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STATE OF THE ART FOR CHLORIDE MANAGEMENT

Chapter 4

PRIVATE WATER SOFTENING AND TREATMENT

4.1 INTRODUCTION

Waste flow discharge from point-of-entry ion exchange water softeners in homes and businesses can be a significant source of chloride in the environment. These systems generate chloride salts during regeneration cycles, and the chloride-containing waste is discharged into either sanitary sewers or septic systems. Chloride in water softener waste is not removed at the wastewater treatment plant (WWTP) by conventional treatment processes and is ultimately discharged into surface water or, more rarely, is allowed to infiltrate into groundwater via infiltration basins. In septic or mound systems, the chloride from water softener waste passes through the system and infiltrates into the soil, eventually entering groundwater and potentially nearby surface waterbodies. Rising chloride concentrations in the water resources of the Region highlights the need to reduce chloride loading to the environment.[1] Chloride reduction from water softeners can be achieved by optimizing existing softener systems, upgrading to more efficient technologies, and implementing programs for responsible softener use and financial assistance for softener upgrades and calibration services.

It should be noted that some of the processes and technologies presented in this Chapter are similar to the processes described in Chapter 3 "Municipal Water and Wastewater Utilities" but at smaller scales. Therefore, some of the descriptions of private water softening and treatment processes will refer to maps and figures that were presented in Chapter 3 of this Report.

[1] *SEWRPC Technical Report No. 63*, Chloride Conditions and Trends in Southeastern Wisconsin, *2025*.

4.2 RESIDENTIAL WATER SOFTENING SYSTEMS

Water softening in homes is common in Southeastern Wisconsin due to the high levels of hardness in the groundwater. Water softening is a process that removes hardness from water and prevents scale buildup in pipes and appliances. Most residential water softeners typically use ion exchange technology, which generates chloride as a waste product. Some alternate and emerging technologies can effectively prevent scale buildup without generation of chloride and may be viable chloride reduction alternatives.

Impacts of Hardness

Areas with naturally hard groundwater used as a source for drinking water supply often have a high prevalence of water softening in homes and businesses. Wisconsin is generally considered to have hard groundwater (often defined as >120 mg/l as $CaCO_3$) which induces substantial water softening activity. Map 3.1 in Chapter 3 of this Report shows average total hardness of groundwater by township throughout the State, measured from private well water samples collected by several state and county agencies over the past 25 years from both shallow and deep wells.[2] Hardness in water primarily refers to the amount of calcium (Ca) and magnesium (Mg) ions. As groundwater percolates through soil and sedimentary rock formations such as limestone, minerals get dissolved into the water, naturally creating hardness. While the presence of hardness in water does not pose a health concern, it can be problematic for piping and equipment. Hard water can lead to scale buildup in plumbing, decreasing the flow of water through pipes (see Figure 3.10 in Chapter 3 of this Report). Scale buildup can also decrease the efficiency and performance of household appliances, such as water heaters, leading to higher energy consumption and operational costs, and potentially decreasing its usable lifespan. In addition, hardness of 120 mg/l as $CaCO_3$ or greater can cause numerous undesirable household issues,[3] including:

- Reduced lathering of soap and other cleaning agents can lead to decreased effectiveness.
- Washed dishes and glasses may look foggy or spotted due to soap scum and residual minerals.
- Laundered clothes may feel stiff and not adequately cleaned. Clothing colors may also become less vibrant.

[2] *University of Wisconsin-Stevens Point, "Well Water Quality Viewer: Private Well Data for Wisconsin", Version 14, April 2024.*

[3] *Virginia Cooperative Extension, "Household Water Treatment", 1999.*

- Surfaces such as bathtubs, showers, and sinks may accumulate a dusty-looking film. Toilets can develop unsightly mineral rings on the surface of the bowl.

