GWI | ULTRAPURE

USE OF MONOCHLORAMINE FEED TO REDUCE RO BIOFOULING

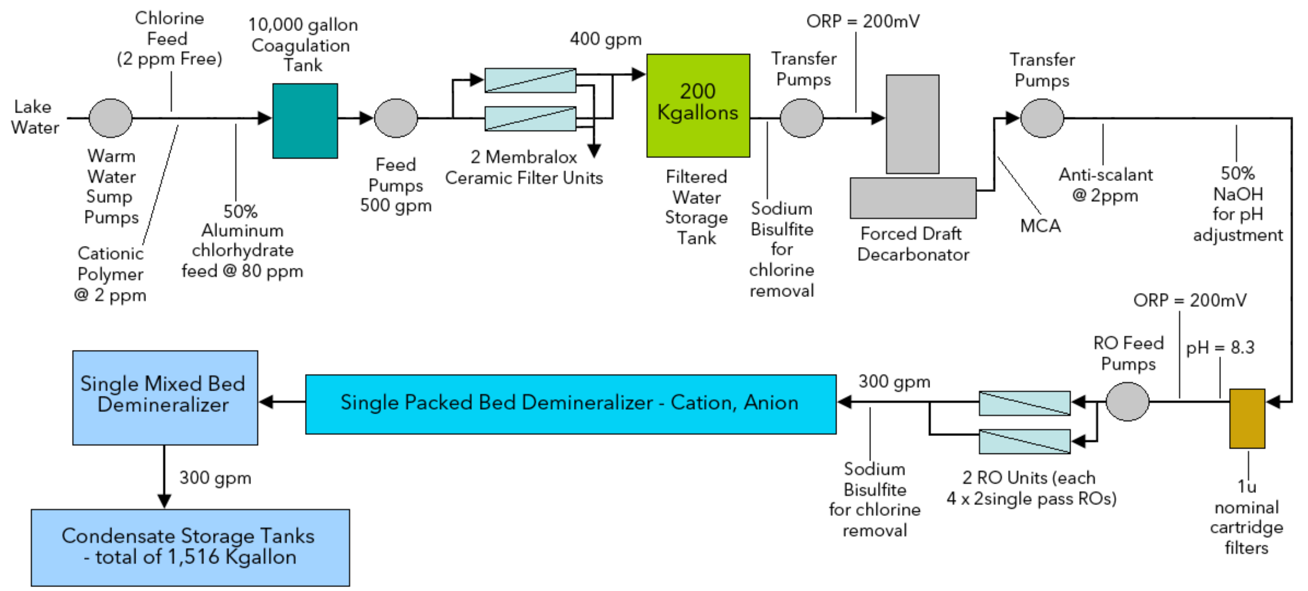

Figure 1. Newton Power Station water treatment overview.

Abstract

Reverse osmosis (RO) membranes used in the Newton Power Station (near Newton, IL) water treatment process were showing short service life. The use of typical biocides was not providing the expected increases in service, even with periodic cleaning. The decision was made to use monochloramine (MCA) as an alternate biocide to extend the useful service of RO membranes. For this project, plant personnel selected a treatment technology[A] that will produce a pure form of MCA. This article reviews use of this alternative treatment and reports on the results.

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Treatment Process Description

The water source for the water treatment process is a surface lake, which has a conductivity of approximately 450 microsiemens per centimeter (µS/cm). The lake is near farm fields and runoff from heavy rain can quickly increase the lake turbidity from the typical 20 Nephelometric turbidity units (NTU) to more than 200 NTU. The raw water has typical biological activity.

The water treatment process is shown in Figure 1, which was before changes related to the MCA feed were made. Chemical feeds of bleach, cationic polymer, and aluminum chlorhydrate are added to a coagulation tank. This water is fed to ceramic microfilters with a pore size of approximately 1 micron (µm). This water goes to the filtered water storage tank, after which it passes through a forced-draft decarbonator. After this step, pre-RO chemical feeds of biocide, antiscalant, and caustic for pH adjustment are added.

Water goes through RO prefilters (RO prefilters since changed to 1-µm pore size), and chlorine is removed with sodium bisulfite. Water then passes through the RO and onto a packed-bed demineralizer, mixed-bed demineralizer, and storage tanks.

