DES MOINES WATER WORKS
Board of Water Works Trustees

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2201 George Flagg Parkway | Des Moines, Iowa 50321-1190 | (515) 283-8700 | www.dmww.com

MEMORANDUM

DATE: May 9, 2016

TO: William Stowe, CEO and General Manager

FROM: Dan Klopfer, P.E., Engineering Services Manager
Nathan Casey, P.E., Project Manager

SUBJECT: Nitrate Removal Report

Nitrate concentrations in Des Moines Water Works' (DMWW) raw water supplies continues to be one of our top water quality concerns. Over the last few years, DMWW has experienced both record high nitrate concentrations and record number of days needing additional nitrate removal. This troubling trend forced staff to begin reviewing new nitrate treatment technologies and preparing for a future of higher raw water nitrate concentrations. In May 2015, staff retained the services of CH2M Hill, an internationally known engineering consulting firm, to assist in evaluating nitrate options.

History

In 1989 and 1990, DMWW exceeded the Environmental Protection Agency's (EPA) Maximum Contaminant Level (MCL) of 10 mg/L for nitrate in drinking water. Design of the Nitrate Removal Facility (NRF) began in 1989 with construction taking place in 1990-1991. Without the NRF, DMWW would have violated the nitrate MCL many times in subsequent years.

Short-Term Health Effects

The primary short-term health hazard of drinking water with nitrate occurs when nitrate is reduced to nitrite in the digestive system. Until infants reach an age of six months, their digestive system secretes lower amounts of gastric acid causing a higher pH level than found in healthy adults. Adults with certain digestive difficulties can also experience reduced stomach acidity. In both cases bacteria capable of converting nitrate to nitrite can proliferate.

Nitrite oxidizes iron in the hemoglobin of the red blood cells to form methemoglobin, which lacks the oxygen-carrying ability of hemoglobin. Excess methemoglobin causes a condition known as methemoglobinemia, commonly called blue baby syndrome, in which blood lacks the ability to carry sufficient oxygen to vital body tissues. Lack of oxygen in the blood stream causes the veins and skin to appear blue. In severe, untreated cases, brain damage and eventual death can result from suffocation. Infants are more at risk from drinking water nitrate poisoning due to a reduced ability to convert methemoglobin back to hemoglobin.

Long-Term Health Effects
Little is known about the long-term effects of drinking water with elevated nitrate levels. Some research suggests that nitrate may play a role in the development of some cancers in adults. The magnitude of the cancer risks are unknown at this time and additional research is required to verify these links and identify any other potential nitrate-related risks.

Health Standards and Criteria
The Environmental Protection Agency (EPA) has established a Maximum Contaminant Level (MCL) and a Maximum Contaminant Level Goal (MCLG) for nitrate (measured as nitrogen) of 10 mg/L. The MCL is set to protect the most sensitive population, infants, from blue baby syndrome due to nitrate exposure. The MCLG is established at a level which is judged to have no known, or anticipated, adverse health effects over a lifetime of exposure.

Nitrate History and Future Trends
Extensive nitrate laboratory testing exists for both the Raccoon and the Des Moines Rivers. Daily sampling for nitrate concentration started in 1974 for the Raccoon River and 1982 for the Des Moines River. A detailed review and analysis of this data looking at average concentration, average concentration during nitrate season, and yearly maximum concentration was performed. The data demonstrated that between 2005 and 2014 the Raccoon and Des Moines Rivers exceeded 10 mg/L of nitrate (as nitrogen) 22 percent and 14 percent of the time, respectively.

By examining the average and maximum nitrate concentrations in the Raccoon River, it is observed that nitrate concentrations have increased over the past 40 years both on an annual basis and during the peak nitrate months (April through June). The annual increase, based on a linear trend between 1974 and 2015, is 0.06 mg/L of nitrate (as nitrogen) for the average and 0.09 mg/L of nitrate (as nitrogen) for the maximum when the full year is analyzed. The annual rate of increase, over the same period, for April through June based on linear tends is 0.10 mg/L of nitrate (as nitrogen) for the average and 0.08 mg/L of nitrate (as nitrogen) for the maximum.

Based on a linear trend between 1982 and 2015, the average and maximum nitrate concentration increase for the Des Moines River is approximately 0.04 and 0.12 mg/L of nitrate (as nitrogen) per year, respectively. The average annual and maximum nitrate increase, over the same period, in April through June is approximately 0.11 and 0.13 mg/L of nitrate (as nitrogen) per year, respectively.

Taking into account the uncertainty associated with projecting nitrate concentrations, using good engineering practices, and a conservative approach for a 20-year planning horizon, a design maximum nitrate (as nitrogen) concentration for both the Raccoon and Des Moines River was established. For the Raccoon and Des Moines River a maximum nitrate concentration is projected to be 30.0 mg/L and 25.2 mg/L of nitrate (as nitrogen), respectively. The maximum nitrate concentration is important as it dictates the treatment requirements for the worst projected event.

In order to determine how much nitrate removal capacity is needed at each plant, a model was constructed to include the projected increase in nitrate concentrations along with projected water demands. This model was used in sizing the alternative nitrate treatment options.