Types of Residential Softeners

To alleviate some of the undesirable effects of hard water, hardness can be removed by a process referred to as water softening. Water softening is common in homes and businesses that receive a hard water supply. Water softening typically occurs at the point where the water supply enters a building, known as point-of-entry water softening. The most ubiquitous form of point-of-entry water softening is ion exchange, which removes calcium and magnesium ions from the water by exchanging them with sodium ions. Ion exchange water softeners either regenerate based on a specified time period or the amount of water that flows through the system. An alternative to ion exchange systems are portable exchange softeners, reverse osmosis, nanofiltration/microfiltration, and water conditioners.

Ion Exchange Water Softening Systems

Most private water softening is currently done at the household level using point-of-entry ion exchange water softeners. Ion exchange water softeners replace calcium and magnesium ions in the influent water supply with cations from an exchange resin, often sodium ions, as shown in Figure 3.1 in Chapter 3 of this Report. Once the resin material gets saturated with calcium and magnesium ions, a regeneration, or recharge, cycle flushes the system with a salt brine solution, typically sodium chloride. The sodium chloride in the brine dissociates, and the sodium ions displace the calcium and magnesium ions on the resin. The displaced calcium and magnesium ions are flushed out as wastewater, along with the chloride ions that were dissociated from the sodium ions in the brine. The regeneration process is shown in Figure 3.2 in Chapter 3 of this Report. For homes connected to a municipal sanitary sewer, this softener waste flow is conveyed to the WWTP and is a significant source of chloride loading to the plant. Similarly, for homes with septic holding tanks, the softener waste flow is stored in the tank with the rest of the wastewater until it is removed by a licensed pumper truck and delivered to a WWTP. For homes with a septic or mound system, the softener waste discharge passes through the drain field, transporting the regeneration chlorides to the soil and eventually to the groundwater or nearby surface waterbody.

Most softeners typically use co-current regeneration (or down-flow regeneration). In this method, the brine flows through the resin bed in the same direction as the water service flow, usually from top to bottom, as shown in Figure 4.Co-Current vs. Counter-Current. Because the regeneration brine cannot completely restore the full capacity of the resin, this process leaves the bottom of the resin bed, the last point the regeneration brine passes through and the nearest location to the service outflow, slightly contaminated with residual hardness that was not removed, leading to a small but continuous leakage of hardness into the finished water. This means the system must regenerate more frequently and requires a higher salt dose. Conversely, counter-current regeneration (also known as up-flow regeneration) is a key feature in some high-efficiency softeners. In this design, the regeneration brine flows in the opposite direction of the service water, usually from bottom to top. This opposite flow has two major benefits for chloride management. First, the brine more effectively cleans the resin, and the freshest, most-regenerated resin is left at the exit point (bottom) of the service flow. This "polishing" effect virtually eliminates the mineral leakage seen in co-current systems, resulting in longer and more complete softening run times between regenerations. Second, by preventing contamination of the polished resin, counter-current systems require significantly less salt and water to achieve the same softening capacity. Less salt used means less chloride is discharged to the environment, with salt savings often ranging from 40 to 50 percent when compared to co-current softeners.[4]

Ion exchange softeners are effective at removing calcium, magnesium, ferrous iron, and manganese. These systems do not remove bacteria, solids, hydrogen sulfide, lead, nitrate, pesticides, or many other organic and inorganic compounds.[5] To remove these additional constituents, supplementary treatment process(es) would need to be implemented. Water testing is needed to determine which compounds are present in the source water. This information can be obtained from municipal water utilities for homeowners connected to a public water system. Homeowners with a private well would need to facilitate their own testing. Test results can also inform the homeowner of the level of hardness present in the water, which is important for efficient softener operation, which will be discussed later in this Chapter.

The regeneration cycle of ion exchange water softeners is an important process, as it restores the softening capacity of the system. Regeneration cycles are either run after a certain amount of water has flowed through the system or after a certain amount of time has passed.