Background of Problem

The short service life of RO membranes at about 1.5 years was increasing operating costs. Off-site RO cleanings extended life 50%, but this was still less than the desired minimum service of 3 years. Changes in lake water because of runoff from rain or seasonal turnover caused periodic rapid differential pressure (dP) increases at the RO system. RO dP increases indicated fouling, and membrane analysis confirmed biofouling/organic fouling was in fact present. The ceramic microfilters remove essentially all the particulate material, so this was not believed to be the main cause of the fouling at the RO.

These thin-film composite (tf) RO membranes have a zero tolerance for free chlorine, so oxidizing biocides cannot be used. Non-oxidizing biocides were fed, both (2,2-dibromo-3-nitrilopropionamide(DBNPA) and isothiazolinone were tried, but these did not prevent the fouling. Based on this information, it was believed that microbes were surviving in the RO after dechlorination. This has been an ongoing problem, and various changes have been tried, with some improvement seen.

The graph in Figure 2 is an example showing RO dP increases. The light blue line shows a rapid increase in second stage dP. These events are more likely in the spring, due to runoff from fields after rain.

Monochloramine Trial

Existing RO biocide treatment was not achieving the target membrane service life. Oxidizing biocides cannot be used, as the RO has no tolerance for these compounds. However, tf RO membranes can tolerate monochloramine (NH_2Cl)[A], which is a weak oxidizer, as long as this can be produced with no free chlorine. Because of this, the chemical can be fed upstream of the RO, and can pass through the RO without dechlorination, so microbes surviving in the RO would be eliminated.

The MCA degrades more slowly than bleach in water, and has the ability to penetrate the biofilm layer produced by the microbes. This had already been shown by the effectiveness of this MCA chemistry in keeping the stainless condenser tubes clean at this same plant. The microbial activity of MCA is also not affected by the water pH.

Supplier assurances were obtained that the process for producing MCA would result in a product with zero free chlorine, so it would not damage the RO membranes. Even if there was slight RO damage, if the overall service life of the RO membranes was longer than with the existing conditions, it would be an improvement.

Since MCA is not a stable compound, it must be produced at the plant site from two chemical precursors. This requires a "generator" to mix these chemicals at the proper ratio and conditions to make only MCA.

The cost of the MCA feed would be offset by stopping the feed of the non-oxidizing biocide. Any increase in

