Chloride and Sulfate Water Quality Values Implementation Plan

1. Introduction

The Michigan Department of Environment, Great Lakes, and Energy (EGLE) developed water quality values (WQV) for chloride and sulfate in August 2019. This implementation plan provides the background on the development of the WQV and next steps for implementation as part of the National Pollutant Discharge Elimination System (NPDES) Permit Program.

EGLE staff formed a workgroup and invited representatives from a range of sectors having the potential to discharge chloride or sulfate to surface waters to provide input on addressing these pollutants. The sectors represented on the workgroup included drinking water treatment, wastewater treatment, road agencies, food processors, mining operations, and water resources commissioners. Input from the workgroup was used to inform this plan.

2. Chloride and Sulfate Impacts to Water Quality

The federal Clean Water Act (CWA; 1972) established an objective of restoring and maintaining the chemical, physical, and biological integrity of the nation's waters. Important to that goal, the CWA established the basic structure for protections and rules related to the maintenance and restoration of water quality. Each state or tribe with delegated authority is required to adopt water quality standards (WQS) for all surface waters: in Michigan this means our streams, rivers, ponds, lakes, wetlands, and Great Lakes. The United States Environmental Protection Agency (USEPA) reviews and approves/disapproves the states' and tribes WQS. Michigan's Part 4, Water Quality Standards, promulgated pursuant to Part 31, Water Resources Protection, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended (NREPA), was reviewed and approved by the USEPA.

An important component of the WQS is the development of numeric criteria, which are specific concentrations of various potentially toxic substances below which there are no anticipated effects on human health or animal health either in, or near, the water. Michigan has developed numeric values for approximately 300 substances, including recently for chloride and sulfate. These numeric values for chloride and sulfate provide a long overdue benchmark for continued protection of aquatic life. Both chloride and sulfate have been shown to be present in lakes and streams around Michigan, sometimes in high levels (Figure 1); without WQV the ability to understand possible impacts to aquatic life wasn't readily available. Chloride and sulfate can have significant harmful effects on aquatic life, such as freshwater mussels, various aquatic stages of insects, fish, and other organisms living in Michigan waters. Effects can range from impacts on growth and reproduction to the ability to survive.

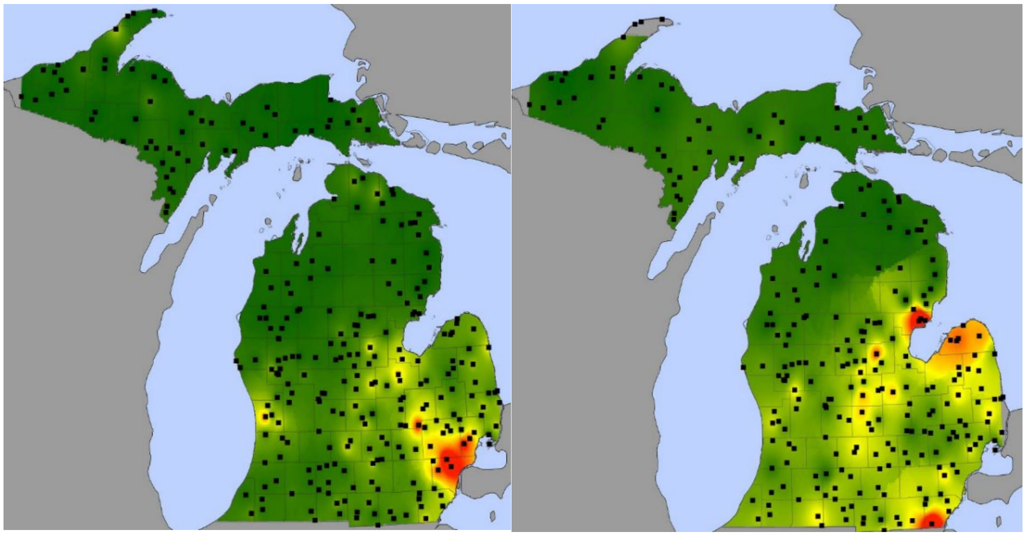


Figure 1.
Inverse Distance Weighting Interpolation map of chloride (left) and sulfate (right) samples from streams showing relative concentrations (red is highest), 2005-2014.

Report: Michigan.gov/-/media/Project/Websites/egle/Documents/Programs/WRD/GLWARM/Monitoring-Watershed/Statewide/statewide-water-chemistry-2018-2019.pdf
Appendices: Michigan.gov/-/media/Project/Websites/egle/Documents/Programs/WRD/GLWARM/Monitoring-Watershed/Statewide/statewide-water-chemistry-2018-2019-appendices.pdf

Additionally, the development of WQV specific to chloride and sulfate help to simplify implementation of Michigan's Total Dissolved Solids (TDS) Rule (Rule 323.1051 of the Part 4 WQS). The chloride and/or sulfate component of TDS are typically elevated when TDS is most toxic to aquatic life, with WQV developed to address the elevated levels. By focusing on the toxic components, the TDS Rule is now able to be implemented more consistently and simply in the NPDES permit program by using technology-driven effluent limits when a discharger is determined to be "controllable" to meet the TDS rule.

The criteria within the WQS are developed to protect water quality which, in turn, supports the various "designated uses" of our waters. The designated uses reflect the values and functions important in our lakes, rivers, streams, and wetlands; the ability to support aquatic life and wildlife, recreation, irrigation and industrial water use, navigation, and fish consumption. Certain waters are also additionally protected for public water supply and coldwater uses. Designated use support is the goal of establishing criteria; the demonstration that the function and integrity of Michigan's waters are maintained. The chloride and sulfate values allow Michigan to move a step closer to supporting our aquatic life designated uses and protecting our water resources more fully.

3. Chloride and Sulfate WQV Development

WQV development starts with a review of published toxicity studies (and occasionally unpublished studies that followed standard methods) that exposed a resident freshwater aquatic organism to multiple concentrations of a substance and whether the acute (e.g., mobility and survival) and chronic (e.g., survival, growth, and reproduction) test results from the study are acceptable to use in the derivation of aquatic life values. The broader the variety of aquatic organisms and more data, the greater the confidence in the value developed and more protective of the range of naturally occurring aquatic life. The datasets used for the development of chloride and sulfate values were extensive, each containing multiple fish species, and numerous invertebrates including snails and mussels, insects, and zooplankton. WQV development follows Rule 323.1057 of the Part 4 WQS, which describes the process used to calculate human health, aquatic life, and wildlife-related chemical-specific values. This process is used for all toxic substance value development in Michigan and, as part of Michigan's WQS, was public noticed and has been reviewed and approved by the USEPA.

The WQV were developed using known and acceptable studies on toxicity of chloride and sulfate, including recently published studies on sensitive invertebrates, specifically freshwater insects and mussels. The resulting thresholds are different than those developed by other states because more recently available data on sensitive species that are in Michigan waters was considered to be protective of Michigan's aquatic life.

WQV are relevant to ambient water monitoring programs by providing benchmarks against which to compare data to aid in identifying problems and set water quality goals. Similarly, WQV are necessary to ensure permitted discharge effluent limits are protective of the designated uses in the receiving waters as well as helping identify areas where additional focus on treatment or other controls are needed. In these ways the development of WQV or updating WQV with new data are a critical step in protecting human health and aquatic life in Michigan's rivers, streams, lakes, and wetlands. Because chloride and sulfate values were developed with the most recent toxicity data, it is anticipated that additional updates to these values will not be needed in the foreseeable future absent additional relevant toxicity data.

3.1 Final Chloride and Sulfate WQV

Michigan finalized acute and chronic aquatic life values for chloride and sulfate in August 2019. Acute values protect against impacts to aquatic life based on short-term exposure, particularly relevant to wastewater discharges; the Aquatic Maximum Value (AMV) (half the final acute value) is the value protective of short-term exposure impacts in ambient surface water. The AMV is relevant to monitoring programs analyzing surface water samples but is not used in the NPDES program. Chronic values are protective against impacts due to longer-term exposure. Both Acute and Chronic values are used in the NPDES program to develop water quality-based effluent limits (WQBEL). Acute values are reflected as daily maximum limits in permits, and chronic values are used to calculate monthly average limits reflecting some mixing with background drought flow, as applicable.

The following values are in micrograms per liter (ug/L), or parts per billion:

Pollutant	Final Acute Value (ug/L)	Aquatic Maximum Value (ug/L)	Final Chronic Value (ug/L)
Chloride	640,000	320,000	150,000
Sulfate	1,200,000	600,000	370,000

4. Municipal and Industrial Wastewater NPDES Permits

Water Resources Division (WRD) staff will evaluate TDS, chloride, and sulfate final effluent results in accordance with the following processes for municipal and industrial wastewater facilities This section does not apply to stormwater discharges from regulated Municipal Separate Storm Sewer Systems (MS4).

4.1 TDS

A TDS controllability demonstration will continue to be required for all NPDES permittees, except municipal wastewater treatment plants (WWTP), when existing or new use effluent quality is expected to exceed WQS. This demonstration will be submitted as part of NPDES permit reissuance, during a new use NPDES permit application request, or as part of the in-effect NPDES permit. The TDS controllability demonstration will identify if there are reliable treatment processes that can help reduce the TDS discharge, and if available are they cost-effective based on flow rate, concentration, and other applicable factors. The TDS controllability demonstration will be reviewed by WRD, Permits Section staff to determine whether the facility has taken all feasible and prudent steps to reduce TDS, including treatment and source reduction/reuse where appropriate. Based on review of the demonstration, the discharge can be considered “uncontrollable” and therefore consistent with Rule 323.1051 (Rule 51) of the WQS. Note that if the discharge is considered “uncontrollable”, chloride or sulfate requirements may still apply consistent with Rule 323.1057 (Rule 57) of the WQS. Appendix A. illustrates the process of evaluating both Rules 51 and 57.

For municipal WWTP NPDES permits, a TDS controllability demonstration is not required as TDS will continue to be considered uncontrollable. Rule 51 will continue to be implemented to address discharges of TDS, but only for controllable TDS discharges.

4.2 Chloride and Sulfate

Individual point source chronic and acute wasteload allocations for chloride and sulfate will be developed in accordance with the Part 8 Rules, (Water Quality-Based Effluent Limit Development, promulgated pursuant to Part 31, Water Resources Protection, of the NREPA) Rule 323.1209, Development of wasteload allocations for toxic substances. Wasteload allocation is defined as the allocation for an individual point source developed in accordance with Rule 323.1209 and which ensures that the level of water quality to be achieved by the point source complies with all applicable WQS.