Timing-Based Water Softener

Older water softeners typically use timer-based regeneration cycles, meaning the unit regenerates the resin at a set time every specified time period determined by the homeowner, even if the resin still has softening capacity. The time for the recharge cycle is generally set to a period of low water usage, typically in the early morning hours. This reduces the likelihood of the system running a recharge cycle during a period of high

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[4] *University of Minnesota Water Resources Center, "Residential Water Softening," wrc.umn.edu/residentialsoftening, accessed on October 16, 2025.*

[5] *University of Nebraska-Lincoln, "Drinking Water Treatment: Water Softening (Ion Exchange)", September 2014.*

water use. If water use is needed during a regeneration cycle, a bypass function that is often built into the system delivers hard water and does not disrupt the recharge cycle or water supply.

Water use in a household varies from day to day and from season to season. This variability means timer-based softeners often regenerate either too infrequently, leaving the home with only hard water for a period of time, or too frequently, wasting energy, water, and salt. Timer-based systems become increasingly less efficient during periods of lower water use. In the most extreme cases when no water runs through the system, such as when a homeowner is away for an extended period, the timer-based system will continue to regenerate if not shut off. On the other hand, during periods of higher than normal water use, such as when hosting guests, the softener may regenerate too infrequently, requiring the system to either be manually recharged or the regeneration timer be temporarily changed in order to not interrupt the service of softened water.

Demand-Based Water Softener

Newer systems regenerate using demand-based, or metered, cycles, which run after a specified amount of water has passed through the system. This results in the recharge cycle running on an as-needed basis, regardless of whether the water use rate has been lower or higher than is typical for the household. Demand-based systems operate more efficiently than timer-based systems, resulting in less energy, water, and salt being used. Due to their efficiency, demand-based softeners are more cost effective to operate for homeowners than timer-based softeners.

By regenerating only as needed, the system prevents two main issues: it avoids gaps in soft water service due to infrequent cycling and does not waste energy, water, and salt through overly frequent cycles. Metered systems maintain their efficiency while water use fluctuates, such as when having guests in the house or while being out of town. Because demand-based softeners regenerate only when needed, cycling may occur during the day when there is household water demand. As described previously, softeners have a built-in bypass system that allows hard water to bypass the softener to satisfy water demand during the regeneration cycle. Some systems have a built-in soft water reserve that can provide a certain amount of soft water during the regeneration cycle, however once the reserve is exhausted during that cycle, hard water is supplied to the household. Other softeners have a dual-tank design, which includes two resin tanks that alternate in use, allowing soft water to be provided continuously, including during recharge cycles. Some demand-based softeners also allow the user to set a time at which the regeneration cycle runs once the specified flow has passed, helping to prevent the recharge cycle running at a time of high water use.

Smart/Connected Water Softeners

Smart softeners represent some of the newest innovations in high-efficiency residential ion-exchange technology, providing a significant jump in efficiency over time-based and metered systems. These systems integrate "Internet of Things" technology and advanced sensors within the softener control valve, enabling a higher level of efficiency and control.

Smart softeners use predictive algorithms to figure out exactly when the resin needs to be regenerated. The smart control valve continuously monitors and learns the water usage patterns and history for a home over time. This adaptive learning allows the system to predict the best time to run regeneration cycles based on actual household usage, rather than relying only on the volume used since the last cycle. This capability allows the system to proactively adjust its schedule based on whether water use changes in a home, such as increased consumption during weekends or lower use during vacations. By only regenerating when it is truly needed, this adaptive technology achieves the highest possible salt efficiency.

Many smart and high-efficiency softeners also feature proportional brining, which is another way they reduce salt usage. Standard softeners clean the resin by flushing the whole tank with a large, fixed dose of salt, even if the resin was only half-used. Proportional brining fixes this inefficiency. The controller tracks the exact water use and calculates the smallest amount of salt and water needed to clean just the part of the resin that has collected hardness minerals. When the cleaning cycle runs, the system uses only that minimum amount of salt brine, which can drastically cut salt and water consumption and therefore greatly reduces the amount of chloride waste discharged.

