**By Tali Harif**

# UV vs. Biofilm

## UV technology combats biofilm in desalination applications

UV system at the Zuckerberg Water Institute.

The depletion of freshwater resources for production of potable water has become a worldwide concern due to expanding populations, pollution and overuse. This has been the main driver in development of reverse osmosis (RO) membrane-based desalination processes, which have become an important source of drinking water production over the past 40 years.

In recent years, especially in arid regions with limited freshwater resources, a new trend has emerged in the form of seawater desalination plants with productions of 100,000 cu meters per day or more. Despite the effectiveness of desalination, operational challenges, including biofouling of the membrane elements, are prevalent.

Biofouling can cause an array of adverse effects, such as membrane flux decline, increased differential pressure, membrane biodegradation, increased salt passage and decreased boron rejection. These issues lead to production water loss, product water quality loss, frequent membrane element replacements and increased energy costs.

### Biocides

Biocides combat biofouling via oxidizing agents injected prior to the membrane modules. Chlorine, chloramines, chlorine dioxide and ozone are the most common biocides, but their use and benefits are controversial in targeting biofilm formation and improving overall membrane performance.

Strong oxidizing compounds can cause harmful byproducts that may pass through the membrane and infiltrate the permeate; increase the assimilable organic carbon (AOC) content of the water, thereby increasing the biodegradable material in the water (ideal for supporting bacterial growth); and oxidize the RO membrane polymeric matrix.

Substances commonly used for biocides reduction, such as sodium bisulfite, may be detrimental. In addition to depleting excess oxygen at the membrane surface, they can serve as a nutrient for microbial populations, in effect creating an ideal environment for anaerobic bacterial growth. In practice, a biocide residual is not maintained in proximity to the membrane surface and microbial proliferation cannot be inhibited there.

### UV Irradiation

Despite the well documented disinfection abilities of ultraviolet (UV) irradiation, this type of technology has been implemented scarcely in desalination plants. Exposure to UV results in damage to the nucleic acids of the microorganisms, which subsequently damages their ability to replicate—a phenomenon known as photoinactivation.

Two types of UV lamps exist: low-pressure (LP) and medium-pressure (MP). The former emits a monochromatic light in the UV range at approximately 254 nm, and the latter emits a polychromatic light ranging from 200 to 400 nm. The use of MP UV lamps versus the more traditional LP UV lamps has become popular over the last decade due to the superior degree of photoinactivation attainable for equivalent germicidal doses. Additionally, MP UV has been shown to be more effective in repressing repair mechanisms, which is vital in minimizing/inhibiting regrowth downstream.

Unlike conventional oxidizing biocides, when used in doses adequate for disinfection applications, UV does not cause harmful byproducts, elevate the water's AOC content or require additional chemicals prior to the membrane that may impede membrane performance.

MP UV may have an additional effect on the ability of bacteria to maintain a fully functional biofilm due to effects of some wavelengths on other biological molecules (e.g., proteins and enzymes) that play an important role in maintaining normal cellular functions. In this context, the use of MP UV as a pretreatment step in a desalination process scheme may prove to be a preferred and sustainable solution for combating biofilm formation in desalination plants.

### Biofouling Research

Atlantium Technologies Ltd., an Israeli company that designs and manufactures MP UV-based systems, has been researching the effect of MP UV on biofouling of RO membranes in brackish and seawater desalination. The company has implemented fiber-optic principles in its system design and developed a UV technology called Hydro-Optic.

Under the auspices and funding of the Chief Scientist's Office at the Israeli Ministry of Trade and Labor, the company has conducted a few pilot runs and teamed up with experts at the Zuckerberg Water Institute of Ben Gurion University to explore at the most fundamental level if and how implementation of MP UV systems prior to RO membranes affects biofilm formation.

The hypothesis, which has laid the foundation for this research and development, suggests that costs related to membrane maintenance and poor plant performance due to biofouling can be reduced, even if the pretreatment does not inhibit biofouling entirely. By reducing biofilm formation rates and provoking the formation of a biofilm structure that exhibits less hydraulic resistance, the biofilm is more easily removed, so substantial cost savings can be achieved.

Results from a full-scale pilot at a brackish desalination plant in northern Israel suggest that MP UV systems can both hinder biofilm formation, leading to slower permeate flux decline, and impact the biofilm characteristics. Biofilm comprises extracellular polymeric substances (EPSs), excreted by bacteria, and cells. EPSs play an important role in bacterial adhesion to the membrane surface and are the primary contributor to the hydraulic resistance of the membrane-to-permeate flow once a biofilm is formed.

Analysis of membranes autopsied following a four-month trial showed that implementation of Atlantium's technology generated a biofilm with diminished EPS content versus the biofilm formed on a membrane with no pretreatment. The normalized permeate flux of the train that received pretreated feedwater was maintained at a higher value, and by the end of the trial was 7% higher than the reference train's. These results indicate favorable operational ramifications. Cost savings depend on sustained performance: less pump energy due to rises in differential pressure, less aggressive and shorter chemical cleaning regimes, faster membrane recovery periods and prolonged membrane replacement cycles.

Bench-scale and full-scale UV systems also have been installed at the Zuckerberg Water Institute in an effort to explore more fundamental application aspects, such as technology as a pretreatment step. The program is examining MP UV systems as a tool that can affect bacterial adhesion to the membrane surface rather than as a disinfection method. Results thus far indicate that this may be a promising avenue. In flow-through trials using a full-scale UV system and flat-sheet membrane cells, flux decline has been slowed to 40% by implementing a system designed to reduce bacterial attachment.

## Final Word

UV technology is implemented as a valid disinfection technology, but it rarely is considered as a method for targeting biofouling in desalination plants. Conventional disinfection methods are practiced widely despite their well documented detrimental effects and their association with additional chemical use.

UV, specifically MP UV, could be advantageous compared to conventional disinfection methods in desalination plants, and it could prove to be a sustainable and viable technology for combating biofouling and reducing operational costs associated with this phenomenon. MT

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