Impacts of Water Softening on Chloride in Minnesota Waters

University of Minnesota: Department of Civil, Environmental and Water Resource Center
Fortin Consulting
MPCA

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University of Minnesota
Driven to Discover℠
Presentation outline

- Salt and chloride background
- Chloride sources
- Our project
- Work to date
- Preliminary recommendations
- Impacts of other water treatment devices
Salt and chloride background
Chloride impacts

- Human health
- Pets
- Wildlife
- Aquatic life
- Vegetation
- Soil
- Infrastructure
Chloride and water quality

• Chronic water quality standard for chloride is (aquatic) **230 mg/L**
  – Equal to 1 tsp of salt in 5 gallons of water

• Chloride accumulates in water - it doesn’t degrade

Images courtesy of Fortin Consulting
Chloride impairments in Minnesota

- **Statewide**
  - 45 total chloride impairments

- **Twin Cities**
  - 39 total chloride impairments
    - 19 lakes
    - 4 wetlands
    - 16 streams
Ground Water

EPA drinking water standard is 250 mg/L

Source: TCMA Chloride Management Plan, MPCA
Sources of chloride
Major sources of chloride

Winter salt

Softening salt
Salt use is increasing in Minnesota

- 349,000 tons of salt per year used for winter maintenance in TCMA
- “water softener use is also a significant source of chloride”

(Novotny et al. 2008)
Other sources of chloride

- Industrial salt use
- Fertilizer
- Human excreta
- Precipitation
- Weathering
Chloride from municipal wastewater

Home

WWTP

Lake, Stream or River

Saline Layer

Shallow Groundwater

Deep Groundwater

Chloride from municipal wastewater
Chloride from on-site wastewater

- Home
- Drain Field
- Shallow Groundwater
- Deep Groundwater
- Percolation
- Lake, Stream or River
- Saline Layer
Chloride from road salt

Salt Application → Snowmelt → Pavement → Infiltration → Shallow Groundwater → Deep Groundwater → Percolation → Surface Runoff → Lake, Stream or River → Flushing

Saline Layer
Chloride sources

Winter Maintenance Activities
- Roads
- Parking Lots
- Driveways
- Sidewalks
- Salt Storage

Other
- Dust suppressants
- Fertilizers
- Land application

Municipal and Industrial Wastewater Sources
- Municipal wastewater
- Municipal water treatment
- Industrial wastewater

Residential Water Softeners

Surface Runoff → Lakes & Streams → Direct Discharge → Groundwater

Publicly Owned Treatment Works

Septic Systems
Salt is used to recharge resin

Salt brine removes hardness minerals and regenerates resin
Our project and its objectives
Project

• University of Minnesota and Fortin Consulting
• Funded by LCCMR
• 3-year project timeline
• 3 main activities
Activity 1 (Year 1):
Estimate statewide chloride use

• Conduct statewide surveys on softening
• Regional case studies
• Estimate overall chloride use for water softening
Activity 2 (Year 2-3): Develop water softener BMPs

- Compare various options for reducing hardness in water
  - Private and municipal options
  - Efficiency of various units
  - Non-chloride options

- Framework and fact sheets for private landowners, municipalities and watersheds to make smart decisions about reducing their chloride load
Activity 3: Transport pathways

How Do Soils Hold Chloride?

In the soil **moisture** and pores

Outcome:
Model chloride movement in soils

Brine Supply (Softening and Deicing)

Freshwater Supply (Deicing only)
Research and preliminary findings
Activity 1: Estimating softening salt use

- Literature review
- Project outreach and meetings
- Gathering data
- Develop analysis approach
- Survey
MPCA wastewater data browser

• Effluent monitoring data
  – Municipalities
  – Industries

• Monitoring values
  – Flow
  – Chloride

https://commons.wikimedia.org/
Wastewater effluent data findings

- In 2013, 76% of 880 chloride monitoring points across municipalities exceeded the limit of 230 mg/L
- In 2013, 81 of 111 municipal facilities with monitoring data exceeded the standard over half of the time
Chloride sources in municipal effluent

- Water softeners
- Human excreta
- Drinking water background chloride
- Infiltration (road salt)

https://commons.wikimedia.org/
Characterizing statewide water softener chloride contributions
Survey of plumbers and water conditioning professionals