Connection to the internet provides homeowners and service professionals valuable information and control. A smartphone application can be used to receive instant alerts about maintenance issues and real-time warnings when the salt level is low. The application also allows the homeowner to control the system remotely, check water use history, and can include optional features like leak detection to monitor unusual water flow and prevent potential plumbing damage.

Alternate Water Softening Systems

While most residential water softening is done using ion exchange systems, there are alternate softening technologies and services that homeowners may use that remove hardness without generating chloride onsite. Portable exchange water softeners use ion exchange technology but get regenerated at a service provider facility that can manage the brine production. Membrane technologies such as reverse osmosis and nanofiltration can soften water without generating any chloride and can remove many other contaminants from the water.

Portable Exchange Water Softener

Portable exchange water softeners can be an alternative to conventional point-of-entry ion exchange water softeners. A portable exchange water softener is a self-contained tank that softens water using ion exchange technology similar to traditional water softeners, where an exchange resin swaps sodium ions on the resin for calcium and magnesium ions from the hard source water to produce softened water. Portable exchange tanks do not require any electricity, use any salt, or produce any wastewater within the home. Once the exchange capacity of the resin in the tank is exhausted, a service provider brings a new tank and returns the spent tank to their facility to regenerate it.

Because the regeneration of portable exchange water softeners does not occur within the household, they are considered to be a more environmentally friendly alternative to conventional ion exchange water softeners. The service provider can implement regeneration waste brine collection and treatment processes at their facility to prevent the discharge of chloride into the sanitary collection system, reducing the amount of chloride entering the environment.

Due to portable exchange systems not discharging chloride on site, they can be a viable option for locations that have brine discharge restrictions on conventional ion exchange water softeners. Often in such locations portable exchange systems are permitted. Similarly, because portable exchange softeners do not consume any extra water in the home, they can be a suitable alternative for areas that have water use restrictions or rationing. They can also be a feasible option for buildings that have limited space or have limited electrical connections. Additionally, these systems can be a good option in cases where whole-house water softening is not needed, as the portable tank can be located in the desired location without the constraint of having a drain connection. Portable exchange softeners are maintenance-free for the homeowner, as all maintenance is completed by the service provider.

Portable exchange services typically have a modest startup cost and a recurring monthly fee for swapping out the spent tank. While the monthly cost of a portable exchange service may be higher than the monthly cost of operating a traditional water softener, the homeowner saves the initial up-front expenditure of purchasing a water softener system as well as the cost of salt and electricity to run the softener.

Reverse Osmosis Systems

Reverse osmosis (RO) systems remove hardness-causing minerals and contaminants from water by passing the water under pressure through a semipermeable membrane. Under high pressure in the system, water moves through the membrane by diffusion, and dissolved solids, as well as nitrates, arsenic, iron, lead, ammonia, PFAS, radium, and many other constituents are rejected by the membrane and remain on the feed water side of the membrane, as shown conceptually in Figure 3.4 in Chapter 3 of this Report. The clean water that passes through the membrane is called permeate, and the recovery rate is the ratio of permeate flow to feed flow, which can be up to 70 to 80 percent.[6] The remaining portion of the flow that stays on the feed water side of the membrane and is known as reject, as it contains the constituents that were rejected by the membrane. RO systems can achieve a removal efficiency greater than 98 percent.[7]

Due to the amount of water wasted in the reject flow and the high energy demand, RO systems may not be appropriate as whole house water softeners, especially for households in areas with water use restrictions or limitations. However, RO may be an option in locations that have restrictions on chloride discharges. Pretreatment such as mechanical filters or activated carbon filters are typically used upstream of the RO system to remove suspended solids and other constituents that may foul the RO membrane,[8] however this may not be needed for households that receive a public water supply that has already been adequately treated. Figure 4.Whole Home RO shows a typical whole home reverse osmosis system configuration.

