. Different waters can have different composition, which is defined by the place of wastewater generation and that influences filtration cycle duration. However, contaminants can be divided into groups of determination contaminants, and such division will allow to minimize mistakes in selection, designing and operation of membrane systems.

Membranes are subject to fouling with colloidal particles, inorganic, organic and biological organisms. So [1] fouling of semi-permeable membrane partition surface can be characterized by different factors as well as by their complex, which depends on physic-chemical processes of natural water and wastewater treatment. For example, oil-product presence in any water considerably decreases performance of membrane elements. Generality of factors, that lead to membrane performance decrease, allows to analyze them and reduce negative influence by including additional filtration stages.

1. ANALYSIS OF PARAMETERS AND FACTORS, THAT LEAD TO DECREASE OF MEMBRANE PERFORMANCE

Analysis of factors, that lead to decrease of membrane performance showed, that the chief factors are adsorption of suspended and solute organic and inorganic components, chemical interaction of membrane material and solute agents, biofouling from feed water. It happens due to membrane capability to permeate one material and reject the other. Therefore appearance of high concentration of rejected particles over the membrane surface is an essential fact. Highly concentrated materials form a layer, which results into increase of resistance to mass transport. This resistance is called concentration polarization. Thus it may be concluded that polarization processes appear in all baromembrane methods of water treatment. Membrane fouling is most often the limiting factor of their application. Agreeably, membrane fouling may be considered to be lowering of membrane operational surface. And this causes decrease of flow under predicted membrane capability. Some parameters, that affect time of membrane fouling are listed below:

- kind and concentration of solutes and solvents;
- membrane type;
- pore size distribution;
- membrane surface and material properties;
- hydrodynamics of membrane module.

Membrane fouling can be associated with processes of adsorption, chemical interaction, pore covering or appearing of contamination above the pores (so called "cake").These factors can cause partial or full blocking of membrane operational surface or coating membrane surface with a layer of particles.

2. BIOLOGICAL FOULING

Biofouling is called by the authors [2] the Achilles' s heel of membrane filtration methods. This is because microorganisms can continuously increase using biodecomposed admixtures from feed water, even if they were 99% rejected on the previous filtration stages.

Biofouling can be caused by the following negative factors [3-7], that influence membrane systems:

- permeate flow decrease due to formation of biofilm, which reduces membrane surface permeability;

- increase of pressure drop across the membrane, which requires increase of pressure to the bulk fluid;

- membrane biodegradation, caused by acid medium which is result of biofilm activity co-products appearance on membrane surface. For example, cellulose acetate membranes are the most susceptible to biodegradation.

- increase of rejected particles penetration and water quality degradation due to concentrating of contaminants in the biofilm, which enlarges the extent of concentration polarization.

- increase of power inputs for water pressurizing through membrane.

Exact understanding of bacteria generation process and biofilm formation will allow providing of undisturbed operation of natural water and wastewater treatment systems with minimum membrane fouling and, also, prevent irreversible membrane modifications. Bacterial surface contamination (e.x. biofilm formation) can be divided into 3 phases: microorganisms transport to the surfaces, fixation on membrane surface, further growth of microorganisms.

Membrane systems design is complicated, it has many extended surfaces, chinks and dead spaces in pipelines and fitments. Elements, included into membrane have a huge surface area, which is easily accessible for microorganisms fixation and growth. These surfaces are particularly subject to biofouling.

When designing membrane systems and calculating their usage efficiency in different productions one should take into account costs, required for maintenance of water microbiological safety (especially in productions, where bacteriological pollution is critical for end product). This can be seen in nutritional, medical, pharmaceutical and electronic productions. In these cases it is incorrectly to save on pipelines and stop valves.

The easiest and the most effective way of preventing biofilm growth on the membrane surface is control of general microbial number. While carrying out control and registration of microbiological contamination it is necessary to observe tendencies of microbiological quality changes in feed and filtered water. Depending on the source of water and season, water can show variable contamination level. Therefore, before designing membrane systems it is necessary (if possible) to examine quality of feed water during the year. But this is not a key method for surface water sources. Bacterial growth often depends on factors, which are hard to predict or foresee and it is very important to understand if there is a tendency to contamination growth. Also it is not always possible to carry out permanent control of water microbiological characteristics in time, which provides membrane performance, which will not lead to irreversible processes.

In work of Flemming H.-C and co-authors [8] it is shown that biofilm forms in three days. Due to bioadhesion this time is enough to cover the whole membrane surface with biofilm. Ghayeni and co-authors [9-10] researched initial adhesion of wastewaters bacteria, which belong to Pseudomonas family, by reverse osmosis membrane. Their research showed, that first irreversible processes of bacteria fixation on the membranes start in several minutes after delivery of feed flux to membrane. It was determined, that bacteria films add more membrane resistance, than concentration polarization, caused by other contaminants of feed flux. It was determined, that microorganisms of Pseudomonas family quickly fix on the membrane surface. Pseudomonas aeruginosa is a gram-negative mobile rodlike bacterium, obligatory (strict) aerobe. Its size - 0.5-0.8 micron thick and 1.5-3 micron length. Widespread in nature. Can be found in biofilm and in plankton form, i.e. a separate bacteria, that moves using its polar flagellum. With that Pseudomonas Aureginosa is one of the most mobile microorganisms, that can be found in water specimens from natural sources. Blue pus bacillus can not only be preserved for a long time in environment (wet atmosphere and water), but also multiply fast. Comfort temperature is 37 ^{o}C, but it can also grow at 42^{o}C. Research works on formation of biofilm on reverse osmosis membranes were carried out by M. Herzberg and M. Elimelech [4]. As a result of experimental studies it was found that due to high concentration of protein and possibility of microorganisms fixation on the membrane surface, Blue pus bacillus grows more intensive in a layer, close to membrane.

Basing on the foregoing it may be concluded that due to high level of nutrients in natural water this bacillus can well multiply on membranes. In case of nutrition lack bacteria growth is considerably slower and biofilm covers not the whole membrane surface. These findings are confirmed by experimental researches, obtained in works [10-11].

3. CONCLUSIONS

Membranes biofouling is one of the factor, that brings down appeal of this method of water and wastewater filtration.

For successful membrane ultrafiltration technology performance periodic sanitation is required.

One of perspective development path is using membranes, that have bactericidal properties and their design should prevent biofilm formation.

The most perspective development path is adding modifying components to membranes material or inoculating of modifying material with bactericidal properties.

New technologies must be developed to control biofouling. This will significantly expand the scope of application of ultrafiltration for the treatment of natural and waste waters

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Recommended for publication: 19.02.2014.