University of Minnesota Morris Digital Well

11-19-2013

City of Morris - Chloride Discharge Assessment

Kelly Asche
Center for Small Towns (UMM)

Sharice Fontenot
University of Minnesota, Morris

Sam Lee
University of Minnesota, Morris

UNIVERSITY OF MINNESOTA MORRIS

"Believing in a bright,
prosperous future
for small communities."

The Effects of Chloride from Waste Water on the Environment

November 19, 2013

Prepared for the City of Morris

Prepared by the Center for Small Towns
University of Minnesota, Morris
In collaboration with Morris Office of Sustainability
Project supported by University of Minnesota | Institute on the Environment

Sharice Fontenot and Sam Lee – Report
Kelly Asche – Staff Lead

Table of Contents

The Effects of Chloride from Waste Water on the Environment

Introduction to the Problem

The purpose of this project is to measure the amount of chloride being deposited into the Pomme de Terre River due to household water softening units. Morris drains its water from sewage treatment ponds into the Pomme de Terre River. This action doesn’t just cause issues locally; the Pomme de Terre River watershed deposits all that enters it elsewhere, draining an area of 875 square miles in agricultural regions of Minnesota, and eventually flowing into Marsh Lake on the Minnesota River.

Figure 1: Morris Sewage Treatment Ponds

Morris has five sewage stabilization ponds that work as a system. Sewage is transmitted to the first pond and then starts to settle, then is moved to one of the four other settling ponds to do its final settling. The pond is then cleared to be released into the Pomme de Terre River system. After the pond is drained, new wastewater is pumped into it to start the process all over.

Proper water quality is crucial to the protection of the natural habitats of fish, bugs, bird, and plant communities. To protect the river from harmful pollutants, the Minnesota Pollution Control Agency (MPCA) recently presented a new regulation on chloride levels in sewage treatment plants. This new regulation aims to secure the health of Morris’ ecosystems.[1]

Chloride is categorized as a pollutant for many reasons. Chloride is necessary for water habitats to thrive, yet high levels of chloride can have negative effects on an ecosystem. Chloride may impact freshwater organisms and plants by altering reproduction rates, increasing species mortality, and changing the characteristics of the entire local ecosystem. In addition, as chloride filters down to the water table, it can stress plant respiration and change the quality of our drinking water. The City of Morris is seeking to take action on the problem of chloride pollution in order to protect its water and environment.

---

[1] The 1972 amendments to the Federal Water Pollution Control Act (known as the Clean Water Act or CWA) provide the statutory basis for the NPDES permit program and the basic structure for regulating the discharge of pollutants from point sources to waters of the United States (NPDES.)

Morris is required by law to comply with MPCA standards for water quality.[2] The MPCA's chloride standard for sewage treatment ponds is 230 milligrams per liter (mg/L.) Morris's sewage ponds have a chloride level of over 700 mg/L. In order to comply with the new regulations, the City of Morris has been working to understand the source of the high chloride levels in its wastewater treatment plant. This report represents a part of those efforts. By complying with MPCA regulations, Morris will not only avoid possible future legal penalties, but also create better water quality in the river for everyone to enjoy.

What is creating the problem?

A main cause of this issue of pollution is the usage of home water softeners. Morris has heavy limestone layers in its aquifer, which deposit minerals into the water that reaches residents, giving Morris its "hard water." Hard water means the water is high in minerals. These minerals affect the taste of water, as well as pipes in residences and home appliances. Softened water reduces the formation of hard water scale which encrusts water heaters, hot water pipes, shower heads, and water-using appliances. This scale can cause premature maintenance and failure. Therefore, water softening is an essential process for Morris residents, as Morris's water is about 40-45 grains of hardness per gallon, one of the highest rates of water hardness in Minnesota.

Water softeners use salt to separate minerals from water. The primary salt utilized in home water softeners is sodium chloride (NaCl), a naturally occurring and commonly used substance. NaCl (commonly called "table salt") normally breaks down into sodium (Na+) and chloride (Cl-) ions. The used salt from water softeners is discharged into the city's sewage system, which eventually returns to Morris's sewage ponds, and ultimately, the Pomme De Terre River.