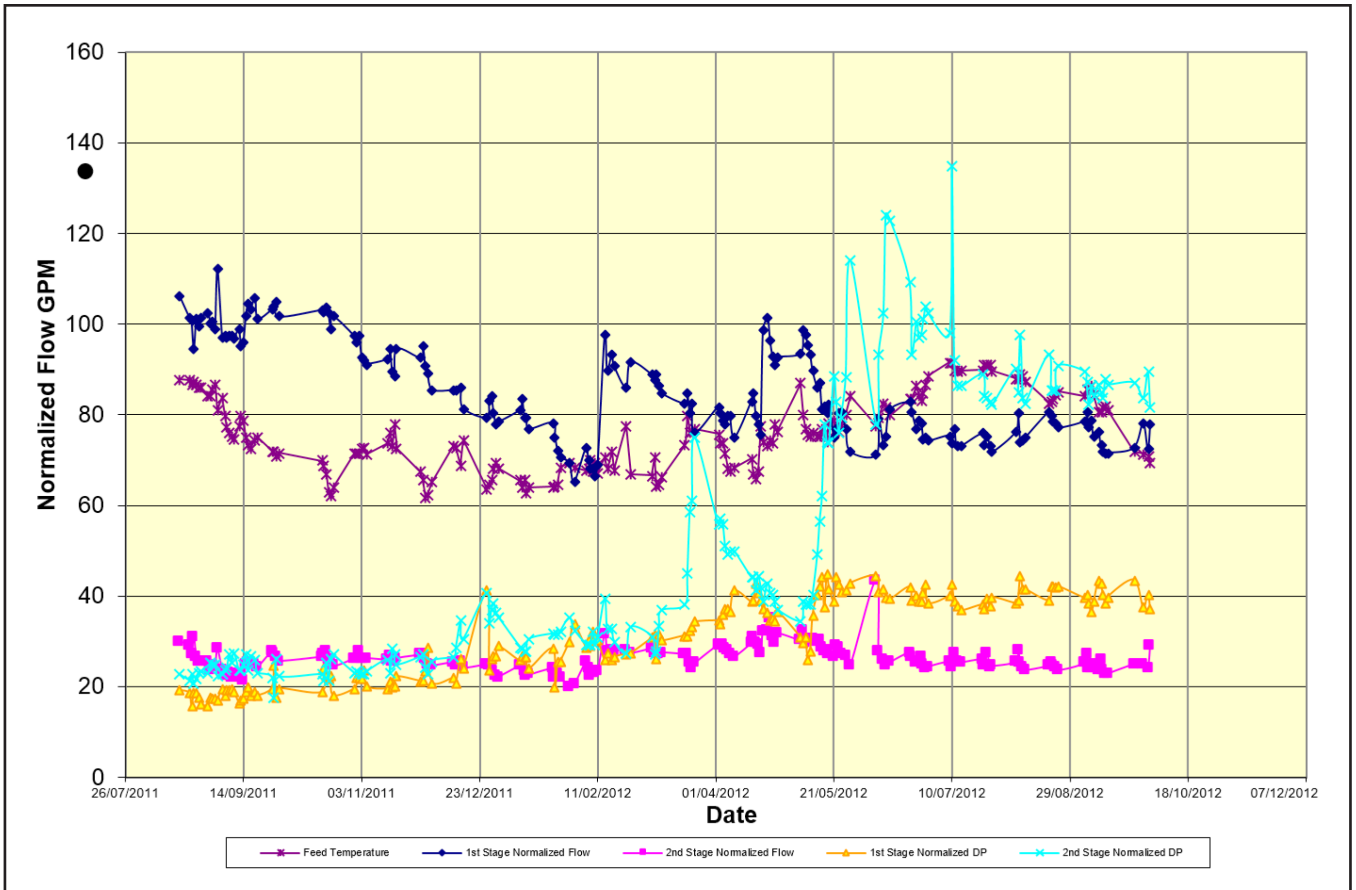

Figure 2. Newton Power Station RO normalized flow and differential pressure.

service life of the RO membranes would be a net cost savings. Based on this, the decision was made to perform a trial. The target feed range is 0.5 milligrams per liter (mg/L) (parts per million [ppm]) of MCA at the RO, with zero free chlorine.

Feed Plan #1. The initial plan was to simplify the water treatment process and feed the MCA at the water plant inlet (chemical coagulation tank), instead of the bleach. Dechlorination of the bleach would no longer be needed, and the MCA would then pass through to the RO. However, the weaker oxidizing properties of the MCA interfered with the normal formation of the floc in this process. The floc is needed to allow the ceramic filters to remove the sediment from the raw water. Adjustment of MCA dosages could not produce a floc that would allow normal operating cycles of the ceramic filters between cleanings, so this plan was abandoned, and the bleach feed resumed.

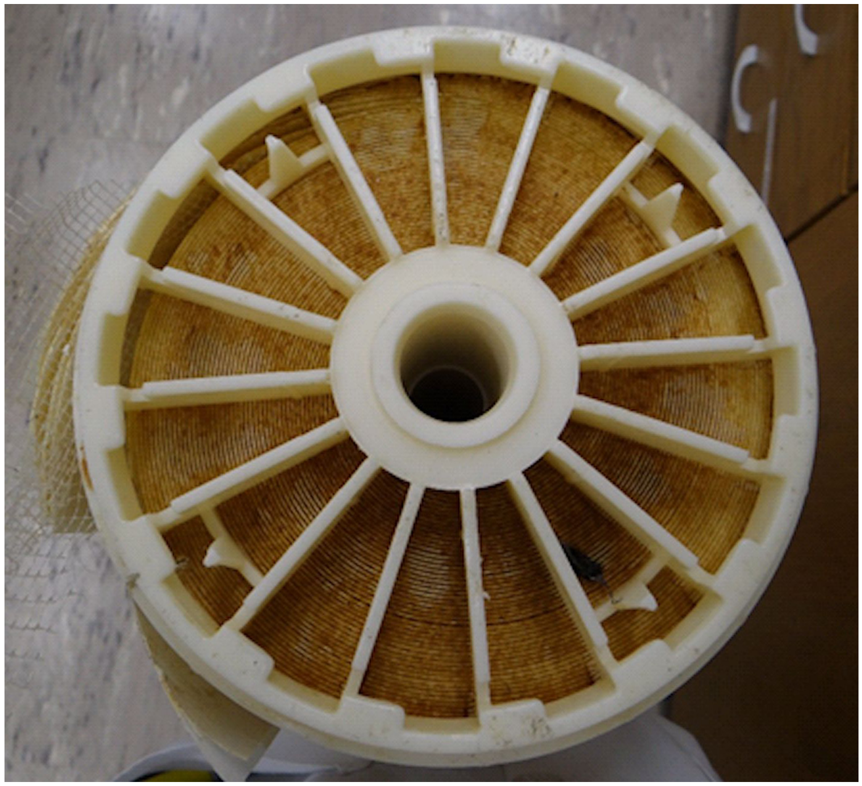

Figure 3. Water contaminants that passed through the RO prefilters and collected on the RO membranes.

