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Every Drop Counts

Plants aim to reduce water consumption and increase recycling

By Seán Ottewell, Editor at Large

WIDE-RANGING WATER optimization efforts, from fixing pipe leaks to minimizing cooling tower blowdown, are providing significant savings to chemical makers.

On March 29th, for example, BASF Research, Ludwigshafen, Germany, highlighted its latest water treatment developments at a conference there.

One of these is a pilot scheme to improve use of Rhine river water at the site. The company currently is benchmarking an existing ultrafiltration system (UF) against one that uses a novel — and unnamed — membrane fiber. In trials, the new membrane has generated lower pressure buildup, requiring 50% fewer cleanings. In addition, it provides higher flux, 114 $L/m^2/h$, compared to 86 $L/m^2/h$ in the other unit, giving 33% additional clean water per module (Figure 1).

BASF also is investigating new flux enhancers to improve antifouling strategies with membrane bioreactors (MBR). To this end, it's developing chemical solutions to enhance MBR economics. Trials with candidate solutions already have demonstrated strong (up to 80%) reductions in reversible and irreversible fouling. In addition, the solutions have shown better filterability and dewatering properties than conventional flux enhancers.

Overall, the company is broadening its water solutions base following last August's acquisition of UF specialist Inge, Greifenberg, Germany. BASF says the two now are jointly developing novel membrane and process chemicals, and applying their combined membrane technology know-how — particularly to surface properties that influence hydrophilicity, surface tension and smoothness.

In addition, BASF has played a significant role in developing the new voluntary European Water Stewardship (EWS) standard. The European Water Partnership (EWP), Brussels, an independent non-governmental organization that focuses on international water issues and undertakes worldwide promotion of European expertise related to water, is coordinating the project.

BASF's water experts have been involved since the inception of the standard three years ago and the company has spent six months testing it in a pilot project at Ludwigshafen.

"The focus of the standard is to develop an overview of all water activities at a production site in relation to the water basin by looking at the water supply as well as water emissions, biodiversity impact or roles and responsibilities. The focus of the pilot in Ludwigshafen was to test the applicability of the standards set out in the draft under real on-site conditions. Therefore, we established a team with BASF water experts and sustainability experts supported by the EWP water stewardship team," explains Brigitte Dittrich-Krämer, senior sustainability manager at BASF.

"During the pilot the standard was further developed. The assessment criteria were discussed and the documents further improved. Now the European Water Stewardship standard is found to be comprehensive, relevant and complete," she adds.

As part of its input into the standard, BASF proposes that global companies focus its application at production sites in water-stressed regions. "Therefore, we developed a new global goal: by 2020 BASF will review its existing water-management systems at all sites located in water-stress areas worldwide and introduce new sustainable systems wherever necessary," says Dittrich-Krämer.

Interestingly, the pilot scheme didn't focus on technical measures to reduce water use. Rather, it looked at improving the understanding of sustainable water management, to incorporate the needs of the chemical industry into a European approach for sustainable water management and to gain early experience in implementing a new water stewardship system.

"The European Water Stewardship standard provides BASF with a framework to advance our sustainable water management at production site level, as well as to evaluate water-related risks. Through the work we established a common understanding of the concepts and issues related to water stewardship also with reference to our stakeholders' expectations. We have added new goals this year related to the responsible use of water: in addition to the goal of reviewing our water management systems as mentioned previously, we

LUDWISHAFEN INITIATIVE

Figure 1. Optimizing use of Rhine water at the site is a key focus for BASF. *Source: BASF.*

want to reduce the use of drinking water in production processes by half in 2020, compared with 2010."

Although the new standard is voluntary at the moment, Dittrich-Krämer foresees that it might provide the basis of future legislation, either in Europe or elsewhere around the world.