It is important to understand that households are not the only contributors to this issue. Much of the land in and around Morris is utilized for agricultural production. Oftentimes, agricultural waste contributes to pollution. Agricultural waste can contain biological waste, solid waste, hazardous waste, universal waste, and used oil. Chloride can be found in any of these waste streams. Morris also has industries which discharge brine water, containing chloride, every day.

Observation and Experimentation

The City of Morris tested the sewage ponds' chloride content in 2012. The results were as follows:

Date	Chloride Concentration
April 18, 2012	727 mg/L
April 20, 2012	732 mg/L
April 26, 2012	686 mg/L
May 4, 2012	708 mg/L
Average Chloride Concentration	713.2 mg/L

[2] The Pomme de Terre River is classified under Class 2 Receiving Water, and the City of Morris is required to follow Minnesota Rule 7050.0222's chronic standard and lower its chloride levels.

The data shows that the average chloride concentration of the sewage treatment ponds in Morris during this time period was 713.2 mg/L. Center for Small Towns performed additional chloride level testing experiments by titration. Four samples from Morris Sewage Ponds #1 and #5. The average chloride content was 745.25 ppm or mg/L (See Appendix A.) From the available data and model testing results, it appears that Morris's sewage treatment ponds' average chloride concentration level is over 700 mg/L, which is over three times the MPCA standard of 230 mg/L.

Center for Small Towns was asked to build a model to estimate the chloride amounts that are discharged to treatment ponds by residents, depending on the number of meter connections in each household, and amount of water used. This model does not take into account other factors that may contribute to the final chloride concentration in sewage treatment ponds, such as industrial water usage; this fact may cause the model's results to be higher or lower than the actual chloride concentration in sewage treatment ponds. However, the Center took care in creating as accurate of a model as possible. To build an accurate model, Center for Small Towns used the Morris community's water usage data. In 2012, there were 1,515 meter connections and 159,043,523 gallons of water sold. Average residential water usage in 2012 was about 8748 gallons per month. Center for Small Towns also took into account efficiency ratings for water softeners, depending on their age. This information was attained through a local business, EcoWater, which assisted in developing estimates on both low and high-efficiency water softeners.[3]

For this model we assumed that, on average, one person uses 80 gallons of water every day, and three people share one meter connection. It is also important to note that 60.66% of salt is chloride. Center for Small Towns modeled two test cases. In Test Case #1, it was assumed that 90% of Morris residents use high-efficiency water softeners.

Water Softener Type	**Percent of Residents Using This Type**	**Number of Meter Connections for this Type**	**Amount of Salt Used Monthly by this Type**	**Total Monthly Salt Usage by Morris Residents**	**Total Monthly Chloride Pollution from Residents**
Low-efficiency	10%	151.5	360 pounds	152,712 pounds	838 mg/L
High-efficiency	90%	1,363.5	72 pounds		

In Test Case #1, the model calculates a total concentration of 838 mg/L of chloride (discharged from residents) in Morris sewage treatment ponds.

In Test Case #2, the model assumptions were changed to 50% percent of Morris residents using high-efficiency softeners, and 50% using low-efficiency. The model calculates a total concentration of 1,483 mg/L of chloride (discharged from residents) in Morris sewage treatment ponds.

[3] According to our source from EcoWater, high-efficiency water softeners use 80% less salt than low-efficiency water softeners. High-efficiency water softeners use 1 pound of salt to soften 5,000 grains of hardness. 50 grains of hardness is found in every 1 gallon of water. High-efficiency water softeners need 120 gallons of water to recharge.

Water Softener Type	Percent of Residents Using This Type	Number of Meter Connections for this Type	Amount of Salt Used Monthly by this Type	Total Monthly Salt Usage by Morris Residents	Total Monthly Chloride Pollution from Residents
Low-efficiency	50%	757.5	360 pounds	327,240 pounds	1,483 mg/L
High-efficiency	50%	757.5	72 pounds		

These experiments provided data that explains only *residential* chloride discharges. Other factors take part in contributing to the final chloride level in the ponds themselves. Such factors can include: rainwater, waste water treatment plant evaporation, and commercial chloride waste.