Lake Source Water Assessment
DMWW has been using lakes at the L.D. McMullen Water Treatment Plant to mitigate the nitrate concentration of the Raccoon River for several years. In 2015, DMWW performed a lake sampling program of several lakes. The intent of this program was to quantify how much nitrate reduction the lakes could provide along with addressing other lake related water quality concerns. The sampling program included Crystal Lake, Maffitt Reservoir, Bishop Farms Lake, Hallett Lake, Gray's Lake, and the Fleur east and west infiltration ponds. Based on the results of the sampling program, with proper lake management, Crystal Lake, Bishop Farms Lake, and Hallett Lake could provide the McMullen Water Treatment Plant with 35 million gallons per day (mgd) of low nitrate water when the nitrate concentration in the Raccoon River is 30 mg/L. Proper lake management includes aeration, destratification, and chemical addition.

Nitrate Removal Alternatives
Several alternatives were evaluated to comply with the nitrate MCL and ensure safe drinking water for all customers. These alternatives included ion exchange, reverse osmosis, electrodialysis reversal, biological denitrification, wetland treatment, and additional riverbank filtration. These options were reduced in favor of detailed evaluation of ion exchange, wetland treatment, and additional riverbank filtration.

Anion exchange is a relatively simple, moderately priced alternative for nitrate removal which is currently being used in the existing NRF. The process uses a resin to exchange nitrate for a different ion on the resin surface. It was projected that in order to maintain a treatment capacity of 75 mgd at the Fleur Drive Treatment Plant, a total of 40 mgd of ion exchange would be needed. This alternative was not deemed viable due to the cost of operation along with the difficulty and cost of waste disposal.

The second alternative evaluated was surface flow wetland treatment. Wetlands remove nitrate through a natural biological process known as denitrification. Wetland denitrification is well understood and easily modeled. It was estimated that for Fleur Drive Treatment Plant to continue to meet the nitrate MCL under future demand projections and nitrate trends, a total of 50 mgd of wetland would be required. Unfortunately, there is insufficient land available to construct a natural wetland capable of treating the peak Raccoon River nitrate concentration of 30.0 mg/L. For this reason and intensified, or optimized, treatment wetland was evaluated. In order to optimize the treatment wetland, an additional carbon source will be added during times of peak nitrate concentrations. The idea is that the carbon source will increase natural microbiological activity thus increasing the treatment efficiency. In this way it is projected that an 80 acre wetland at the west end of Water Works Park would be able to provide 45 mgd of low nitrate water. Because this is a relatively unproven concept, DMWW is currently constructing a pilot wetland to test this alternative. Because the wetland alternative alone is unable to meet the required treatment capacity, provides no treatment of gallery water, and may not be reliable year round, an expansion of the existing nitrate removal facility was included in this project.

The highest quality water available to the Fleur Drive Water Treatment Plant is from the Infiltration Gallery System. Augmenting the water supply to provide additional gallery quality water is an obvious benefit. The gallery also provides some mitigation of the river nitrate concentration, but is at times over 10 mg/L of nitrate (as nitrogen). Additional ground water at the Fleur Drive Treatment Plant was evaluated by looking at constructing a parallel infiltration system or radial collector wells. If additional ground water is used, additional nitrate removal would also be required during times when ground water nitrate is high. In order to continue to provide 75 mgd of safe drinking water from Fleur Drive with augmented groundwater, 30 mgd of ion exchange would also be needed.

Nitrate Waste Disposal Alternatives
Waste from the NRF is currently sent to the Raccoon River. Based on the Board of Trustees' intent to no longer return removed nitrate to the river, a new waste disposal alternative was needed. Disposal of ion exchange waste is extremely difficult due to the dissolved nature of the pollutants. An initial technology screening of disposal options included sanitary sewer discharge, land application, wetlands treatment, brine reverse osmosis treatment, evaporation ponds, solar ponds, crystallization, spray drying, and deep well injection. These options were further reduced to sanitary sewer disposal, membrane treatment of brine, and solar ponds. In the end, sanitary sewer disposal with evaluation of alternative chemical regeneration was selected.

Summary of Fleur Drive Water Treatment Plant Implementation Plan
Based on future water demand and nitrate concentration projections, a plan was developed to allow the Fleur Drive Water Treatment Plant to produce 75 mgd in the summer during a peak nitrate concentration of 30 mg/L. The primary treatment method will be a 45 mgd wetland with an expansion of the existing NRF to 20 mgd. In addition, DMWW will continue to maximize the performance of existing low-nitrate sources by completing an ongoing condition assessment of the gallery and performing tests in an attempt to maximize gallery production.

Summary of L.D. McMullen Water Treatment Plant Implementation Plan
Based on future water demand and nitrate concentration projections, a plan was developed to provide the L.D. McMullen Water Treatment Plant with 35 mgd of low nitrate water. This plan includes capital projects to utilize Crystal Lake, Bishop Farms, and Hallett Lake to reduce river nitrate concentration prior to the plant. The included projects are the Crystal Lake Pump Station, the new pretreatment facility at L.D. McMullen Water Treatment Plant, and lake improvement to provide for proper lake management.

Summary of Saylorville Water Treatment Plant Implementation Plan
The treatment technology at the Saylorville Water Treatment Plant already has the ability to remove nitrate from the source water. It is expected that any expansion of the Saylorville Plant will continue to use this technology, or a similar technology, to maintain compliance with the safe drinking water act.

Summary of Project Costs and Schedule
The current capital improvement plan (CIP) includes budgets totaling $77,061,976 for nitrate compliance at the Fleur Drive and McMullen Water Treatment Plants. These funds are scheduled to be spent between 2016 and 2022. The CIP is scheduled to be updated this year to include updated costs from the final nitrate report and more detailed costs for what is learned during pilot testing.