NPDES wastewater permits that, at the time of reissuance, do not include monitoring requirements for chloride or sulfate, will include a monitoring requirement for chloride and sulfate for the full term of the next permit. The permit will specify the sample type, analytical method, and quantification level that shall be used for the collection and analysis of chloride and sulfate.

NPDES wastewater permits that, at the time of reissuance, already include monitoring for chloride and/or sulfate and generate sufficient final effluent results (i.e. at least 50 sample results), will be evaluated using the reasonable potential analysis consistent with the Part 8 Rules, Rule 323.1211, Reasonable potential for chemical-specific WQBELs. Reasonable potential analysis is the process used to determine whether a discharge, alone or in combination with other sources of pollutants to a waterbody and under a set of conditions arrived at by making a series of reasonable potential assumptions, could lead to an excursion above an applicable water quality standard.

If there is no reasonable potential in accordance with the Part 8 Rules, Rule 323.1211, monitoring will continue in the reissued NPDES permit at a frequency of no greater than monthly for the full term of the permit unless sufficient information is available to determine that a lesser monitoring frequency is warranted or no monitoring is needed. The permit will specify the sample type, analytical method, and quantification level that shall be used for the collection and analysis of chloride and/or sulfate.

If there is a reasonable potential in accordance with the Part 8 Rules, Rule 323.1211, limitations for chloride and sulfate will be included in the reissued NPDES Permit. If compliance cannot be achieved upon the effective date of the NPDES permit, a compliance schedule will be included that specifies the date the limitation(s) will go into effect. In addition, the permit will specify the sample type, analytical method, and quantification level that shall be used for the collection and analysis of chloride and sulfate.

Compliance schedules may be included with any final effluent limitation(s) for chloride and sulfate if applicable and will be in accordance with the Part 8 Rules, Rule 323.1217, Compliance Schedules. A compliance schedule, up to five years, before the limit(s) become effective may be established in the NPDES Permit. It is EGLE’s intention to provide adequate time to allow evaluation of sources, source removal before a limitation goes into effect, and possible treatment upgrades.

4.3 Compliance Options

There are a variety of options available to address chloride and sulfate, that will vary based on site specific conditions at each facility. Compliance options include installation of treatment, optimization of existing treatment, implementation of best management and good housekeeping practices, source reduction practices, dilution of higher concentrations in accordance with federal regulations, and employee education. Appendix B. provides information on treatment options for reducing the discharge of chloride and sulfate. For municipal WWTPs, a specific indirect industrial discharge to the collection system that has a high chloride discharge may be targeted for source reductions. A municipal WWTP may also consider installation of a community drinking water system that uses lime-softening if drinking water is currently treated by residents with on-site water softeners.

Variances submitted by individual NPDES permittees will also be a compliance option for permittees unable to achieve compliance with the final effluent limitations. Variance requests will be evaluated in accordance with the Part 4 Rules, Rule 323.1103, Variances (Appendix C). Variance requests will require a demonstration to be completed by the permittee in accordance with Rule 323.1103. If a variance is approved for chloride and/or sulfate by WRD, the NPDES permit will also include requirements for a Pollutant Minimization Program (PMP). For municipal WWTPs, the PMP may include an education program for residents to soften their water to a lesser degree (e.g. 90-100 parts per million hardness instead of complete softening) or a water softener rebate program. In addition, it is EGLE's hope that the water softening industry continues to develop the methods and/or equipment to reduce the chloride discharge to the sewer system.

A PMP will include the following:

1. An annual review and semiannual monitoring of potential sources of chloride and/or sulfate.
2. Quarterly monitoring for chloride and/or sulfate in the influent to the wastewater treatment system.
3. A commitment by the permittee that reasonable cost-effective control measures will be implemented when sources of chloride and/or sulfate are discovered. Factors to be considered shall include significance of sources, economic considerations, and technical and treatability considerations.
4. An annual status report that includes all minimization program monitoring results for the previous year, a list of potential sources, a summary of all actions taken to reduce or eliminate the identified sources.

The goal of the PMP shall be to maintain the effluent concentration of chloride and sulfate at or below the WQBEL.

5. Chloride in Stormwater Discharges

In Michigan, road salt application is an important strategy for managing ice and snow for safe winter travel conditions. Although road salt use has doubled since 1975, road agencies in Michigan have reduced salt application rates per lane mile in recent years. Additionally, in the Upper Peninsula and Northern Michigan a sand-salt mix is used effectively. Even with these reductions, when snow and ice melt, the salt applied to paved surfaces washes into wetlands, lakes, and streams through stormwater conveyance systems. The salt from managing winter storm events combines with other sources of salt (e.g. water softener backwash and industrial discharges) draining to stormwater conveyance systems resulting in concentrations that may impact the quality of Michigan's waters.

> "We've actually reduced by about half the salt spread rates on our trucks, from 400 pounds of salt per lane mile to 200 pounds of salt per lane mile," he said.
>
> *Craig Bryson, spokesman for the Road Commission for Oakland County. Detroit Free Press April 2017.*

This section of the Implementation Plan will focus on strategies to reduce road salt application while continuing to provide safe travel conditions for the public. Pollutants associated with road and parking lot runoff are conveyed to surface water through storm sewers, roadside ditches, and direct sheet flow. These conveyances and structural controls associated with the road are considered part of an MS4. Parking lots may discharge directly to surface waters or connect to the MS4. The USEPA requires municipalities who own or operate an MS4 in a Census-defined regulated area to obtain an NPDES Permit authorizing the discharge of stormwater to surface waters. Michigan has over 300 MS4 permittees. The following types of municipal entities have regulated MS4s: state agencies, primarily the Michigan Department of Transportation (MDOT); county agencies, primarily Water Resources/Drain Commissioners and Road Commissions/Departments; cities; villages; townships; and school districts.

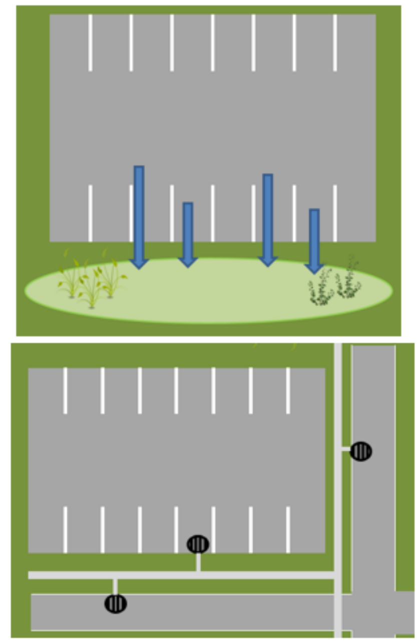


Figure 2.
Top: Sheet flow to surface waters
Bottom: Discharge to an MS4

The MS4 permit requires implementation of best management practices (BMP) to reduce the discharge of pollutants in stormwater runoff to surface waters. At this time, EGLE is not developing numeric effluent limits for chloride discharges from regulated MS4s as part of implementation, but instead will continue to focus on the implementation of BMPs as part of an overall chloride reduction strategy. This focus is consistent with the entire basis of the MS4 program.

MS4 permits currently include requirements to reduce the discharge of pollutants associated with cold weather operations, including salt application, salt storage, and strategic street sweeping to remove excess salt. Based on recent data, the current procedures developed and implemented by an MS4 permittee may not be sufficient to address the impacts of existing and future elevated chloride levels on aquatic life.

Runoff from roads and parking lots discharging to surface waters is often treated only through catch basins with a sump to collect sediment. As a component of salt, the chloride dissolved in stormwater is discharged without treatment to surface waters so the strategies shared within this section will focus on source control.

The workgroup discussed the potential for reducing the discharge of chloride in stormwater runoff through implementation of structural and non-structural BMPs focused on source control. The following BMPs should be considered to develop a balanced program that reduces chloride discharges to protect aquatic life and stormwater infrastructure and maintains safe winter travel conditions.

5.1 Salt Application

Salt application rates vary by applicator, equipment, and deicing strategy. For example, salt application rates for commercial parking lots may be elevated to address liability concerns even though a lesser amount of salt applied may be protective of public safety. In 2012, MDOT published their *Salt Bounce and Scatter Study Project Summary Report* (MDOT Study) with the findings from testing different application methods with the following goal.

"Salt is a very effective deicer, widely available and less expensive than other deicing options. However, the use of salt does have its drawbacks. Excessive application can adversely affect bodies of water and vegetation, and salt is corrosive to vehicles, bridges and other structures on or near the roadway. While salt is the cheapest deicer, its price has gone up significantly over the past decade. This puts even more emphasis on the need to use salt as efficiently as possible and apply it at the lowest effective rate possible."

High quality data on road and weather conditions should be used to inform a salt application strategy that considers opportunities to address the entire winter storm event. The following BMPs should be considered as part of a strategy to ensure salt is used as efficiently as possible while maintaining safe travel conditions.

- Anti-Icing – At the onset of the winter storm event (e.g. the day ahead of the projected storm) brine solutions can be applied to pre-treat roads. Anti-icing operations are conducted to prevent the formation of bonded snow and ice for easy removal and save time addressing conditions during the storm event.

- Pre-Wetting – Pre-wetting of salt before application allows it to better adhere to the road, minimizing bounce and scatter and extending the temperature range salt can be used effectively. The MDOT study recommended the following specific BMP:

  > "Due to the proven reduction of the bounce and scatter of salt that has been treated, it is recommended that all of the salt being applied to the Michigan trunklines be pre-wet with a liquid deicer, utilizing any of the following methods; stock pile injecting, batching, pre-wetting a loaded truck, pre-wetting with an onboard spray system or purchasing pre-mixed "enhanced" salt."

- During-Storm Direct Liquid Application (DLA) – Applying a brine solution during and after some storm events has been proven to optimize salt use and produce cost savings. DLA has been shown to minimize the storm response resulting in savings and often better post-storm road conditions to resume safe travel conditions. DLA has been found to require 50% less salt. Maintaining the brine solution (23% salt/ 77% water) and monitoring pavement temperatures are important considerations when using DLA.

- Reduced Speed – Applying salt at lower speeds reduces bounce and scatter and maintains salt on the road surface. The MDOT study evaluated how truck speed affects salt distribution. The study recommended the following specific BMP:

  > "Salt should be applied at the lowest reasonable speed possible and every attempt should be made to follow the MDOT guideline that all salt must be applied at speeds of 35 mph or below. Salt should be applied at 25 mph whenever possible."