Center for Small Towns then modeled the amount of salt usage required to meet the MPCA's regulation. According to the model, residents' salt usage has to be 72% lower to meet the regulation. Assuming that 10% of people use low-efficiency softeners and 90% use high-efficiency softeners, then the average salt usage per month for a low-efficiency softener would be 100.8 pounds, and a high-efficiency softeners' average salt usage per month would be 20.16 pounds. Total salt used by Morris residents would therefore be 42,760 pounds. The final chloride concentration based on only residential water usage would be 234.50 mg/L. This solution would require residents to use less than a third of the water that they currently use, which is impractical, and it does not factor in commercial water use. The concentration of the actual sewage treatment ponds would be higher than 234.50 mg/L when factoring in commercial use. It is uncertain how much higher that number would be, though. However, the data clearly demonstrates that even if every resident of Morris used high-efficiency water softeners, chloride pollution levels would still not meet MPCA standards.

Possible Solutions to the Problem

There are several possible solutions for the chloride pollution challenge. The city could pass new regulations or laws about old or low-efficiency water softeners. As shown in our data, using high-efficiency softeners and putting less salt in softeners can help lower the city's chloride level. The data also reveals, however, that the responsibility of lowering chloride levels cannot be taken on solely by residents' private use of water. Successfully meeting the MPCA's new standard is highly likely to require a combination of solutions.

It is possible to treat hard water before it reaches residents. This is often done by building a central water treatment plant. To explore solutions for this project, Center for Small Towns contacted the engineer that worked on the Breckenridge, MN water treatment plant. The information we received was from a contact at Advanced Engineering and Environmental Services, Inc. Similar to Morris, the City of Breckenridge dealt with a "hard water" problem. However, they are now using lime softening technology to soften the community's water. As a result, the city dramatically reduced the chloride level in their sewage ponds.

Lime softening usually consists of the steps of chemical feed, rapid mix, flocculation, sedimentation, and re-carbonation. This process is a way to remove minerals from hard water without disposing of those minerals into sewage treatment areas. The time and money it takes to construct or upgrade a regular water treatment plant into a lime softening water treatment plant depends upon many variables. Such variables include: where the plant will be located, the ability to upgrade an existing plant, and considerations regarding how the untreated water should be "plumbed" into the water treatment plant. It may take between 16 months and 20 months to construct a new water treatment plant (See Appendix B.)

Besides lime softening, there are other softening processes available for consideration. Membrane softening, or split treatment with reverse osmosis are two alternatives. However, these alternatives could produce their own waste. In some situations, these processes may be more feasible than lime softening. Further review would be needed for a community the size of Morris.

In the event of building a new water treatment plant, some residents would still prefer to use water softeners, but the concentration of chloride that the wastewater system would receive would be significantly lower with the water being "pre-softened" through lime softening or other water treatment technologies before it reaches residents. The amount of salt used per month to soften home water would drop significantly, and a large portion of the community would likely get rid of their softeners once they needed to be replaced or upgraded.

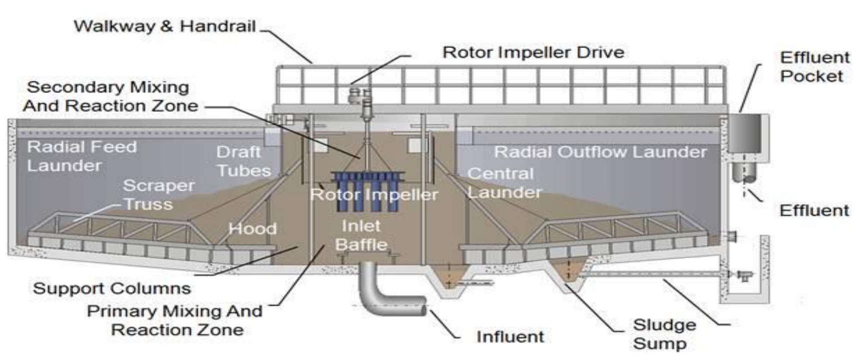
The challenge facing Morris is demanding, but with careful consideration of the data and possible solutions provided, it is possible to preserve the quality of Morris's water, meet MPCA standards, and sustain a healthy Pomme de Terre River.