Feed Plan #2. The bleach feed remains on at the water plant inlet, and the bisulfite feed for dechlorination was moved to just upstream of the forced draft decarbonator. The decarbonator would oxidize the sulfite to sulfate, to prevent it entering the RO as nutrients for any microbes, and the MCA was fed after the decarbonator before the RO.

After a short time, another problem was noticed, in that the 1 µm RO prefilters were plugging rapidly with brown material that looked like rust. This required frequent changes of these prefilters, with the added cost of the filters and labor to change them. A filter was removed and the residue analyzed, with the following findings of deposit compositions:

- 69% iron oxide
- 11 % silica
- 6 % calcium
- 5% aluminum
- 34% organics

Infrared analysis also showed an amide was present in the organic residue, which likely was originating from the coagulant polymer, which is a polyamine. This was forming a gel on the RO prefilters.

The iron oxide was from rust coming from the fill material in the decarbonator. The rust originated from the large carbon steel filtered water storage tank. It appears the sulfite feed to the decarbonator was causing this rust to be released from the fill material. Figure 3 shows some of the small amount of this material that passed through the RO prefilters and collected on the RO

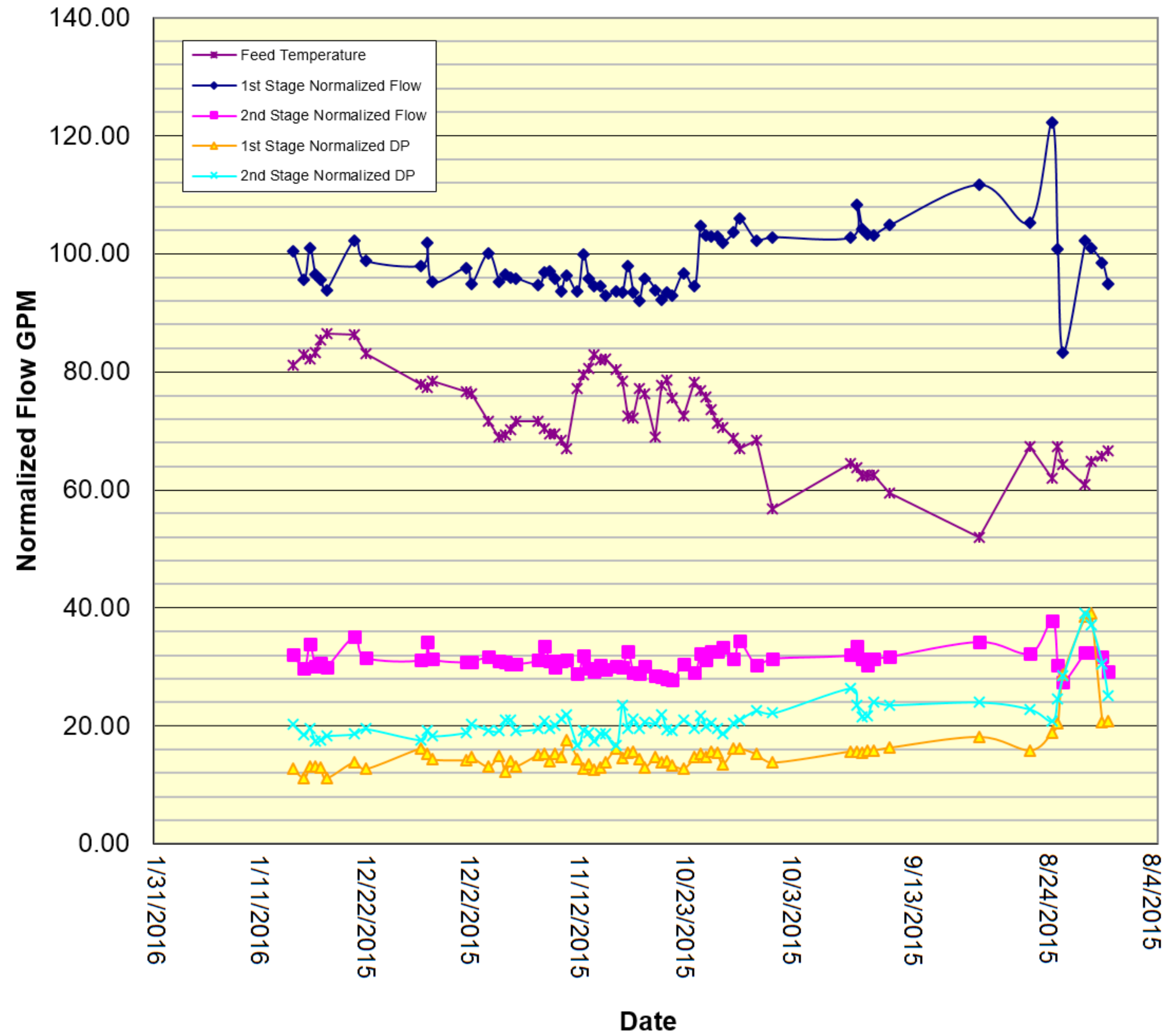

Figure 4. Data showing the RO differential pressure since the use of MCA.

membranes.

Changes made— Plan #3. Because of this problem of residue accumulation, the following changes were made. The fill material was removed from the decarbonator to eliminate this as a source of iron oxide. And, the feedrate of the coagulant polymer was reduced from 10 ppm to 2 ppm, so there would be less of this to foul the RO. These changes stopped the accumulation of the brown residue, and the frequency of RO prefilter changes has returned to normal.

Project Results

Since the feed of MCA began in August 2015, RO dP has been stable for approximately 11 months, indicating biofouling appears to have been controlled, as shown in Figure 4. The light blue and yellow lines show normalized dP of the first and second stages. This performance has continued through the end of June 2016, although the graph ends in March 2016.