"The EWS standard is in line with current European legislation and got a strong encouragement by the European Commission, especially from E.U. commissioner Janez Potočnik. During the launch of EWS, the Commission emphasized the need to build in additional incentives to promote a change in behavior and practice of water use, management and governance," she notes.

SPECIFIC INITIATIVES

At the plant level, business success can add to water optimization challenges. For example, at Air Products, Allentown, Pa., in 2010 global water consumption — including water pumped, piped or otherwise brought on-site for use in manufacturing and related activities and excluding water returned to its source — was 16.1 billion gallons. This compares to 15.6 billion gallons consumed during 2009. However, production was higher in 2010, with greater processing and cooling needs boosting water demand.

At Air Products, water plays an important role in two key processes. The first is hydrogen production, which requires high purity water for steam generation and chemical reactions. The water purification processes used, typically reverse osmosis (RO) or ion exchange, usually produce some wastewater in meeting water purity targets. The second is air separation and industrial gases production. These processes rely on large compressors and equipment that require cooling water; water is lost in the evaporative cooling process and in cooling tower blowdown to maintain solids/pH/chemistry for optimum operation.

Among several sustainability goals, Air Products has a water reduction target — and says it's the only company in the industrial gases sector to have publicized such a figure. The target is to cut consumption by 10% globally by 2015 compared to 2009. That reduction is based on intensity of use and relates to the controllable portion of fresh water consumption. It excludes water used stoichiometrically in reactions, exported to customers as steam or water, and returned to the original source.

Reaching this reduction target requires understanding and managing water use at a site level. This allows appropriate actions that fit with concerns or challenges at a particular plant but also enables developing, sharing and maximizing best practices among facilities that rely on the same or similar processes and engineering design.

Such an approach offers benefits as the company grows in emerging markets like Asia, where water isn't necessarily an abundant resource. It will enable new plants there to take advantage of water-reduction best practice already firmly established in production processes.

Meanwhile, the firm is collaborating with an expert from GE on sustainability. This has led to assessments particularly aimed at reducing water consumption at a number of Air Products' facilities in the U.S., Europe and Asia. A number of best practices and improvement opportunities for better controlling water use have emerged from these assessments.

Among the options to reduce fresh water consumption being evaluated are use of gray water (used water that contains a variety of contaminants) and increased water recycling. During 2010, Air Products recycled or reclaimed 2.1 billion gallons of water.

Some examples of successful water reclamation and recycling include: 1.5 billion gallons of water from recycled process condensate from global hydrogen production; 37 million gal/year of boiler feed water from removing oil and minerals from an Illinois refinery's wastewater; and 565 million gal/year of process feedwater from local recycled industrial and sanitary grey water in Edmonton, Alta., preserving the water in the North Saskatchewan River and decreasing demand on processed potable water (Figure 2).

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"Air Products recognizes that water is a critical resource for our facilities and is determined to reduce our water use. While this is about being responsible, it also makes good business sense as it ultimately helps us to be more efficient. Naturally, our focus is mostly on our manufacturing facilities around the world where water demands are greatest and the water is scarcest, but we are looking at ways to reduce our need for water in other ways. Just one example is our use of recycled water at our Santa Clara, Calif., facility, which has reduced our fresh water consumption by 62 million gal/year, enabling more fresh water to be provided to our neighbors. By eliminating waste, increasing recycling and reuse, and offsetting water withdrawals with supply from reclaimed sources, we are driving to meet our 2015 water reduction goal," notes Julie O'Brien, sustainability manager.

PHARMACEUTICAL PROJECTS

Eli Lilly & Co., Indianapolis, Ind., also is taking aim at water use. For instance, water optimization is a central part of programs being implemented to improve overall environmental performance at its Erl Wood site in the U.K.

To better understand and control waster use, facility managers installed a site-wide automated monitoring and targeting system. Each building on the site now has a meter to record consumption of both potable and process water. The meters paid for themselves in a matter of months and have been central to identifying consumption anomalies.