Appendix A – Chloride Titration Experiment Procedure

A. Materials Needed
   i. Chemicals
      1. Silver nitrate solution of known concentration
      2. Sodium chromate indicator
      3. Water samples for analysis
   ii. Equipment
      1. 24-well wellplate
      2. 2 graduated-stem plastic pipets
      3. Small stirring rod or toothpick
      4. 2 small beakers or other containers for silver nitrate (AgNO3) and water
      5. Piece of white paper
B. Experiment Procedure
   i. Collect water samples at sewage ponds.
   ii. Practice doing chloride titrations with tap water and silver nitrate.
   iii. Titrate the collected water samples with silver nitrate.
   iv. Calculate the concentration of chloride in the collected samples.
   v. Compare class data for different water samples.
   vi. Draw conclusions about human impact on the local aquatic environment.
C. How to Calculate the Concentration (Molarity) of Chloride
   i. Molarity of chloride = molarity of silver nitrate × number of drops of silver nitrate ÷ number of drops of water sample
D. Experiment Result
   i. Center for Small Towns has tested four samples from Morris Sewage Pond #1 and #5. The average chloride content was 745.25 ppm or milligrams per liter.

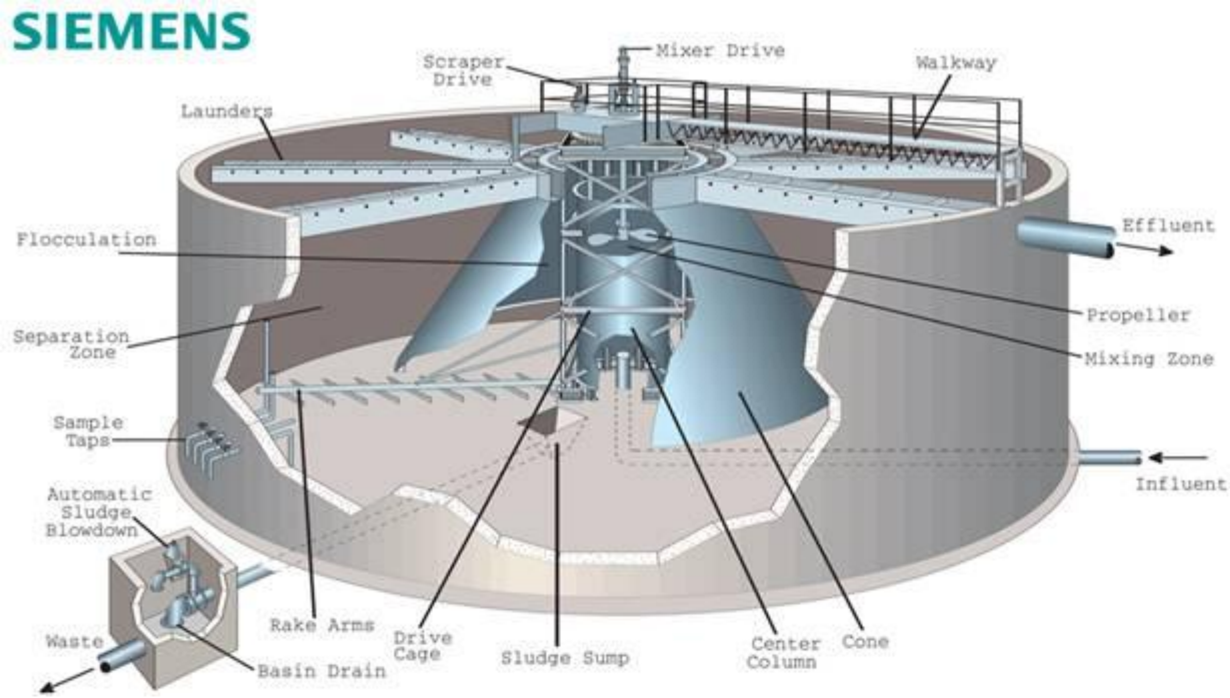
Appendix B – Lime Softening Details

The process of lime softening can work in different ways. Lime and lime-soda ash softening design is presented in Section 4.4 of *Ten States Standards*. Lime and lime-soda ash softening usually consists of chemical feed, rapid mix, flocculation, sedimentation, and re-carbonation. The lime softening processes may be categorized as single-stage, two-stage, or split-treatment processes, the latter two of which require two softening sedimentation basins. Single-stage softening is ideal for removal of carbonate hardness (calcium and magnesium associated with bicarbonate ions.) The addition of soda ash to the single-stage process will remove some non-carbonate hardness (calcium and magnesium associated with chloride and sulfate ions.) Two-stage and split-treatment processes accomplish both carbonate and non-carbonate hardness removal effectively using two basins in a series. The second sedimentation basin is primarily to accomplish the non-carbonate hardness removal. Greater chemical efficiency is achieved and chemical costs are reduced by using the split-treatment process when raw water magnesium concentrations are high. In split-treatment, the entire lime dose (excess) is applied to only the fraction of the total plant flow that passes through the first stage. When split-treatment is used, the bypass line around the first stage should be sized for the total plant flow, and a means of measuring