When used as a point-of-entry whole house treatment system for hardness removal, the membranes can wear out quickly due to constantly filtering large volumes of hard water, which can be taxing on the membranes. Additionally, metals present in the source water can cause damage to the RO system when the metals are in an oxidized state. This can be a significant threat to the RO system, as only a small amount of oxidized metal can cause extensive damage.[9,10] Due to increased water waste and the need for more

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[6] *M.M. Tare et al., "Economics of desalination in water resource management – a comparison of alternative water resources for arid/semi arid zones in developing countries,"* Desalination*, 81: 57-76, 1991.*

[7] *S. Adham et al., "Comparison of Advanced Treatment Methods for Partial Desalting of Tertiary Effluents," September 2009.*

[8] *University of Missouri Extension, "Understanding Home Water Treatment Systems", June 2017.*

[9] *Personal communication with Snyder & Associates, February 2024.*

[10] *Calcium chloride can be added to the raw water to alleviate this risk, which can add maintenance costs and operational complexity, as well as add chloride into the water. Metals in the source water that are in an unoxidized state do not pose a hazard to RO systems and can be effectively removed by the membranes.*

frequent membrane replacement, RO systems can incur higher maintenance costs, making them a less economical option for water softening compared to ion exchange softeners.

Reverse osmosis and ion exchange softeners are often operated in conjunction with each other, where the reverse osmosis provides additional water purification once the hardness has been removed by the ion exchange softener. This configuration alleviates the excess wear and tear on the reverse osmosis membranes from the hardness-causing minerals, resulting in lower maintenance and replacement costs for the RO system. The use of a reverse osmosis system after ion exchange water softening can remove compounds that create an unpleasant smell or taste, salts, and many contaminants that can be harmful. Additionally, RO systems are highly effective at removing sodium, which is present in softened water from the ion exchange process. This can be particularly beneficial for individuals who need to limit their sodium intake.

Nanofiltration and Ultrafiltration Systems

Nanofiltration (NF) is a pressure-driven membrane filtration technology. NF operates similar to reverse osmosis, where pressure applied to the feed side of the system forces water through a semipermeable membrane, creating a pure permeate flow of treated water and a reject flow that contains the removed contaminants. The operating pressure for NF is lower than that of RO, where the pressure employed for NF is between 80-150 pounds per square inch (psi) compared to 150-300 psi for RO.[11] The lower operating pressure of NF compared to RO can result in lower operating costs for NF due to less energy consumed. Nanofiltration is substantially more effective at removing multivalent ions than monovalent ions.[12,13] Removal efficiency of multivalent ions can range from 90 to 99 percent, whereas the removal of monovalent ions can be as low as 10 percent.[14] The recovery rate, or amount of feed water verses amount of treated permeate recovered, for nanofiltration is typically 85 to 95 percent.[15] Because the calcium and magnesium ions that cause hard water are multivalent, nanofiltration is an effective technology for removing hardness

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[11] *American Membrane Technology Association, "Nanofiltration and Reverse Osmosis (NF/RO)", undated.*

[12] *A monovalent ion is an ion with a single positive or negative charge, such as sodium (Na^+) or chloride (Cl^-). A multivalent ion is an ion with a charge of positive or negative two or more, such as magnesium (Mg^{2+}) or aluminum (Al^{3+}).*

[13] *O. Labban, C. Liu, T.H. Chong, and J.H. Lienhard, "Fundamentals of low-pressure nanofiltration: Membrane characterization, modeling, and understanding the multi-ionic interactions in water softening",* Journal of Membrane Science*, 521:18-32, 2017.*

[14] *B. Van der Bruggen, "Nanofiltration", April 2013.*

[15] *American Membrane Technology Association, undated,* op. cit.

from water. Nanofiltration is not highly effective at desalination, due to salts being monovalent; RO is significantly more effective than NF for sodium removal. In addition to removing hardness, NF is also effective at removing radium, bacteria, viruses, color-causing compounds, organics, and other chemicals.