- Developed with Fortin Consulting
- Pilot in January 2017 with MWQA
- Conduct in January 2017
Survey of plumbers and water conditioning professionals

• Questions about:
  – Training and setting water softener
  – Prevalence of water softener types across regions
  – Salt use by softener type
Create “hardness regions”

- Apply region-specific estimates of:
  - Prevalence of softener use
  - Softener types
  - Chloride use

- Data sources: MPCA, survey
Hardness regions

**Soft water**: dark blue

**Moderately hard to hard water**: blue-green

**Very hard water**: yellow-green, yellow, orange, red
Characterizing chloride sources in municipal effluent

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<th>Data source?</th>
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<td>Census, survey results</td>
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<td>Excreta</td>
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<td>Drinking water background chloride</td>
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<td>Infiltration (road salt)</td>
<td>Statistical analysis of MPCA effluent monitoring data</td>
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Variation in seasonal concentrations (2013)

Chloride concentration (mg/L)

- Long Prairie WWTP
- New Prague WWTP
- Albertville WWTP
- Pelican Rapids WWTP
- Rochester WWTP

Graph showing the variation in seasonal chloride concentrations for different wastewater treatment plants from January to December 2013.
Estimating non-point source chloride contributions

<table>
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<td>Published fertilizer application estimate(s), DNR land cover dataset</td>
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<td>Precipitation</td>
<td>National Weather Service, National Atmospheric Deposition Program</td>
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Assessing results

• Compare statewide estimates using:
  – USGS Salt Yearbook data
    • Most recent: 2013
    • Salt imported into Minnesota
    • National estimates of salt used for water conditioning, road salt, fertilizer, etc.
  – MN Department of Agriculture fertilizer data
  – Groundwater monitoring data from MPCA
Preliminary recommendations
Reduced salt usage from softeners

- Iron pre-filter
- Pre-filter for high chlorine water
- Water conservation
- Do not soften water used in landscaping
- Alternative technologies (de-scalers)
Preliminary recommendations

• Chloride reductions can be achieved through:
  – Using demand-based regeneration softeners instead of timer-based units
  – Checking the softener resin and settings
  – High-efficiency softeners for industrial users

• *But are these reductions enough to meet the standard?*
Preliminary recommendations

• Centralized softening is an option, but has challenges:
  – Centralized lime softening is expensive
  – It may not fully “soften” water
  – Households may continue using their softeners

• Use of wastewater funds to upgrade drinking water treatment facilities
What can you do?

• Encourage
  • use of high efficiency
  • water conservation
  • maintenance
Preliminary recommendations

• Chloride reductions can be achieved through:
  – Using demand-based regeneration softeners instead of timer-based units
  – Checking the softener resin and settings
  – High-efficiency softeners for industrial users

• But are these reductions enough to get municipalities into compliance…?
Preliminary recommendations

• Centralized softening is an option, but has challenges:
  – Centralized softening is expensive
  – It may not fully “soften” water
  – Households may continue using their softeners

• Use of wastewater funds to upgrade drinking water treatment facilities
  – Lincoln-Pipestone, Morris
Impacts of other treatment devices on septic systems
SSTS impacts from treatment devices

- Water softener
- Reverse osmosis
- Iron filter
- Kidney dialysis effluent
Water softener impacts

• Debate exists about impacts
• It is a fact that water softener brine regeneration discharges change the consistency and chemistry of the wastewater stream
• Studies with septic tanks have shown that the high concentration of salt introduced by slugs of backwash brine cause salt stratification in the tank, which inhibits the ability of solids and FOG to stratify
Water softener impacts

• Sodium concentrations greater than 3,500 mg/L have been reported to inhibit anaerobic digestion

• Chloride concentrations greater than 180 mg/L have an inhibitory effect upon nitrifying microorganisms

• Chloride concentration in regenerate can reach into the 10,000 mg/L range, with sodium in the 6,000 mg/L range
Recent WQA study

• Laboratory study

• Results:
  – Use of efficiently operated water softeners (at or above \(~3000\) gr/lb salt efficiency) improves septic tank performance
  – Use of very inefficient home softeners (at or below \(~1000\) gr/lb salt efficiency) may have a negative effect on solids discharge to the drain field
Water softener impacts