and splitting the flow must be provided. Solids go through type rapid mix and flocculation, and sedimentation equipment is typically used for softening. Design requirements are presented in Section 4.1.5 of *Ten States Standards*. Examples of solids contact clarification systems by Degremont Technologies and Siemens are shown in Figure 1.1 and Figure 1.2. The units should be designed for the maximum daily demand adjusted for desired plant operation hours. It is recommended that lime be fed directly into the rapid mix zone. This rapid mix zone should have a hydraulic detention of 30 seconds or less and a velocity gradient sufficiently large to ensure rapid dispersion of the chemical and sludge solids. The flocculation equipment speed and/or pitch shall be adjustable, provide coagulation in a separate chamber or baffled zone, and provide flocculation and mixing of at least 30 minutes. A minimum slurry concentration of one percent must be maintained, but typically such units maintain slurry concentrations exceeding two percent. A means of providing sludge recycling to the rapid mix should be included in the solids contact units' design.



Courtesy of Infilco Degremont, Inc.

Figure 2.1) Solids-Contact Clarification System - IS Accelerator by Degremont Technologies



Courtesy of Vessco, Inc.

Figure 2.2) Solids-Contact Clarification System - Contraflow by Siemens

Ten States Standards also recommends the use of sludge concentrators and sludge removal for solids contact units. Sludge concentrators should be either internal or external designs, which obtain a concentrated sludge with a minimum wastewater. A total water loss of three percent is considered acceptable for softening units. The minimum solids concentration in the waste sludge is typically at least five percent by weight. Mechanical sludge removal equipment should be provided in the solids contact units. Large basins should have at least two sumps for collecting sludge located in the central flocculation zone. Sludge removal pipes must be at least three inches in diameter, arranged to facilitate cleaning and operator observations, and with valves located outside the tank. Upflow velocities should not exceed 1.75 gpm/ft^2 of effective tank plan area measured at the slurry separation line. Weirs should be spaced so that maximum horizontal travel of water across the surface to the collection trough is 10 feet. Weir height shall be adjustable, and weirs shall be at least equivalent in length to the tank perimeter. Weir loadings shall not exceed 20 gpm per foot of weir length. *Ten States Standards* also provides for the use of inclined tubes or plate settlers within the solids contact units to allow increased hydraulic loads.