In order to achieve optimal removal efficiency, pretreatment is required for nanofiltration. Pretreatment can remove suspended solids and debris from the source water and reduce the amount of membrane fouling. Excess amounts of suspended solids in the water can plug the membrane pores, which can reduce the removal efficiency, require higher amounts of energy to operate, and potentially shorten the useable lifespan of the membranes. When used for residential water softening, the amount of pretreatment needed for suspended solids may be minimal, especially for households that receive a public water supply that has already been adequately treated. Nanofiltration can be a viable option for whole home water softening, as it is less energy intensive and has a higher recovery rate than reverse osmosis.

When compared to conventional ion exchange technology for residential water softening, nanofiltration offers the benefit of not generating a chloride-containing waste stream. The reject waste flow from NF systems will only contain calcium and magnesium that was in the source water.[16] This can help reduce chloride loading to the environment and can similarly make NF a viable alternative for residential water softening in locations that prohibit ion exchange softeners due to chloride restrictions or encourage softener brine reduction. Additionally, NF does not require any chemical inputs. Homeowners using a nanofiltration system for softening can also experience a cost savings from not buying water softener salt.

Ultrafiltration (UF) is another treatment technology similar to RO and NF that uses pressure across semipermeable membranes to filter water. The operating pressure for ultrafiltration is even lower than that of nanofiltration, typically between 15-35 psi.[17] Ultrafiltration is effective at removing turbidity and microorganisms from water[18] and can achieve a recovery rate of 90 to 98 percent.[19] While it is an effective tool for water treatment, UF does not remove hardness from water and thus is not a viable alternative for water softening. Figure 4.Membrane Treatment Hierarchy summarizes the main membrane filtration technologies and the respective constituents removed.

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[16] *This assumes the presence of no other constituents besides hardness in the source water.*

[17] *American Membrane Technology Association, "Application of Membrane Technologies", undated.*

[18] *American Membrane Technology Association, "Membrane Filtration (MF/UF)", February 2007.*

[19] *American Membrane Technology Association, undated,* op. cit.

Emerging Technologies

While traditional technologies for water softening are effective at removing hardness, each system has its respective set of drawbacks and constraints. Conventional ion exchange water softeners generate chloride in the regeneration waste stream as well as introduce sodium into the finished water. With increasing concern around chloride pollution of surface water, groundwater, and soil, some communities in the study area have instated programs to reduce softener brine and some communities outside of Wisconsin have implemented full bans on ion exchange water softeners. Membrane filtration systems can remove hardness along with myriad other undesirable constituents from water without producing chloride, however they can waste substantial amounts of water and consume large amounts of energy. Newer technologies have entered the water softening and conditioning market that can alleviate some of the drawbacks of these traditional technologies. Water conditioners and capacitive deionization have shown promise in being viable alternatives to ion exchange water softeners.

Water Conditioners

Rather than remove the ions that cause hardness from the water, water conditioners interact with the ions to change their propensity to create scale. As such, water conditioners are not true water softeners, as hardness is not removed from the water, but rather they condition the water to reduce the undesirable effects of hardness. Water conditioners typically do not generate chloride or add any constituents to the water. The most common types of water conditioners are template assisted crystallization, electromagnetic treatment, and electrically induced precipitation.

Template Assisted Crystallization

Template assisted crystallization (TAC) water conditioners induce the formation of microcrystals composed of calcium and magnesium to effectively bind up the hardness-causing ions.[20] These microscopic crystals are stable and do not cause buildup of scale, as is the case with the ionic form of calcium and magnesium. The crystals do not dissolve back into ions but rather remain suspended in the water and pass through pipes, water heaters, and appliances. The crystals can also remove existing scale throughout the plumbing system, which can provide the benefit of improved performance, reduced energy use, and reduced cost of water heater operation as well as restore flow capacity in pipes, fixtures, and appliances.