• Manufacturers void warranties
  – Many manufacturers of wastewater treatment systems have clauses in their warranties voiding the warranties if water softener backwash brine is discharged to the treatment system
Water softener discharge options

- Replace old units to reduce discharge amount and concentration
- Route out of system:
  - Separate drainfield/rock pit
  - Surface
Reverse osmosis is a technology that is used to remove a large majority of contaminants from water by pushing the water under pressure through a semi-permeable membrane.
Reverse osmosis

- **Point of Use**
  - Under the sink
  - Lower volume

- **Point of Entry**
  - Whole house system
  - Greater volume
Reverse osmosis loading

• Ranges from 2-4+ gallons wasted per 1 gallon purified
• Can add a significant load to system
Effluent options

- During design this clean water could be included in design or
- Discharge can be directed to a different location
  - Surface – challenges with freezing
  - Subsurface – stay above water table
Iron filters

- Iron in water may cause taste, staining and accumulation problems in the plumbing system
How do iron filters work?

- Oxidation followed by filtration
- Oxidation converts soluble contaminants during a chemical reaction to a product that can be mechanically filtered out
- These particles are removed from the filter during the backwash cycle
Iron filter discharge impacts

• It is uncertain what happens to backwashed particles:
  1. They settle out in the sludge layer of the septic tank and will increase the need for maintenance
  2. During times of turbulence or if sludge depths get too thick this material may travel through the septic tank to downstream components
  3. In the anaerobic environment of the septic tank the insoluble iron is converted to soluble iron going into solution and traveling out of the septic tank and downstream
What should be done with discharge?

- **Preferred**: Install a separate soil treatment system for regeneration water which includes a septic tank to settle out the solids (trench bottom must be above the periodically saturated soil or bedrock and trench must meet water supply well setbacks)

- **Secondary option**: Discharge to the surface not directly into a surface water, wetland or intermittent stream (must stay on the property and not cause erosion or nuisance conditions)

- **Less-preferred** - Installed a larger septic tank (double the capacity is the recommended minimum) with an effluent screen and alarm and clean the septic tank annually evaluating sludge levels
Kidney dialysis

- Dialysis is a treatment for kidney failure that removes waste and extra fluid from the blood, using a filter
- Two types:
  - Hemodialysis (HD): Where blood is taken out of the body through a complex set of tubes, run through a filter called a dialyzer, cleaned off various impurities, and returned back to the patient
  - Peritoneal Dialysis (PD): a synthetic tube is placed in the abdominal cavity which then allows dialysis by exchange of dialysis fluid at regular intervals
Dialysis impacts

• The effluent from both types of dialysis has been shown to damage septic systems and should not be discarded to septic systems

• It will add additional water and contaminants the septic system is not designed to treat/remove and can negatively impact the beneficial microbes needed to treat the wastewater
Dialysis impacts - HD

- Reverse osmosis (RO) reject water clean should be reused or applied to the surface
- Post dialysis effluent has a high concentration of sodium and chloride (over 3,000 mg/l for both)
  - Can alter, kill, or to cause unwanted and incorrect organism overgrowth in the septic tank and downstream and negatively impact concrete
  - Contains small amounts of glucose (1 mg/L reported by one company).
- Though the typical duration for individual patient varies, it is done every day with each individual session duration ranging from 3-6 hours is typical using around 100 gallons per week
Dialysis impacts - PD

- **PD influent** for the patient has a glucose concentrations ranging from 1.5 – 4.25% glucose (1.5gm/100ml of glucose = 15gm/L or 15,000 mg/L - 4.25% PD fluid contains 42,500 mg/L)

- Depending on the system, 40-50% of the glucose is absorbed by the patient so this generates BOD in the effluent

- PD is done every day for 6-8 hours with 6 cycles every day generating approximately 25 gallons per week of effluent.

- The high glucose content of PD effluent can also promote the formation of a co-polymer that can coat the surface of the soil and can block the lateral lines
Dialysis effluent – where should it go?

• Determine what kind of system are they using and request a report on the amount of RO water and effluent characteristics

• Currently many patients are told to drain their bags into the toilet and follow the effluent with a cupful of bleach

• Check local regulations and preferably the effluent from dialysis should be discharge below the ground into a shallow rock pit or chamber
References


Questions?

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