For example, an unexpected increase in water flow in one part of a building was found to be due to a broken pipe — its repair saved 11 million L/year of water. The site has reduced overall water use to 19,931 m^3 in 2011 from 35,160 m^3 in 2008.

LESS RIVER WATER

Figure 2. Recycled industrial and sanitary gray water have displaced much potable water at Air Products' Edmonton plant. *Source: Air Products.*

This has been achieved thanks to the automated monitoring and targeting system, as well as much-improved staff awareness, says Greg T. Spratt, advisor environmental sustainability, global safety health and environment, in Indianapolis.

Also in the spotlight is the company's manufacturing site in Fegersheim, France, where purified water is a key ingredient in its injectable products. In 2008, the facility used 310 million liters of city water to produce 155 million liters of purified water. However, a new RO unit now recycles about half of the water rejected by other units. This is cutting demand for city water by more than 93 million L/year, equivalent to 16% of total water consumption and 63% of purified water process rejects. The original investment of $228,000 is generating $87,000/year in savings.

Meanwhile, recycling non-contact cooling water is part of a strategy to improve energy and water use in fermentation processes at the firm's Augusta, Ga., site, which manufactures a range of animal health products.

Pfizer, New York City, also is targeting water reduction. For instance, the company initiated a water conservation and wastewater reduction program at one of its manufacturing facilities in Puerto Rico, where discharge regulations are becoming stricter. The long-term goal is to reuse 100% of the wastewater or ensure any water discharged into the local wastewater collection system is of high quality.

The first attempt, which involved an RO system with minimal pretreatment, became an out-of-control expense due to membrane replacement frequency, maintenance cost and high electrical consumption. The system was installed with the aim of reusing some treated wastewater and reducing discharges by 50,000 gal/day. Previously, the wastewater generated by the facility had to be transported in tankers around the clock to a municipal waste treatment facility located about two hours away.

Eventually Pfizer called in Xylem, White Plains, N.Y. After analyzing the complete process, Xylem's engineers proposed a UF system followed by dual RO units.

Xylem installed a 50,000-gal/day UF system and a 30,000-gal/day RO train for redundancy of the process. The UF system takes care of suspended and colloidal matter and acts as a barrier to provide the required quality of water for the RO membranes.

From the UF system, the treated water goes to a 1,000-gal filtration tank from which a set of pumps sends the water to the RO system. The addition of pretreatment chemicals further enhances the conditioning of the feed water supply for the RO process.

The system has slashed wastewater to about 8,000 gal/day. Additionally, any RO permeate water not reused within the facility now exceeds discharge-quality regulations and simply can be disposed locally. Pfizer also is benefiting from lower treatment chemical requirements and reduced blowdown cycles due to high concentrations of contaminants in the facility's cooling towers. ●

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Make the Most of RO Membranes

Proactive steps can maximize life and performance for water purification

By Gregg Poppe, Dow Water & Process Solutions

MANY PROCESSORS striving to lower operating costs are missing an opportunity for savings in their reverse osmosis (RO) water treatment systems. Proactive steps to optimize both the cleaning frequency and cleaning method can extend the life of the installed membranes. Proper tracking of system performance combined with this optimized cleaning can reduce chemical, electrical and membrane-replacement costs. Additionally, a wise choice when it's time to replace membranes that operate in a fouling-prone environment can pay dividends.

MAINTAIN OPTIMAL OPERATION

Proper maintenance is the key to protect the investment in your current membranes. So, here, we'll look at some guidelines that can help you extend the productive life of the membranes and reduce overall operating costs of the RO plant.

The loss of permeate flow during operation is normal for a membrane system, so the first question is: "When to clean?" The frequency depends on the feed water source, operating parameters such as flux, and pretreatment. Commonly, systems are cleaned two-to-three times/year with well water, three-to-four times/year with city water, and four-to-six times/year with surface water. But it really depends on the specific situation. So, it's important to vigilantly look for signs of fouling. Any of the following observations should trigger a cleaning:

- Normalized permeate flow declines by 10–15%.
- Normalized feed pressure increases by 10–15%.
- Pressure drop rises by 10–15%.
- Normalized salt passage increases by 5–10%.