5.2 Calibrating Equipment

Annual calibration of equipment is necessary to ensure proper application rates. Calibration procedures should be a part of a road agency's annual winter readiness program. A road agency should contact the equipment vendor to ensure proper calibration procedures are being implemented for the specific brand of equipment. Some case studies have suggested monthly calibration to ensure continued application at desired rates after measuring quantities at nearly double the intended amount.

5.3 Equipment Options

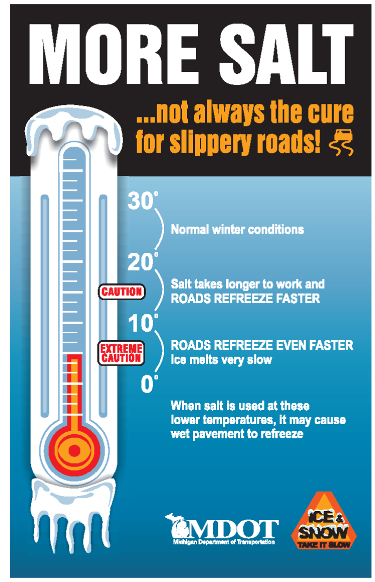
Automated spreaders allow operators to program salt application rates to change with ground speed. These programs can account for curves and hills that require more salt than flat or straight roads. Historically, salt application has been measured by lane miles; however, using GPS, the application rate can be tracked by coordinates allowing for a better understanding of specific application rates.

Two types of salt spreaders were evaluated as part of the MDOT study. MDOT concluded that pre-wetted salt applied close to the paved surface at lower speed (25 mph) resulted in reduced salt bounce and scatter. Other options, such as adding boots or sleeves to salt distributors or using more advanced techniques like salt slurry generators or zero-velocity spinners, can also be effective in reducing bounce and scatter of salt. Liquid-only applicators may also be used when DLA is implemented as part of the storm event response.

Modern plows are designed to more efficiently remove precipitation from the road to maintain ice-free conditions. For example, live edge plows have articulated segments that conform to uneven ground. Snow removal using this type of plow has helped to realize up to a 40 percent reduction in salt application in some areas. A flexible plow blade can also extend the life of the plow to assist with additional long-term savings.

5.4 Managing Mobility

During workgroup meetings, road agencies shared the public's expectation for pre-winter storm event travel conditions within two hours following the end of the event. These types of pressures can lead to excessive salting and, at times, ineffective salting. The Minnesota Department of Transportation was able to adjust its practice of maintaining bare pavement during a storm to maintaining bare lanes after surveying the public. MDOT has developed outreach using the phrase "More Salt…not always the cure for slippery road." The goal is to educate the public that normal winter conditions are considered between 20-30 degrees. When temperatures decrease below 20 degrees salt becomes less effective and the wet pavement may refreeze requiring extreme caution when driving.



Some municipalities have communicated adjusted salt application approaches with residents through social media and email distribution lists. A municipality may communicate a focused strategy of salting intersections and hills as a priority versus ineffectively salting.

5.5 Salt Storage Rules

Michigan has long been focused on salt storage as part of the Part 5 Rules, Spillage of Oil and Polluting Materials, promulgated pursuant to Part 31, Water Resources Protection, of the NREPA. The Part 5 Rules require secondary containment structures for one or more of the following scenarios:

- Solid Form Salt – Used, stored, or otherwise managed at any location at or above 5 tons.
- Liquid Form Salt – Used, stored, or otherwise managed at any location at or above 1,000 gallons.

The Part 5 Rules also require salt storage to be located at least 50 feet from the shore/bank of any lake, stream, or designed wetland. Secondary containment structures located within the 100-year floodplain must be designed and structured to remain effective during a 100-year flood. Loading areas should be covered or enclosed within the storage structure to prevent salt-contaminated runoff. Outdoor loading areas must be surrounded by curbing or graded to direct salt-contaminated runoff to an appropriate collection area for disposal. Catch basins located in loading areas should be covered during any outdoor loading and the area cleaned of all salt after trucks are loaded and dispatched.

For liquid brine storage, the secondary containment must be able to contain at least 100 percent of the largest tank capacity or at least 10 percent of the total volume of tanks within the containment area, whichever is larger. Secondary containment structures should be designed for access at all times.

5.6 Excess Salt Removal

Roads and parking lots should be swept to remove remaining salt prior to spring wet weather. Street sweeping and catch basin cleaning are requirements as part of the MS4 permit. Streets are often swept in the spring to remove sediment and other debris; however, a review of the schedule may be needed to ensure the timing of sweeping maximizes removal of residual salt. Additionally, salt discharged in error on a road or parking lot should be quickly addressed.

5.7 Education

Educational outreach was discussed as part of the workgroup meetings. Outreach with a focus on building awareness of instream impacts from elevated chloride could assist with beginning the conversation to change expectations among applicators, businesses, and the public. Ideally education would also be specific to the type of sector. For example, commercial applicators and businesses may need to understand the impacts of over- or improper application of salt balanced with liability concerns. Municipal officials may benefit from an approach using the concepts of asset management and the impact of salt on infrastructure to convey the importance of reducing salt discharges to the public. Metropolitan Planning Organizations or university outreach programs may be able to develop and provide this type of educational outreach and training.

Internal training is required as part of MS4 permits and couples well with annual calibration of equipment. An applicator may lack an understanding of the importance of chloride reductions outside of maintaining a similar application rate from year-to-year for budget purposes. A road agency can gather feedback from road crews and police jurisdictions on the effectiveness of BMPs on various roads and share this information with staff to make appropriate adjustments to future storm events.

5.8 Evaluation

As part of implementing the BMPs described above, an evaluation should be performed to understand effectiveness and inform adjustments. The Federal Highway Administration included the following recommendation in its *Manual of Practice for an Effective Anti-icing Program: A Guide for Highway Winter Maintenance Personnel*:

> "In addition to evaluations during a storm, it is beneficial for the personnel of each maintenance area to conduct a post-storm evaluation of the treatment effectiveness. This can help identify areas needing improvement and changes that can be made in the treatment strategy. A post-season review of treatment effectiveness is likewise helpful. It can help identify where changes are needed in equipment, material, and route configurations, and can begin a process of engineering an anti-icing program to fit the exact needs of a site or agency. It can also help identify where changes in personnel procedures and training are needed to improve the effectiveness of the winter maintenance program."

The County Road Association of Michigan reported that as a matter of daily business, county road agencies routinely evaluate storm event response effectiveness, time to restore travel conditions to normal, staff effectiveness, and use of equipment and deicing materials. This type of post-storm evaluation provides information that can also be reviewed as part of a post-season evaluation of effectiveness to identify opportunities to further reduce salt applications.

Road salt continues to be applied throughout Michigan on public and private paved surfaces, at times in excess of needed levels to ensure safe travel conditions. The road salt will persist and may remain in Michigan's waters creating a legacy effect by degrading water quality. Using the above BMPs to inform a salting strategy should lead to a balanced approach of reducing salt discharges and maintaining safe winter weather driving conditions.

EGLE would like to thank the following Chloride and Sulfate Water Quality Value Implementation Plan Workgroup members for their participation and input to inform this plan.

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Michigan Aggregate Association
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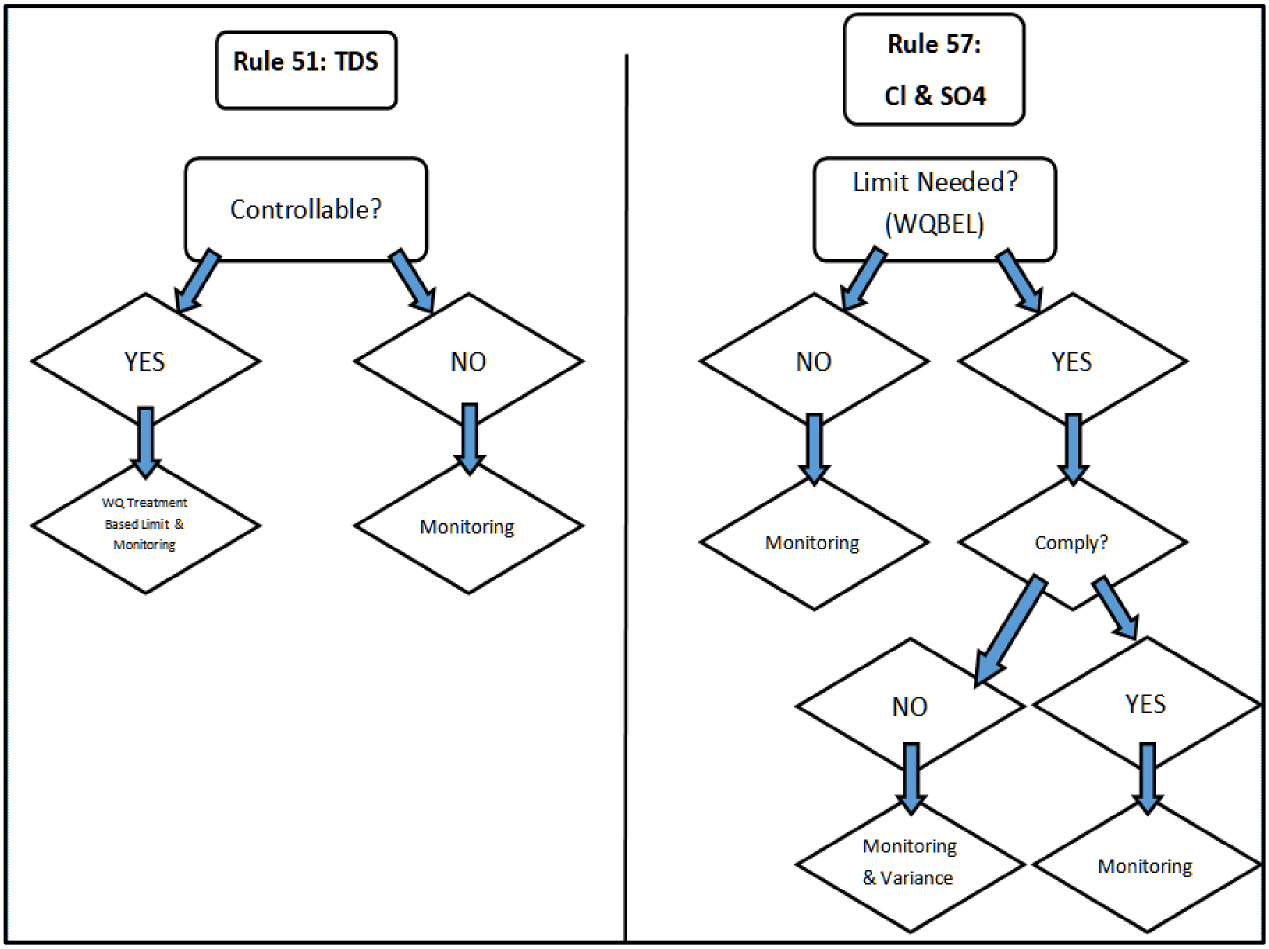
Brian Ross
Brian Van Zee