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[20] *A. Alnashwan, M. Alsahali, K. De Silva, & F. Yu, "Research Plan on Conditioning Water Using Template Assisted Crystallization to Prevent Scaling in Boilers," 2018.*

To induce the formation of microcrystals, TAC technology utilizes media beads that are specifically formulated to attract calcium and magnesium ions. The beads contain nucleation sites, which are designed to aggregate the ions and start the nucleation of the crystals.[21] The microcrystals continue to grow on the beads until they reach a certain size, at which point they break off and become suspended in the water. This process is illustrated in Figure 4.Template Assisted Crystallization. The crystals get flushed out of the conditioner tank in the finished water and the TAC beads remain in the vessel to continue to treat inflow water. Finished water containing the microcrystals is safe to drink and can even be a beneficial source of calcium and magnesium. Throughout the plumbing system, the microcrystals can act as further nucleation sites that can help bind calcium and magnesium ions that have dissolved back into the water from existing scale buildup dissolution.[22] Template assisted crystallization water conditioners can reduce scale buildup by up to approximately 90 percent as compared to no hardness removal.[23]

TAC water conditioners offer multiple advantages over other water softener or scale prevention technologies. No salt is used in TAC water conditioners, and as a result, no sodium is introduced into the finished water and no chloride is produced. The absence of waste chloride can make TAC water conditioners a suitable alternative for locations that have restrictions on ion exchange water softener brine discharge. Additionally, no chemicals are added, which makes it a very low maintenance system for homeowners. The media beads may last three to five years before needing to be replaced.[24] Factors such as influent water quality and the amount of household water use may impact the lifespan of the media beads. Replacement of the media is relatively simple and can be completed by a service provider. Furthermore, TAC water conditioners use no electricity and do not waste any water, so no drain connection is needed.

Water treated by a TAC water conditioner will retain some of the negative aspects of untreated hard water. A residue will still be left on surfaces when water dries, but it is more easily wiped away than the residue formed from hard water. Additionally, because the hardness is not removed from the water, treated water will not have the "slippery" feeling of softened water and soap lathering will not be significantly improved.

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[21] *Nucleation is the initial process in which ions or molecules aggregate to form a stable cluster of a new phase (or structure), such as ions or molecules in solution forming a solid crystal. This tiny cluster is called a nucleus or seed.*

[22] *L. Shen, "Drinking Water Softening/Scale Prevention Technology Assessment and Performance of Template Assisted Crystallization", 2019.*

[23] *A. Alnashwan, M. Alsahali, K. De Silva, & F. Yu, 2018,* op. cit.

[24] *L. Shen, 2019,* op. cit.

On the other hand, laundered clothes will feel soft and the vibrancy of the fabric colors will be preserved due to the prevention of mineral buildup.

Despite its benefits, because TAC water conditioning is a newer technology compared to ion exchange water softening technology, the costs are unknown, and it is not known to be used in the study area at this time.

Magnetic Treatment

Magnetic hard water treatment utilizes electromagnetic fields, which can be generated in two ways: either a wire wrapped around a water supply pipe to create a solenoid coil or by permanent magnets attached to the pipe, as shown in Figure 4.Magnetic Treatment. For a solenoid coil arrangement, an external energy source applies electrical current through the wires, creating a magnetic field within the pipe, similar to the magnetic field created by permanent magnets. The magnetic field draws cations (positive) towards the wall of the pipe and concentrates anions (negative) in the center of the pipe or vice versa, depending on the direction of the electrical current. The current can be reversed to pull cations and anions in the opposite direction, facilitating collisions and interactions. This creates minute clusters that act as nucleation seeds that form soft precipitate. Soft precipitate does not firmly adhere to surfaces in heating environments, such as in water heaters, as does hard scale and can be more easily removed.