To make proper judgments, it's essential to normalize the permeate flow, feed pressure and salt passage to a standard reference point. Otherwise, fluctuations in feed temperature, salinity or pressure will either mask or accentuate the trends, leading to inaccurate conclusions about when to clean. Membrane suppliers can help provide software tools to normalize the data.

Foulants usually can be cleaned from the membrane surface with the right cleaning chemicals

and good technique. Waiting too long to clean can permanently reduce RO performance (Figure 1).

ACHIEVE EFFECTIVE CLEANING

Before cleaning, it's very important to determine the type and location of the fouling:

- Colloidal and particle fouling (Figure 2) is specific to the first RO stage. (Its feed screen tends to catch these foulants.)
- Scaling (Figure 3) appears in the second stage. (Recovery of product water in this stage boosts the concentration of salts in the remaining water, possibly exceeding the solubility limit of certain salts.)
- Organic and microbiological fouling (Figure 4) can occur in either the first or second stage of the system.

Before starting to clean, find out the cleaning pH and temperature limits set by the membrane manufacturer and make sure the cleaning chemicals are compatible with the membranes.

Clean with alkaline cleaners first and then, if necessary, with acid. High-pH cleaners are more likely to break down fouling layers. Acid may react with organics, silica and biofouling, possibly leading to irreversible performance decline — that's why you should remove these foulants first with an alkaline cleaner.

Clean at the appropriate pH and temperature to remove the foulants:

- To remove biofouling, cleaning at pH 12 is much more effective than pH 11— about an order of magnitude better at restoring

PERFORMANCE DECLINE

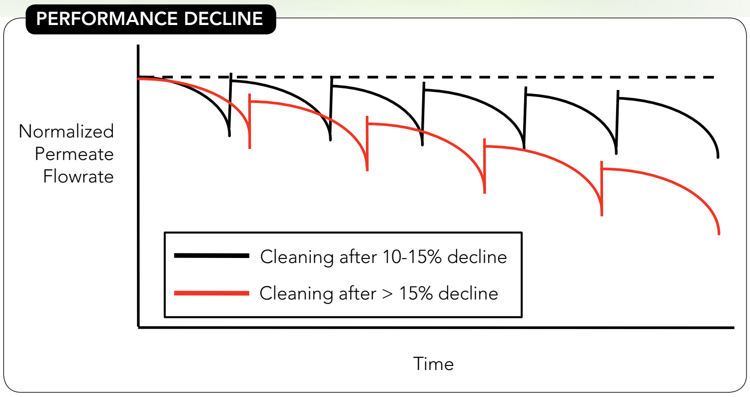

Figure 1. Waiting too long to clean can lead to permanent performance loss.