Mining Operations
Jennifer Nutini

Appendix A. Process for evaluating both TDS (Rule 51) and chloride and sulfate WQV (Rule 57) as part of NPDES permits



Appendix B. Treatment Memo

MICHIGAN DEPARTMENT OF ENVIRONMENT, GREAT LAKES, AND ENERGY

INTEROFFICE COMMUNICATION

TO: Christine Alexander, Manager, Permits Section, Water Resources Division

FROM: Daniel Schwanik, Industrial and Storm Water Permits Unit, Permits Section, Water Resources Division *Daniel Schwanik*
Jay Oh, Municipal Permits Unit, Permits Section Water Resources Division *Jay OH*

DATE: October 7, 2020

SUBJECT: Total Dissolved Solids Guidance for National Pollutant Discharge Elimination System Permitting

The purpose of this memo is to convey treatment technologies that might be feasible for removal of total dissolved solids (TDS), chlorides, and sulfates in wastewater. This is a cursory review developed to provide a base understanding of common treatment technologies. This memo is intended to serve as a reference for staff while reviewing feasibility and controllability determinations, determine if TDS reductions are required as a technology requirement (per Rule 51, Dissolved Solids, of the Part 4 Rules, Water Quality Standards, promulgated under Part 31,Water Resources Protection, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended [NREPA] [R 323.1051]; controllable/non-controllable), and determine if treatment or best management practices may help to meet water-quality based limits for chlorides and sulfates (per Rule 57, Toxic Substances, of the Part 4 Rules, Water Quality Standards, promulgated under Part 21, Water Resources, of the NREPA [R 323.1057]). Some treatment may be appropriate at lower flowrates, but not at higher flowrates. Due to the complexity and unique situations for various industries and individual facilities, this memo is not intended to be an all-encompassing document, and each facility should be evaluated on a case-by-case basis. This is a living document and is subject to change with time. This guidance document does not substitute for applicable statute and rules.

OVERVIEW

Several treatment technologies were investigated in order to determine feasible options for reduce TDS, Chlorides, and/or Sulfates in wastewater. The most commonly used treatment technologies used to reduce TDS, Sulfate and/or chloride from waste streams includes reverse osmosis (RO) and ion exchange. It should be noted that there is limited data available for the remainder of the treatment technologies' application to treat wastewater. A majority of the information available is relevant to the treatment of influent streams for potable drinking water plants, seawater desalination, or water to be treated for industrial applications (e.g. water for boilers). According to a United States Environmental Protection Agency (USEPA) document ("Section 2.306 Site Specific Water Quality Study for Chloride, Sulfate and TDS", August 30, 2006), the USEPA has no best available technology (BAT) for removal of chloride, sulfate, or TDS from wastewater.

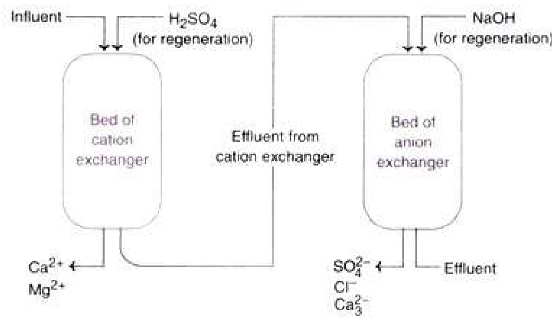
Factors considered while investigating treatment options include operational cost of treatment, capital cost of the installation of equipment, flow rate, and removal efficiencies. There are other engineering aspects to take into consideration. Most notably, concentrated waste streams (often referred to as "brine") require disposal or additional treatment. The following table is a brief summary of the feasibility and limitations for the treatment technologies which were investigated:

Treatment Technology	**Flow Rate**	**Max Influent Concentration of TDS**	**% TDS Removal**	**Capital Cost**	**Operational Cost**
Ion Exchange	5 - 10 $gal/ft^2 \cdot min$	< 5,000 mg/L	No Data	$0.28 - $1.21 per 1,000 gallons (Annualized)	$0.37 - $4.65 per 1,000 gallons
Clark's Method	No Data	No Data	No Data	> $100,000	$0.50 - $1.00 per 1,000 gallons
Distillation	2.6-85.8 MGD	> 45,000 mg/L	≤ 100%	$14,000,000 (0.5 MGD plant)	$2.65 - $12.11 per 1,000 gallons
Ion Electrosorption	< 10,000 gallons/day	3,000 – 6,000 mg/L	83%	No Data	$0.23 per 1,000 gallons
Reverse Osmosis	0.43-2.88 MGD	35,000 mg/L	95-99%	$45,000 - $2,000,000	$2.30 per 1,000 gallons
Membrane Biological Reactors	Up to 42 MGD	No Data	No Data	$0.75 - $6.00 per gallon of plant capacity	$0.30 - $0.55 per 1,000 gallons
Membrane Filtration	20 gallons per square foot per day (**GFD**)	36,200 mg/L	45-98%	$0.75 - $8.25 per gallon of plant capacity	$0.55 - $5.00 per 1,000 gallons

ION EXCHANGE

DESCRIPTION OF TECHNOLOGY

Ion exchange is a process in which dissolved ions from solution are replaced with other similarly charged ions from insoluble exchange material. Contaminant ions are adsorbed on an exchange medium. A synthetic plastic resin is usually used for the ion exchange medium, and its surface is designed as either cationic (positively charged) or anionic (negatively charged). The exchange medium is saturated with the exchangeable ion before treatment operations. The ionic contaminants are exchanged with the regenerant ions because the exchange medium has a higher affinity for the contaminant ions. When the resin reaches its exchange capacity, the resin is regenerated with a saturated solution, which resaturates the resin with the appropriate ions and restore the capacity.



Ion exchange is used in wastewater applications for the removal of nitrogen, heavy metals, and TDS. Both cationic- and anionic-exchange resins must be used in order to reduce TDS. The wastewater is first passed through a cation exchange resin where the positively charged ions are replaced by hydrogen ions. The effluent form cation exchanger is then passed through an anionic exchange resin where the anions are replaced by hydroxide ions. The reduction of TDS can take place in multiple columns connected in series, or both resins can be combined in a single reactor. Wastewater application rates range from 0.20 to 0.40 $m^3/m^2\cdot min$ (5 to 10 $gal/ft^2\cdot min$). Typical bed depths are 0.75 to 2.0 m (2.5 to 6.5 ft).

ENGINEERING ASPECTS

The main limitation with the ion exchange process is pretreatment requirements. Excessive influent total suspended solids can plug the ion exchange beds, causing high head losses and inefficient operation. The application of ion exchange is also limited because of concerns about the life of the ion exchange medium and the complex regeneration system requirements.

COST OF TREATMENT

Capital and operational costs for ion exchange can vary depending on flow rates, the type of pretreatment, resin replacement and disposal, the quality of the water, and

ION EXCHANGE

chemicals, and brine disposal or treatment. Reuse of spent regenerants allows to minimize waste disposal and reduce costs.

System Flow	< 0.5 MGD	0.5 - 5 MGD	> 5 MGD
Annualized Capital Cost ($/1000 gallons)	0.37 - 1.12	0.28 - 0.94	0.28 – 0.61
O&M Cost ($/1000 gallons)	0.60 – 4.65	0.46 – 1.25	0.37 – 0.87

FEASIBILITY AND NON-ENVIRONMENTAL IMPACT

ADVANTAGES

- Insensitive to fluctuating flow rates.
- Effluent contamination is almost impossible.
- Wide variety of specific resins are available.

LIMITATIONS

- Spent ion exchange resins require careful disposal.
- Potential for peaking of contamination in effluent.
- Pretreatment required.
- Sensitive to the presence of competing ions reducing ability of the resin to remove target contaminants.
- Limited applicability because the ion exchange process is not an economically viable treatment technology for removing TDS levels greater than 500 mg/L or sulfate over 50 mg/L.

CLARK'S METHOD

DESCRIPTION OF TECHNOLOGY

Clark's Method, also known as Clark's Process or lime softening, is a treatment which uses a hydrated lime slurry (calcium hydroxide) to remove hardness (calcium and magnesium) ions by precipitation. As lime is added to raw water, the pH is raised, and the equilibrium of carbonate species is shifted. Dissolved carbon dioxide changes into bicarbonates and then carbonate. This process reduces dissolved minerals in the water, as well as heavy metals and other elements. This causes calcium carbonate to precipitate due to exceeding the solubility product.

Lime softening substantially reduces TDS. Lime softening removes hardness and therefore TDS. Lime softening can also be used to remove iron, manganese, radium, arsenic, uranium, silica, fluoride, and certain organic compounds. Lime softening can also supplement disinfection and reduce algal growths.

This technology is typically used on an industrial scale to remove water from the influent in order to bring TDS to levels that will not harm equipment (e.g. boilers). It is also used in drinking water plants (to reduce hardness) in conjunction with other drinking water related treatment processes.

ENGINEERING ASPECTS

Lime softening is often combined with newer membrane processes to reduce waste streams. This process can be applied to the concentrate of membrane processes, thereby providing a stream of substantially reduced hardness and TDS, that may be used in the finished stream. Lime softening can also be used to pretreat membrane feed water.

Principal types of pretreatment used before lime softening are aeration (to remove carbon dioxide from groundwater where carbon dioxide concentrations are relatively high) and presedimentation (for plants treating high turbidity surface waters). These pretreatments are more likely to be employed in drinking water and industrial applications as there is not much information on lime softening being used as a wastewater treatment technology used to bring TDS to a level which would not violate water quality standards as a discharge to surface waters.

The lime softening equipment typically consists of a filter press, lime slakers to convert the mined lime into a hydrated lime slurry, clarifier, and pumps. One challenging aspect of lime softening is the operation and maintenance of lime feeders and lines carrying lime slurry to the point of applications. Also, plant operators must understand lime softening chemistry. Failure to maintain the proper pH could result in precipitation or excess lime in finished stream. The footprint of the equipment is substantial, and there must be a storage container constructed for the raw material (mined lime material).

CLARK'S METHOD

Water containing little or no noncarbonate hardness can be softened with lime alone. Water with high noncarbonate hardness may require both lime and soda ash to achieve the desired hardness.