The spike in dP values at the right of the graph was due to temporary use of media filters. These were used because of a severe rain and turbidity event that exceeded the ability of the ceramic filters to remove sediment. Note that dP values decreased once the ceramic filters were back in use, and have remained stable since then. Previously, major increases in RO dP would occur approximately every six months. The MCA feed has been maintained at approximately 0.5 mg/L at the RO (total chlorine), with zero free chlorine. There has been no indication of RO damage because of oxidation from the MCA, although no membrane has yet been removed for exam, as membranes are performing well. Permeate flow and water purity have remained normal.

As this feed is continuing, the ultimate service life extension of the RO membranes is yet to be determined, but as the cause of RO replacement in the past has been foulants that could not be removed by cleaning, longer service is now expected.

The feed of non-oxidizing biocide has been stopped, eliminating that cost, which offsets the cost of the MCA. Extended intervals between RO membrane replacements will be a net cost savings.

MCA's Effect on DI Resin

As a precaution against the MCA oxidizing demineralizer resins in the downstream packed bed and mixed vessels, a small bisulfite feed was added after the RO, before the packed bed. This feed was stopped about March 2016. In April 2016, after a regeneration of the packed bed and return to service, the resistivity of the downstream mixed bed decreased from 17 megohm-cm (0.056 µS/cm conductivity) to about 5 megohm-cm (0.2 µS/cm conductivity).

Numerous investigations and analysis were performed, including resin analysis for fouling, total organic carbon (TOC) analysis of the water, etc. All analysis values were within the normal ranges. This issue was temporary, and is believed due to the MCA removing biofouling from the piping between the RO and the packed-bed demineralizer. Once this was removed and then regenerated off the resins, the mixed bed returned to normal.

Sulfite feed has been resumed as a precaution; however, all demineralizers have been operating normally without it.

Acknowledgement

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Endnote

[A]The proprietary treatment selected by plant personnel was Buckman's Oxamine® technology, which produces a pure form of monochloramine.

Author Robert Mitzel has worked in the fossil utility industry for 39 years, as a chemist, central lab supervisor, and corporate chemist. He has experience with steam-cycle chemistry, problem solving, water treatment processes, and trace analysis. Mr. Mitzel has worked at Central Illinois Public Service, Ameren, and now Dynegy.

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