PARTICLE FOULING

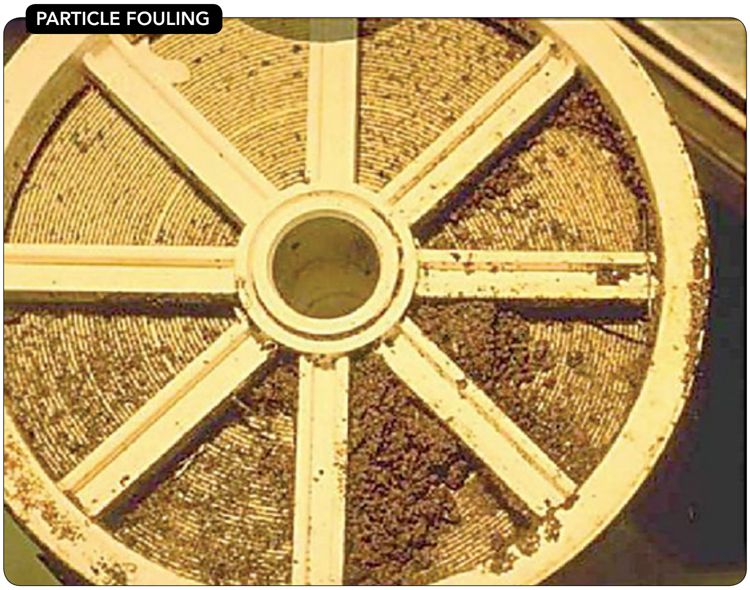

Figure 2. Such fouling occurs in the first RO stage, particularly on its feed screen.

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permeate flow. It's important to know the temperature range permissible for the membrane type at the high pH.

- To remove calcium carbonate scale, cleaning at lower pH and higher temperature restores permeate flow more fully (Figure 5). Some plants use citric acid (Cleaner A in the figure) to remove scale but it's usually not very effective compared to HCl at pH 1 (Cleaners D and E).

More extreme pH is more effective at removing foulants — but not all membrane manufacturers allow cleaning at a pH as high as 12 or as low as 1.

Different foulants require different cleaning protocols to achieve effective results. Consider the following guidelines (if the membrane can handle these conditions):

- Inorganic salts (such as $CaCO_3$): 0.2 wt.% HCl, 25–40°C and pH 1–2.
- Metal oxide (such as iron): 1.0 wt.% sodium hydrosulfite ($Na_2S_2O_4$), 25°C and pH 5.
- Inorganic colloids (silt), silica, biofilms and organic compounds: 0.1 wt.% NaOH, 35°C max and pH 12 or 0.1 wt.% NaOH and 0.025 wt.% Na-DSS [sodium salt of dodecylsulfate], 35°C max and pH 12.

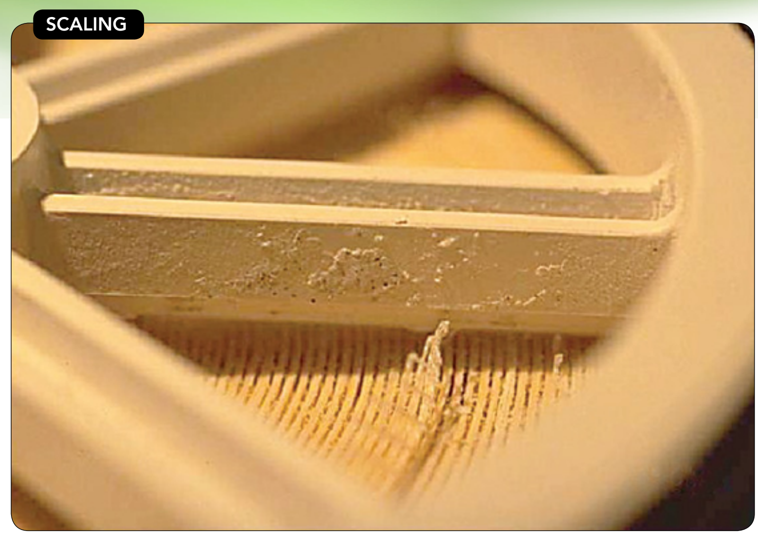

Figure 3. This appears in the second stage when salts exceed their solubility limits.

Figure 4. Both the first and second stages of a system can suffer from such fouling.

USE THE PROPER PROTOCOL

The cleaning procedure is important. When mixing the cleaning solution, ensure all chemicals are dissolved and well mixed before circulating it through the membrane elements. When first introducing the cleaning solution into the RO system, use a low flow rate while the water in the system is displaced. Also, to avoid driving foulants into the membrane surface, apply only enough pressure to compensate for the pressure drop. Dump the concentrate stream at first for as long as necessary to prevent diluting the cleaning solution upon recycle.