The cost effect sulfate removal (CESR) process was developed to address the shortcomings of other technologies used for sulfate removal. The CESR process reduces the sulfate concentration in the wastewaters to less than 100 mg/L through the use of a proprietary powdered reagent.

After water is softened by the use of lime, the precipitated solids must be removed before the water can be used for its desired application (drinking water, boiler water, cooling water, or discharge to surface water). By using a filter press, lime slurry generated in clarifiers can be dewatered using pressure filtration. The resulting filter cake can be easily disposed of or even used in agricultural applications by farmers as a soil amendment.

COST OF TREATMENT

Cost of lime softening equipment is relatively expensive. According to a representative from MW Watermark, a lime softening equipment supplier based in Holland, Michigan, the cost for lime slakers can cost between $50,000 - $100,000, and the pumps can cost around $30,000. Cost estimates of the filter press equipment and clarifiers, which would likely account for a majority of the initial capital costs, were not readily available. The prices listed do not include engineering/design nor do they include installation.

Operating cost ranges from $0.50 per 1,000 gallons for larger plants (4.4 million gallons per day [MGD]) to $1.00 per 1,000 gallons for a relatively smaller plant (0.35 MGD).

FEASIBILITY AND NON-WATER QUALITY ENVIRONMENTAL IMPACT

Lime softening produces a large volume of precipitate (calcium carbonate and magnesium hydroxide) to be disposed. The precipitate can contain some organic matter flocculated out of the raw water. There are practical uses for the precipitate byproduct. In areas where there are abandoned coal strip mines, the precipitate can be pumped to abate serious stream pollution by neutralizing the acid water. For farming areas in which the soil pH is too low for plant growth, the precipitate can be land applied to adjust the pH of the soil to a level which promotes crop growth.

Advantages:

- Pretreatment typically not required.
- Relatively lower operational costs.
- Non-Landfill options for disposal of byproduct.

CLARK'S METHOD

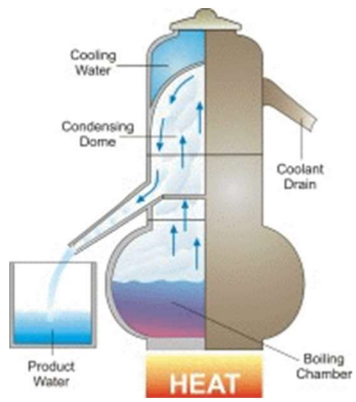
Limitations:

- Relatively high initial capital costs.
- Requires full-time trained personnel to run the equipment.
- Wide variations in raw water and flow rate make control difficult since it involves adjusting the amounts of lime and/or soda ash being fed.
- Safety concerns for handling and monitoring the chemicals.
- TDS removal not as efficient as other technologies.

DISTILLATION

DESCRIPTION OF TECHNOLOGY

Distillation is a water treatment technology used for commercial and household applications. Water is boiled and the steam is sent to cooling tubes to be condensed and collected as purified water in a second container. This technology is used primarily for desalination. Illustration of Distillation (below).



Flash distillers pump the influent into a vacuum chamber where it flashes into pure water vapor. The use of the vacuum reduces the vapor pressure, which lowers the boiling point. Lowering the boiling point requires less thermal input (i.e. reduced energy consumption). Both the evaporator and distiller are combined into a single chamber, although most plants use two joined vacuum chambers. The first chamber will typically work at 80 kPa, and the second at 88-91 kilopascals (kPa). The cold saline water is supplied via a pump, and passes through a condenser coil of each chamber before being heated by steam in an external feedwater heater. The heated saline water enters the lower part of the first chamber, then drains over a weir and passes to the second chamber, encouraged by the differential vacuum between them. This process is commonly used to distill crude oil.

Multi-stage flash distillation (MSF) is a water desalination process which distills saline water by flashing a portion of the water into steam in multiple stages of what are essentially countercurrent heat exchangers. Each stage contains a heat exchanger and condensate collector. The sequence has a cold end and a hot end while intermediate stages have intermediate temperatures. The stages have different pressures corresponding to boiling points.

DISTILLATION

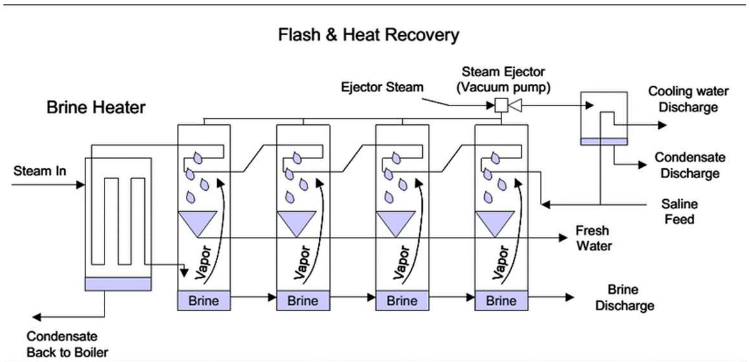
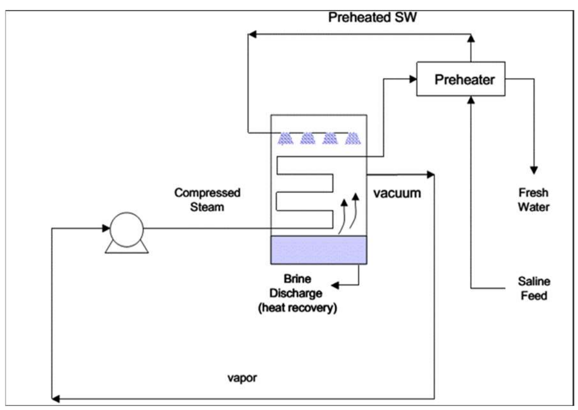


Illustration of MSF (above)

Mechanical vapor compression (MVC) is a method by which a blower, compressor or jet ejector is used to compress/increase the pressure of the vapor produced. The vapor can be used to heat the medium for the saline water being concentrated, from which the vapor was generated to begin with. If no compression was provided, the vapor would be at the same temperature as the boiling liquid/solution, and no heat transfer could take place. Illustration of MVC (below).



ENGINEERING ASPECTS
Distillation can remove nearly 100 percent of TDS. MSF systems are designed to desalinate TDS concentrations below 45,000 mg/L. MVC can be used to desalinate higher TDS (> 45,000 mg/L) wastewater.

COST OF TREATMENT
Initial capital costs are relatively expensive (approximately $14 Million to install a 0.5 MGD plant). The life cycle cost of distillation (including all operating, direct and indirect costs) varies from $0.70/m^3 ($2.65 per 1,000 gallons) for very large plants (85.8 MGD), and up to $1.25/m^3 ($4.75 per 1,000 gallons) for small plants (2.6 MGD). For very small capacity plants, operation costs are as high as $3.20/m^3 ($12.11 per 1,000 gallons).

DISTILLATION

FEASIBILITY AND NON-WATER QUALITY ENVIRONMENTAL IMPACT

As with other technologies, there is a concentrated brine (byproduct) which must be disposed. Volatile organic compounds in the wastewater would likely be volatilized and create fugitive air emissions.

Advantages:

- Lower energy demand compared to other thermal processes.
- Vacuum distillation can achieve a lower energy use (i.e. lower boiling point).
- No pretreatment required.
- Low maintenance costs.
- Continuous operation with minimal supervision.

Limitations:

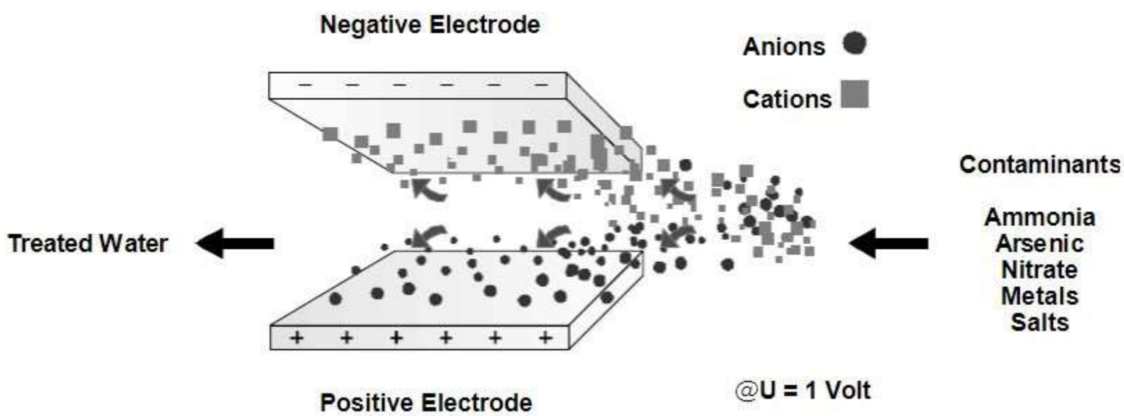
- Large energy demand to boil water.
- The distilled water contains low amounts of oxygen and high levels of acidity.
- High installation and operational cost.

ION ELECTROSORPTION

DESCRIPTION OF TECHNOLOGY

Ion Electrosorption, also known as capacitive deionization (CDI) is a newer emerging technology. In this process, water is deionized by applying an electrical potential difference (voltage) over two (2) electrodes. The system consists of two (2) cycles; the adsorption phase (capture) and the desorption phase (similar to filter backwash).

The electrodes behave as capacitors which are energized using direct current. This creates positive and negatively charged surfaces. Ionic compounds are attracted to and absorbed onto the surface of the electrodes via an electrostatic charge. The negative electrodes attract positively charged ions (such as calcium, magnesium, and sodium), and the positive electrodes attract negatively charged ions (such as chloride, nitrate, and sulfate). Optimized carbon aerogel is an ideal electrode material because of its high electrical conductivity, high specific surface area, and controllable pore size distribution. To release the captured contaminants, the polarity is reversed, and the cell is flushed with a small amount of liquid. This forms a concentrated solution (brine).



This is considered energy efficient in comparison with other desalination techniques because it removes salt ions from the water, while other technologies extract water from the salt solution.

ENGINEERING ASPECTS

Previous designs were limited to the treatment of relatively low ionic strength solutions (TDS < 3,000 mg/L), though recent treatment systems can be applied to relatively higher concentrations (TDS < 6,000 mg/L).

Ion Electrosorption systems treat relatively low volumes of water. Most systems operate at flow rates ranging from 300 to 400 mL/min (114 – 152 gallons/day). Purification cycles typically range from 120 to 600 seconds, while recharge cycles are

ION ELECTROSORPTION

between 90 to 120 seconds. CDI has been pilot tested for 10,000 gallons/day water treatment.