Re-carbonation of the lime-softened water is required to stabilize the water chemistry. Section 4.8 of *Ten States Standards* presents the re-carbonation process design requirements. Adequate detention time for re-carbonation is necessary to ensure the chemical reaction between the carbon dioxide and the water is complete. *Ten States Standards* recommends a minimum detention time of 20 minutes, but this is assuming the use of a gas type carbon dioxide chemical feed system. If a carbonic acid pressurized solution feed system is used, the required chemical reaction time between the solution and the water is much less than with a gas carbon dioxide system. In carbonic acid pressurized solution feed systems, the majority of the chemical reaction (99.9 percent) takes place within three minutes of the carbonic acid injection. pH probes should be located near the injection point of the carbonic acid solution in the re-carbonation basin in order to maintain close control of the pH and stabilize the water within this three minute period. *Ten States Standards* also recommends that two compartments be provided in the re-carbonation basin. The first compartment (mixing compartment) should have a depth of at least 7.5 feet to provide adequate submergence on the diffuser and have a detention time of at least three minutes. The second compartment (reaction compartment) should provide adequate detention to complete the reaction. Where liquid carbon dioxide is used, adequate precautions must be taken to prevent carbon dioxide from entering the plant. The tank shall have provisions for draining and removal of sludge.

Within Section 5.1 of *Ten States Standards* there are design requirements outlined for lime and soda ash feeders and storage facilities. Separate feeders are required for lime and for soda ash. If automated controls are used, manual override shall be provided. The chemical feed rates should be flow proportional to the flow stream being dosed. Provisions to be considered when installing lime and soda ash chemical feed equipment also include: (1) locating the equipment within a separate room because of potential dust problems, (2) making the equipment readily accessible for observation/service, (3) measuring of the dry chemicals either volumetrically or gravimetrically, (4) providing adequate solution water and agitation, and (5) providing gravity feed from the solution tank to the rapid mix zone through convenient lines of minimum length. Solution water should be metered and must be protected against backflow cross-connections. Space for dry chemical storage should be provided for 30 days of chemical supply, or a minimum of 1.5 truckloads, and allow for convenient and efficient chemical handling.

The amount of water that lime softening can soften depends on the raw water hardness and the goals the city establish for the water utility. If the raw water hardness is 600 mg/L and the goal is to reduce to 150 mg/L, the city would be removing 450 mg/L as $CaCO_3$ of hardness. 450 mg/L ÷ 17.1 grains per gallon per mg/L as $CaCO_3$ = 26.3 grains per gallon.

Construction materials typically used for water treatment plant are block, bricks, precast, and other construction materials. Single-story is not recommended for a water treatment plant, because of the depth of the basins required for lime softening. Storages are recommended for lime and chemicals.

Cost per million gallons per day (mgd) is probably between $4 and $5 per gallon. In other words, if the city has a 1.5 mgd lime softening water treatment plant it will cost between $6.0 million and $7.5 million to construct. There are some economies of scale as the city gets larger. For a 3.0 mgd lime softening water treatment plant, the values may be closer to between $3.75 and $4.75 per gallon. The Breckenridge area has constructed lime softening water treatment plants at costs as low as about $2.50 per gallon. However, that was about five years ago and the construction economy was very tight back then. This was also for a 6.8 mgd expansion (Bergantine.)

Works Cited

1. Bergantine, Brian R. "List of Questions about Lime Softening." Message to the author. 17 July 2013. E-mail.
2. "Clean Water Act." *National Pollutant Discharge Elimination System (NPDES)*. N.p., n.d. Web. 16 Aug. 2013. <http://cfpub.epa.gov/npdes/cwa.cfm?program_id=45>.
3. "Minnesota Pollution Control Agency." *What Is a Watershed?* Minnesota Pollution Control Agency, n.d. Web. 16 Aug. 2013. <http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/watershed-approach/what-is-a-watershed.html>.

University of Minnesota, Morris Center for Small Towns
The mission of the Center for Small towns is to focus the University's attention and marshal it's resources toward assisting Minnesota's small towns with locally identified issues by creating applied learning opportunities for faculty and students. For more information about the Center for Small towns and its other programs, please give us a call or visit our Web page.

Center for Small Towns
University of Minnesota, Morris
600 East Fourth Street
Morris, MN 56267
320-589-6451
ummcst@morris.umn.edu
centerforsmalltowns.org

Center for Small Towns

University of Minnesota
MORRIS