Once cleaning chemicals have displaced water, recycle concentrate and permeate to the cleaning tank. Measure the pH and adjust as needed to maintain the desired value. Monitor the color of the cleaning solution — a color change indicates removal of foulants. Then dispose of the heavily contaminated cleaning solution and mix fresh solution. Continue this for as long as it appears new foulants are being removed. However, with an acid cleaning, recirculating for longer than 20–30 minutes increases the risk of any heavy metals falling out of suspension and becoming permanently embedded on the surface of the membrane, making it more difficult to clean.

Prepare fresh cleaning solution for the soaking step. The length of the soak varies. While alkaline cleanings may require an overnight soak, acid cleanings typically only need 30 minutes. To maintain the desired elevated temperature during an extended soak, use a low recirculation rate through the elements. As before, monitor the color of the cleaning solution and dispose or refresh the solution when you observe a change in color.

After the soak, recirculate the cleaning solution at a high flow rate for 30–60 minutes to flush out foulants removed from the membrane surface. Finally, flush out the cleaning solution using RO permeate or deionized water. During the flush, the minimum temperature should be 20°C.

CALCIUM CARBONATE REMOVAL

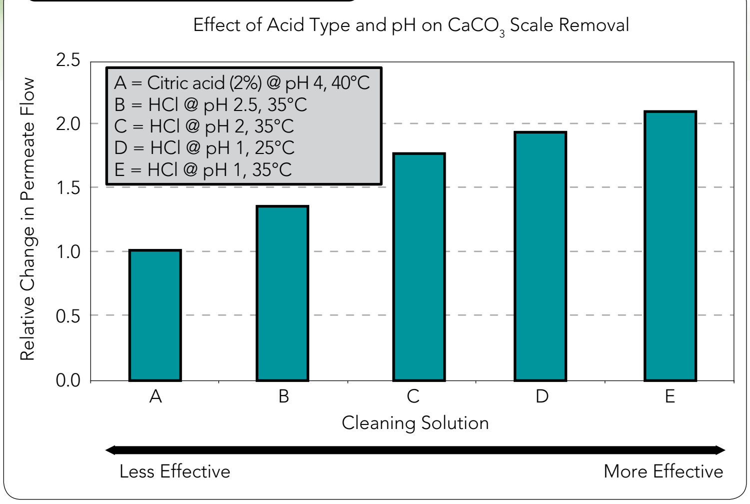

Figure 5. Temperature and pH impact the performance of acid cleaners.

RETHINK MEMBRANE CHOICE

When it's finally time to replace RO membrane elements that handle fouling-prone water, check into technological developments introduced by membrane manufacturers to help mitigate fouling. For example, there's been a growing acceptance that elements with 34-mil spacers foul less quickly and are easier to clean than those with thinner spacers.

Membrane manufacturers continue to innovate in their quest to optimize spacer geometry and thus flush the membrane surface more effectively. Work also is advancing to improve the fouling-resistant properties of the spacer material and membrane surface.

All these development efforts aim to extend the time between cleanings, improve the effectiveness of cleaning, and lengthen the overall lifetime of the membranes. Plants benefit from lower operating costs via: 1) decreased consumption of cleaning chemicals due to less frequent cleanings, 2) less electricity use due to slower increases in feed pressure, and 3) reduced membrane replacement costs due to longer life.

CUT COSTS

As this article has stressed, timely and proper membrane maintenance is necessary to ultimately achieve the lowest operating costs.

Monitor the condition of the plant, normalize and assess the data, and use the results to decide when to clean so membrane performance isn't irreversibly reduced.

Before starting to clean, determine the type of fouling and its location so you can use the proper cleaning chemical. Cleaning at more extreme pH is much more effective — but first always check the membrane manufacturer's literature for information about pH (and temperature) limits for cleaning.

Waiting too long to clean will shorten membrane life and cost far more than appropriate cleaning to keep membranes healthy.

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