Systems can be tuned to operate at various levels of ion removal and water recovery efficiency. The systems can also be tuned to remove specific ions without complete deionization of the water stream.

One bench test in Canada for which CDI treatment was applied to a water sample from Hamilton Harbour in western Lake Ontario had the following results:

Parameter	Influent (mg/L)	Effluent (mg/L)	% Removal
Calcium	55	5.4	90
Chloride	121	21	80
TDS	462	77	83

Minimal pretreatment is required, typically consisting of cartridge filtration. There is a relatively high-water recovery at 80 percent to 95 percent.

By inserting two (2) ion exchange membranes to increase salt absorption efficiency, modified CDI is obtained. This is called membrane capacitive deionization. Co-ions do not leave the electrodes during the adsorption phase. Instead, due to the addition of the membranes, the co-ions will be kept in the interparticle pores of the electrodes which enhances the salt adsorption efficiency. Since the co-ions cannot leave the electrodes, and because the electroneutrality condition applies for the interparticle pores, extra counter-ions must pass through the ion-exchange membranes, which gives rise to a higher salt adsorption as well.

COST OF TREATMENT

Studies have shown that CDI is cost competitive when compared to the RO process only at low feed TDS concentration ranges (<3,000 mg/L) due to the high cost of CDI modules with increased water TDS concentration.

Cost of treatment depends on amount of removed salt, while the cost of treatment for other technologies (e.g. RO) depends on the volume of treated water. The approximate cost for the treatment via CDI is approximately \$0.06 per m^3 (\$0.23 per 1,000 gallons).

Specific information on the cost of installation of a CDI system could not be located, though the consensus is that it is a relatively low investment cost.

FEASIBILITY AND NON-WATER QUALITY ENVIRONMENTAL IMPACT

Power consumption depends on the amount of salt removed. Per cell the energy demand is approximately 0.17 kWh/m^3 of water treated to achieve 88 to 89 percent

ION ELECTROSORPTION

removal from a 2,500 mg/L TDS feed, or 0.76 kWh/m^3 of water treated to achieve 88 to 89 percent removal from a 6,000 mg/L TDS feed. The total power consumption for the latter system including cells, pumps, and controls is measured at approximately 1.37 kWh/m^3 of water treated.

Advantages:

- Minimal pretreatment.
- No water softening.
- Long life cycle of capacitors.
- No chemicals needed.
- Low maintenance.
- High water recovery.
- Small footprint.
- Low operation and maintenance requirements.
- Less fouling/scaling (in comparison to RO).

Limitations:

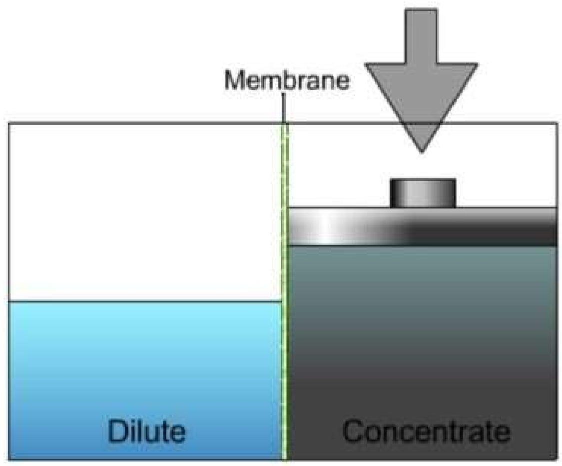
- Treats relatively lower TDS concentrations (maximum 3,000 – 6,000 mg/L).
- More viable for low salt streams (e.g. brackish water).
- Processes relatively lower volume of wastewater (less than 10,000 gallons/day).
- Becomes more expensive at higher TDS concentrations.

REVERSE OSMOSIS

DESCRIPTION OF TECHNOLOGY

Reverse Osmosis (RO) is a method for treating wastewater in order to reduce TDS in the effluent discharge. The process involves applying pressure to the influent water stream through semi-permeable membranes to overcome osmotic pressure, extracting salt and impurities, and reverse the natural osmosis process.

It is commonly used in the mining industry and the oil and gas industry. When combined with electrocoagulation as pretreatment, RO can be used in applications where it has not been applied successfully in the past.



ENGINEERING ASPECTS

The RO process filters out salt ions down to 0.0001 microns. The process removes 95 to 99 percent of TDS, and over 99 percent of suspended solids. Current systems are capable of treating influent levels up to 35,000 mg/L of TDS. The smaller container systems are capable of treating up to 300 gal/min (0.432 MGD), and each skidded system can treat up to 2,000 gal/min (2.88 MGD). Water recovery is approximately 70 percent.

RO is not a standalone system. Pre-filtration such as sand filters, activated carbon, or green sand filter is usually required to protect the RO membrane and remove organics. Chemicals are also required to wash the RO membranes. The configuration of the system will generally depend on the application and the characteristics of the wastewater in relation to the desired level of effluent purity. Most systems will include:

- Inlet collection tank.
- Feed pump skid and tank.
- Filtration system.
- Membrane/module rack.

REVERSE OSMOSIS

- Receiving tank.
- Backwash pumps.
- Chemical cleaning systems.
- Compressed air for scouring the membrane.
- Automation Instrumentation.

The footprint of the system is also a consideration as there is a space requirement to install. Automation level is also a consideration. Higher level of automation is more expensive upfront, though an operator would not be required for much of the time. A higher level of automation also minimizes human error.

COST OF TREATMENT

The cost of installation of a RO system ranges depending on the design flow rate of the system (small commercial units to larger industrial systems) as well as the type of pretreatment required. The following table approximates the cost of installation only, taking into account the cost of design and engineering of the project:

Design Flow Rate		Cost of Installation
5 – 10 gal/min	7,000 – 14,000 gal/day	$45,000 - $60,000
30 – 50 gal/min	0.04 to 0.07 MGD	$200,000
100 gal/min	0.144 MGD	$1,000,000
300 gal/min	0.432 MGD	$2 to $4 Million

Operation cost varies depending on the characterization of the wastewater (influent concentration, surface water vs. well water, etc.). For desalination of seawater from an RO plant, the lowest price is $750 per acre-ft ($750 per 325,851 or $2.30 per 1,000 gallons).

FEASIBILITY AND NON-WATER QUALITY ENVIRONMENTAL IMPACT

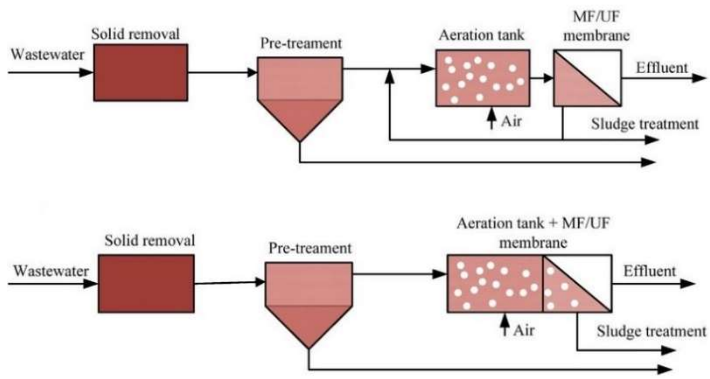
Overall, the limitations outnumber the advantages of a RO system to treat wastewater:

- Relatively low water recovery (approximately 70 percent).
- High installation cost.
- High operation cost.
- Equipment is difficult to maintain.
- Produces large amounts of a byproduct of concentrated brine (RO reject).
- RO reject requires further treatment (e.g. aerobic granular sludge).
- Membrane backwash has high levels of TDS.
- Uses a large amount of energy (480V/3 Phase, amperage depends on flow rate).

MEMBRANE BIOLOGICAL REACTORS

DESCRIPTION OF TECHNOLOGY

Membrane biological reactors (MBRs) consist of a biological reactor with activated sludge and solids separation by membrane filtration with nominal pore sizes ranging from 0.1 to 0.4 um (Hai et al., 2014). MBR systems have two basic configurations: (1) the recirculated MBR with external membrane module and (2) integrated MBR with an immerged membrane separation unit.



ENGINEERING ASPECTS

Pretreatment is imperative to the MBR process to protect membranes from physical damage and avoid excessive fouling. Typically, fine screening and grit removal are used in MBR systems. To prevent operational problems and potential damage to the system, fibrous or stringy material must be removed because this material may become entangled and wrap around the hollow fibers, stuck within the space between flat plate membranes, and plug the membrane scour aeration systems. Oil and grease removal is also required to prevent fouling of the membranes if the oil and grease concentration exceeds 100 mg/L.

The most commonly used pore size of commercial MBR materials is in the coarse ultrafiltration (UF) to fine microfiltration (MF) region because of sufficient rejection and reasonable fouling control.

COST OF TREATMENT

Equipment cost for small MBR facilities, not including package plants and less than one MGD, is expected to be in the range of $1.00 to $6.00 per gallon of plant capacity, and total construction costs for complete MBR system ranges from $5.00 to $22.00 per gallon per day of treatment capacity. Operations and maintenance costs including the labor, utilities, chemicals, and membrane replacement range from $350 to $550 per million gallons treated.

MEMBRANE BIOLOGICAL REACTORS

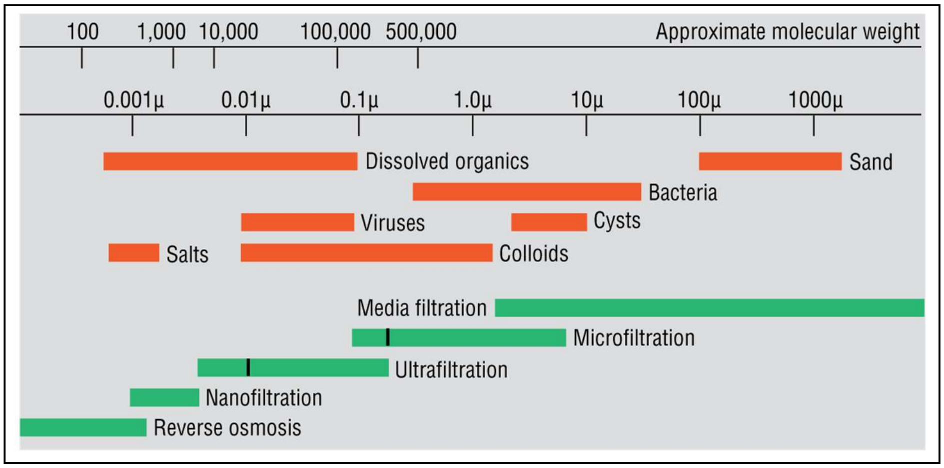
For facilities with a capacity greater than one MGD, equipment cost ranges from $0.75 to $1.50 per gallon per day of treatment capacity, and total construction cost ranges from $3.00 to $12.00 per gallon per day of treatment capacity. Operation and maintenance costs for these plants generally range between $300 and $500 per million gallons treated.

FEASIBILITY AND NON-WATER QUALITY ENVIRONMENTAL IMPACT
Due to the fact that chloride is considered a conservative substance which is not affected by any process, chloride removal using biological treatment is not a feasible option.

FILTRATION

DESCRIPTION OF TECHNOLOGY

The molecular weight cutoff (MWCO) for ultrafiltration (UF) membranes range from about 10,000 Daltons (Da) to about 100,000 Da. These MWCO values correspond to an ability to retain particles ranging from about 0.005 to 0.2 µm in diameter.
UF membranes have pore sizes small enough to remove dissolved compounds with high molecular weight such as colloids, proteins, and carbohydrates.



Nanofiltration (NF) membranes typically have pore sizes of 0.001 microns and an MWCO ranging from 1,000 to 100,000 Da. NF membrane systems is used for the removal of selected dissolved constituents from wastewater such as the multivalent metallic ions (hardness), and a fraction of the monovalent species (sodium and chloride).

Removal Capabilities of Micro-, Ultra-, Nanofiltration, and Reverse Osmosis

Contaminant	MF	UF	NF	RO
Suspended Solids	Yes	Yes	Yes	Yes
Dissolved Solids	No	No	Some	Yes
Bacteria and cysts	Yes	Yes	Yes	Yes
Viruses	No	Yes	Yes	Yes
Dissolved organic matter	No*	No*	Yes	Yes
Iron and manganese	Yes, if oxidized	-	Yes**	Yes**
Hardness	No	No	Yes	Yes

*Could Remove some with appropriate pretreatment
**High levels with foul these membranes.

FILTRATION

COST OF TREATMENT

	Membrane Treatment					NF and RO				
Design Flow (MGD)	0.01	0.1	1.0	10	100	0.01	0.1	1.0	10	100
Average Flow (MGD)	0.005	0.03	0.35	4.4	50	0.005	0.03	0.35	4.4	50
Capital Cost ($/gallon)	18.00	4.30	1.60	1.10	0.85	8.25	1.75	1.00	1.00	0.75
Annual O&M Cost ($/1000 gallons)	4.25	1.10	0.60	0.30	0.25	5.00	1.50	0.90	0.65	0.55

Capital costs are based on US $ per gallon of treatment plant capacity, excluding pre- and post-treatment processes.

ENGINEERING ASPECTS

Pretreatment is required for treating hard water prior to NF membranes to prevent precipitation of hardness ions on the surface of membranes. A higher operating pressure than MF or UF is required in NF membranes in order to push water molecules through the smaller membrane pores. Operating pressure ranges from 500 - 1,000 kPa.

NF and RO membranes are often made from the same or similar materials. Both systems typically use the same pressure vessels and require the same pretreatment steps. Compared to RO membranes, NF membranes allow the passage of more monovalent ions, while providing high rejection of multivalent ions. NF systems operate at a lower feed pressure than RO and therefore can be lower in cost. NF can still provide an effluent water quality comparable to RO unless TDS reduction is required.

FEASIBILITY AND NON-WATER QUALITY ENVIRONMENTAL IMPACT

Advantages:

- High flux at low operation pressure.
- Relatively low investment and low operation/maintenance costs than RO.
- Softens hard water when specific softening membranes are used.

Limitations:

- NF membranes require higher energy (5.3 kWh/m^3) than UF (3.0 kWh/m^3) and MF (0.4 kWh/m^3).
- Due to the reduced space of the retentate channels of spiral wound configuration, additional pretreatment of feed water is required to avoid fouling and/or clogging of NF and RO membranes and maintain the integrity of the system.
- NF membranes have low rejection univalent ions.
- NF membranes have low resistance to oxidizing chemicals such as chlorine.

WATER SOFTENERS

Water softeners often be used to treat hard water (high concentrations of calcium and magnesium) can be a significant source of sodium in household water. With a few exceptions, most water softeners add sodium during the hardness removal process (about 1 mg/L of sodium added for every 2.1 mg/L of hardness removed). The following practices and alternative water conditioning systems will help to reduce the amount of salt being discharged to a wastewater treatment plant:

- Switch to high efficiency ion exchange softeners.
- Know the hardness level of local water supply and consider whether a water softener is needed and avoid the ongoing expenses if it isn't. Water hardness greater than 120 mg/L CaCO3 needs to be softened.
- Do not over soften. Program the water softener to obtain an optial level of hardness.
- Use potassium chloride in their water softeners instead of sodium chloride.
- Using demand-based regeneration softeners instead of timer-based units to minimize backwashing.
- Check to see how often the water softener is set to regenerate. Typically, softener units are set to regenerate more often than necessary, causing more salt to be released into the sewer effluent and environment.
- If using a timer-based softener, set to recharge at the lowest effective rate and turn it off when on vacation.
- Consider alternatives to salt-based water softeners.
- Move to centralized water softening using lime rather than salt.
- Properly dispose of the brine solution salts.

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Appendix C. Guidance for Water Quality Standard Variances for National Pollutant Discharge Elimination System Permits

Guidance for Water Quality Standard Variances for National Pollutant Discharge Elimination System Permits

Prepared by the Michigan Department of Environment, Great Lakes, and Energy (EGLE), Water Resources Division (WRD)
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Summary

A variance is a regulatory tool used to make incremental and defined progress towards achieving a Water Quality Standard (WQS). Variances from a WQS are allowed under state and federal regulations. Variance eligibility and requirements are outlined in these state and federal regulations. EGLE considers site specific variances an option for facilities to make incremental progress to meet Water Quality Based Effluent Limits (WQBEL) developed for chloride and sulfate. This process includes consideration of unreasonable economic effects on the discharger and effected communities.

Other states in the Great Lakes Region have developed frameworks to assist dischargers in the development, approval, and implementation of variances for chloride and sulfate. EGLE plans to review and utilize, as appropriate, the tools developed by other states, like Minnesota and Wisconsin, as a model to assist Michigan dischargers. EGLE plans to develop guidance documents to assist dischargers with submitting a complete variance package for chloride and sulfate. EGLE anticipates a streamlined variance option for certain sectors of dischargers.

Regulatory Framework

EGLE is authorized by the United States Environmental Protection Agency (USEPA) to issue National Pollutant Discharge Elimination System (NPDES) permits under Section 402(b) delegated to implement of the federal Clean Water Act and in Title 40 Code of Federal Regulations (CFR), Part 123, State Program Requirements. EGLE and has the authority to grant variances. A variance is a temporary Water Quality Standard (WQS) and used to make incremental progress to improve water quality in the final effluent when it is uncertain how much progress can be achieved. Michigan Rule 323.1103, Variances, of the Part 4 Rules, Water Quality Standards (Part 4 Rules), promulgated pursuant to Part 31, Water Resources Protection, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended, (Attachment 1), allows for a variance from a Michigan WQS that is the basis for a water quality-based effluent limit (WQBEL) in an NPDES permit where various conditions prevent the attainment of a WQS. Federal requirements under 40 CFR, Subpart 131.14, Water Quality Standards Variances, provides states, territories, and authorized tribes a mechanism to adopt WQS variances. Michigan is part of the Great Lakes system and, therefore, is not only subject to 40 CFR, Part 131, Water Quality Standards but also 40 CFR, Part 132, Water Quality Guidance for the Great Lakes System's Procedure 2, Variances from Water Quality Standards for Point Sources.

R 323.1103 allows an NPDES permitted facility to request a temporary modification to the WQBEL and/or WQS through a variance request. A variance must include an achievable interim effluent limit that represents the highest attainable level for the pollutant of concern and a schedule of pollutant reduction activities intended to result in a discharge of the highest quality effluent possible. A variance does not exempt the NPDES permittee from the requirement to be compliant with all other applicable treatment technology-based effluent limits (TTBELs) or WQBELs for other pollutants. All variance requests must be approved by the USEPA prior to inclusion in an issued NPDES permit.

Scope of Facilities Eligible for Consideration for a Chloride and/or Sulfate Variance

A variance can be an appropriate tool for facilities where the permittee is not able to achieve a WQBEL due to high costs associated with advanced treatment technologies and/or when a facility has opportunities to improve its final effluent quality (and possibly meet criteria), but the timeframe to achieve compliance with a limitation is uncertain. A WQS variance applies only to the permittee requesting the variance and only to the pollutant or pollutants specified in the variance. A variance does not affect the corresponding WQS for the waterbody as a whole.

The USEPA regulates variances under the 40 CFR, Subpart 131.14. The permittee requesting the Variance must be able to demonstrate that attaining the WQS is not feasible for any of the following reasons:

1) Controls more stringent than the treatment technology requirements in the federal Clean Water Act of 1972, as amended, 33 U.S.C 301(b) and 306 would result in unreasonable economic effects on the discharge and affected communities.
2) Naturally occurring pollutant concentrations prevent the attainment of the WQS.
3) Natural, ephemeral, intermittent, or low flow conditions or water levels prevent the attainment of the WQS.
4) Human-caused conditions or sources of pollution prevent the attainment of the WQS and cannot be remedied or more environmental damage would occur in correcting the conditions or sources of pollution than would occur by leaving the conditions or sources in place.
5) Dams, diversions, or other types of hydrologic modifications preclude the attainment of the WQS, and it is not feasible to restore the water body to its original condition or to operate the modification in a way that would result in the attainment of the WQS.
6) Physical conditions related to the natural features of the water body preclude attainment of the WQS.

A Variance is not applicable:

1) to new dischargers or recommencing dischargers unless the proposed discharge is necessary to alleviate an imminent and substantial danger to the public health or welfare. New discharge means any building, structure, facility, or installation from which there is or may be a discharge of substances to the surface waters of the state, the construction of which commenced after March 23, 1997.
2) when a variance to a WQS would likely jeopardize the continued existence of any endangered or threatened species listed under Section 4 of the Endangered Species Act (ESA) or result in the destruction or adverse modification of such species' critical habitat.

A WQS variance shall not be granted if standards will be attained by implementing effluent limits required under sections 301(b) and 306 of the Clean Water Act (CWA) and by the permittee implementing cost-effective and reasonable best management practices for nonpoint source control.

Prior to Requesting a Variance
The permittee must evaluate all alternatives prior to considering a variance. This includes, but is not limited to evaluating source reduction, study of treatment capabilities, and consideration given to relocation of the outfall to a surface water that provides more dilution. After evaluating all possible alternatives, if the permittee is still not reasonably certain when or if a WQBEL or treatment requirement will be achieved, then a variance may be appropriate.

Timing for a Variance Request
A permittee may request a variance for chloride and/or sulfate when a NPDES permit application is submitted or with a request for a permit modification. 40 CFR, Part 132, Water Quality Guidance for the Great Lakes System Procedure 2, Variances from Water Quality Standards for Point Sources allows a variance to be granted for a maximum of five years. The term of the variance cannot exceed the term of the NPDES permit; however, variances may be requested and approved in future permits. If the time frame of the variance is the same as the permit term, then the Variance shall stay in effect until the permit is reissued or revoked.

Variance requests for Chloride and/or Sulfate will be site-specific variances tailored to the permittee requesting the variance. Once a variance request for Chloride and/or Sulfate is received by a permittee, EGLE will review the request for approval, and if approved, incorporate the variance conditions in the NPDES permit. The draft NPDES permit is then subject to public review and comment during the public notice process. After this process is complete, the NPDES permit with the variance request is sent to USEPA Region 5 for final review and approval. Once USEPA has reviewed and granted final approval of the variance, the NPDES permit conditions can be finalized and prepared for issuance.

Renewal of a variance requires a request by the permittee. As part of a renewal, a permittee needs to again demonstrate that attaining the WQS is not feasible based on one or more of the reasons described above under eligibility. A variance renewal shall also contain information concerning the permittee’s compliance with the conditions incorporated into the permittees permit as part of the original variance and progress made to achieve the final effluent limitation. A variance submitted for renewal will follow the same review and approval process as the initial approval. This includes review and approvals by Michigan EGLE and USEPA and public participation.

Variance Demonstration Information
A variance should include the following information:

1) Description of the WQS that is the basis of a WQBEL in an NPDES permit that is being modified.
2) The highest attainable condition that can currently be achieved. The highest attainable condition is the condition that is both feasible to attain and is closest to the protection afforded by the designated use and criteria. R 323.1100, Designated Uses, in the Part 4 Rules describes all of the designated uses Michigan’s surface waters are protected for.
3) The term of the Variance. Not to exceed five years.

4) Documentation that the variance will not jeopardize the continued existence of any endangered or threatened species listed under Section 4 of the ESA or result in the destruction or adverse modification of the species' critical habitat.
5) Documentation characterizing the extent of any increased risk to human health and the environment associated with granting the variance compared with compliance with the WQS. This information provided must allow for EGLE conclude that the variance is consistent with the protection of the public health, safety, and welfare.
6) Documentation describing that the Variance will not impair an existing use.
7) Documentation describing that the Variance will comply with antidegradation requirements of Rule 323.1098 in the Part 4 Rules.
8) Consideration of final effluent and any sufficient ambient surface water data collected prior to submission of a variance request.

Variance Conditions in a Permit

If EGLE determines that the variance request demonstrates that attaining the WQS is not feasible, then the EGLE shall authorize the variance through issuance of the NPDES permit. The permit shall contain all conditions needed to implement the variance, including, at a minimum, all the following conditions:

1) Compliance with an effluent limitation that, at the time the Variance is granted, represents the level currently achievable by the permittee. For an existing discharge, the effluent limitation shall be no less stringent than that achieved under the previous permit.
2) Reasonable progress be made in effluent quality toward attaining the water quality standards. This will be conducted through development and implementation of a Pollutant Minimization Program (PMP). EGLE shall consider the cost-effectiveness during the development and implementation of a PMP.
    a. A Pollutant Minimization Program (PMP) is a control strategy designed to proceed towards achievement of meeting the WQBEL. This strategy will include the following:
        i. The goal of the PMP shall be to maintain the effluent concentration of the toxic substance at or below the WQBEL.
        ii. An annual review and semiannual monitoring of potential sources of the toxic substance.
        iii. Quarterly monitoring for the toxic substance in the influent to the wastewater treatment system.
        iv. A commitment by the permittee that reasonable cost-effective control measure will be implemented when sources of the toxic substance are discovered. Factors to be considered shall include all of the following:
            1. Significance of sources
            2. Economic considerations
            3. Technical and treatability considerations
        v. An annual status report will also be required and shall include all PMP monitoring results for the previous year, a list of potential sources of the toxic substance, and a summary of all actions taken to reduce or eliminated the identified sources of the toxic substance.
3) If the duration of a variance is shorter than the duration of a permit, then compliance with an effluent limitation that is sufficient to meet the underlying

4) WQS shall be achieved when the variance expires.

Additional Guidance
Michigan Part 4, Water Quality Standards: EGLE - Applicable Rules and Regulations (michigan.gov).

USEPA has additional resources for WQS Variances as well as a Checklist for Evaluating State Submission of Discharge-Specific WQS Variances.

Please refer to the following links for these resources:

- Water Quality Standards Variances | Water Quality Standards: Regulations and Resources | US EPA

- Checklist For Evaluating State Submission Of Discharger-Specific Water Quality Standards Variances (epa.gov)

For information or assistance on this publication, please contact EGLE, through EGLE Environmental Assistance Center at 800-662-9278. This publication is available in alternative formats upon request.

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Attachment 1: Michigan's Part 4 Water Quality Standards, promulgated pursuant to Part 31, Water Resources Protection, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended, Rule 323.1103 Variances

Rule 323.1103. (1) A variance may be granted from any water quality standard (WQS) that is the basis of a water quality-based effluent limitation in a national pollutant discharge elimination system (NPDES) permit, as restricted by the following provisions:

(a) A WQS variance applies only to the permittee or permittees requesting the variance and only to the pollutant or pollutants specified in the variance. The variance does not modify the water quality standards for the water body as a whole.

b) A variance shall not apply to new dischargers unless the proposed discharge is necessary to alleviate an imminent and substantial danger to the public health or welfare.

(c) A WQS variance shall not be granted that would likely jeopardize the continued existence of any endangered or threatened species listed under section 4 of the endangered species act or result in the destruction or adverse modification of the species' critical habitat.

(d) A WQS variance shall not be granted if the standard in the receiving water will be attained by implementing the treatment technology requirements under the clean water act of 1972, as amended, 33 U.S.C.§§301(b) and 306, and by the discharger implementing cost-effective and reasonable best management practices for nonpoint sources over which the discharger has control within the vicinity of the facility.

(e) The duration of a WQS variance shall not exceed the term of the NPDES permit. If the time frame of the variance is the same as the permit term, then the variance shall stay in effect until the permit is reissued or revoked.

(2) A variance may be granted if the permittee demonstrates to the department that attaining the WQS is not feasible for any of the following reasons:

(a) Naturally occurring pollutant concentrations prevent the attainment of the WQS.

(b) Natural, ephemeral, intermittent, or low flow conditions or water levels prevent the attainment of the WQS.

(c) Human-caused conditions or sources of pollution prevent the attainment of the WQS and cannot be remedied or more environmental damage would occur in correcting the conditions or sources of pollution than would occur by leaving the conditions or sources in place.

(d) Dams, diversions, or other types of hydrologic modifications preclude the attainment of the WQS, and it is not feasible to restore the water body to its original condition or to operate the modification in a way that would result in the attainment of the WQS.

(e) Physical conditions related to the natural features of the water body preclude attainment of WQS.

(f) Controls more stringent than the treatment technology requirements in the clean water act of 1972, as amended, 33 U.S.C. §§301(b) and 306 would result in unreasonable economic effects on the discharger and affected communities.

(3) In addition to the requirements of subrule (2) of this rule, a permittee shall do both of the following:

(a) Show that the variance requested conforms to the antidegradation demonstration requirements of R 323.1098

(b) Characterize the extent of any increased risk to human health and the environment associated with granting the variance compared with compliance with WQS without the variance in a way that enables the department to conclude that the increased risk is consistent with the protection of the public health, safety, and welfare.

(4) A permittee may request a variance when a NPDES permit application is submitted or during permit development. A variance request may also be submitted with a request for a permit modification. The variance request to the department shall include the following information:

(a) All relevant information which demonstrates that attaining the WQS is not feasible based on 1 or more of the conditions in subrule (2) of this rule.

(b) All relevant information which demonstrates compliance with subrule (3) of this rule.

(5) The variance request shall be available to the public for review during the public comment period on the draft NPDES permit. The preliminary decision regarding the variance shall be included in the public notice of the draft NPDES permit. The department will notify the other Great Lakes states of the preliminary variance decision.

(6) If the department determines, based on the conditions of subrules (2) and (3) of this rule, that the variance request demonstrates that attaining the WQS is not feasible, then the department shall authorize the variance through issuance of the NPDES permit. The permit shall contain all conditions needed to implement the variance, including, at a minimum, all of the following conditions:

(a) That compliance with an effluent limitation that, at the time the variance is granted, represents the level currently achievable by the permittee. For an existing discharge, the effluent limitation shall be no less stringent than that achieved under the previous permit.

(b) That reasonable progress be made in effluent quality toward attaining the water quality standards. If the variance is approved for any BCC, a pollutant minimization program shall be conducted consistent with the provisions in paragraphs (i) through (iv) of R 323.1213(d). The department shall consider cost-effectiveness during the development and implementation of the pollutant minimization program.

(c) That if the duration of a variance is shorter than the duration of a permit, then compliance with an effluent limitation that is sufficient to meet the underlying water quality standard shall be achieved when the variance expires.

(7) The department shall deny a variance request through action on the NPDES permit if a permittee fails to make the demonstrations required under subrules (2) and (3) of this rule.

(8) A variance may be renewed, subject to the requirements of subrules (1) through (7) of this rule. As part of any renewal application, a permittee shall again demonstrate that attaining WQS is not feasible based on the requirements of subrules (2) and (3) of this rule. A permittee's application shall also contain information concerning the permittee's compliance with the conditions incorporated into the permittee's permit as part of the original variance pursuant to subrule (6) of this rule.

(9) Notwithstanding the provision in subrule (1)(a) of this rule, the department may grant multiple discharger variances. If the department determines that a multiple discharger variance is necessary to address widespread WQS compliance issues, including the presence of ubiquitous pollutants or naturally high background levels of pollutants in a watershed, then the department may waive the variance demonstration requirements in subrules (2), (3), and (4) of this rule. A permittee that is included in the multiple discharger variance will be subject to the permit requirements of subrule (6) of this rule if it is determined under R 323.1211 that there is reasonable potential for the pollutant to exceed a permit limitation developed under to R 323.1209.