Similar to other water conditioning processes, magnetic treatment does not remove hardness from the water but rather alters the ability of the hardness to cause hard scale. Magnetic treatment does not require any chemical or salt inputs, and as a result does not produce any chloride. This technology does require an external power source for the solenoid coil configuration to provide the electrical current needed to generate the magnetic field, however the permanent magnet configuration does not require an external power source.

At the time of writing, scientific opinion is divided on the efficacy of magnetic treatment systems. Some studies purport that there is no scientific evidence to support any treatment benefits.[25] Other studies posit that magnetic water conditioning can reduce hard scale formation by approximately 50 percent as compared to no scale reduction.[26] Advocates of the technology claim that treated water alleviates the negative aspects of untreated hard water, such as improved soap lathering and laundered clothes feeling

[25] *Penn State Extension, "Magnetic Water Treatment Devices", 2014.*

[26] *L. Shen, 2019,* op. cit.

soft and the color vibrancy maintained. Further research and development is needed to determine the effectiveness of the technology prior to making magnetic water conditioning systems more widely implemented.

Electrically Induced Precipitation

Electrically induced precipitation (EIP) is a water conditioning process that applies electric fields to precipitate hardness-causing ions. Aggregations of precipitate form on the electrodes as soft sludge, which require periodic cleaning. Soft sludge is merely settled out particles that are not bound to the electrode surface and are easily displaced by flowing water.[27] A portion of the calcium and magnesium ions form microscopic particles that remain suspended in the water as it flows through the plumbing system. These particles then act as additional nucleation sites to capture hardness ions that have dissolved from existing scale, preventing them from forming new scale elsewhere in the system, especially in heating environments like hot water heaters. The EIP treatment process is illustrated in Figure 4.Electrically Induced Precipitation. EIP systems require periodic backwashing to dislodge the sludge buildup.

EIP conditioners do not require any chemical or salt inputs and do not produce any chloride, making it more environmentally friendly and an option for locations that have restrictions on ion exchange water softeners. This alternative does require an electrical connection to operate. Periodic cleaning of the electrodes is needed to remove the buildup of precipitates. Water treated with electrically induced precipitation can reduce scaling by 50 percent when compared to no scale reduction.[28,29] EIP systems can furthermore improve soap lathering, make laundered clothes feel soft, and maintain the vibrancy of the clothes colors. Because this treatment technology is so new, further research and development is needed to make EIP water conditioning systems a more viable and widely implemented practice to potentially replace traditional ion exchange water softening systems.

Capacitive Deionization

Capacitive deionization (CDI), or electrochemical water treatment, is a chemical-free water softening technology. CDI utilizes electrodes to remove ions from the water. In these systems, positively charged anodes and negatively charged cathodes are located on opposite sides of the chamber. A source of

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[27] *P. Fox, M. Wiest, T.M. Thomure, and W. Lee, "Evaluation of Alternatives to Domestic Ion Exchange Water Softeners", 2014.*

[28] *A. Alnashwan, M. Alsahali, K. De Silva, & F. Yu, 2018,* op. cit.,

[29] *L. Shen, 2019,* op. cit.

electrical power creates a potential difference that draws oppositely charged ions to the electrodes, as shown in Figure 4.Capacitive Deionization. The electrodes are commonly made from a porous carbon material due to their large surface area, which provides more capacity for ion capture.[30] Once the electrodes have become saturated with ions, a regeneration process reverses the charge of the electrodes and backwashes the system. The electrode charge reversal releases the captured ions back into the chamber, and the backflow flushes the ions out of the system as a waste flow.

The CDI process removes all ions, not just the hardness minerals, resulting in finished water that is devoid of most ionic content. As a result, CDI offers the significant benefit of removing harmful and undesirable contaminants such as lead, chloride, sodium, nitrates, nitrites, and sulfates.[31] CDI can remove iron, however iron can cause scale buildup and reduce the efficiency of the system. Researchers are currently divided on whether monovalent ions are removed more effectively[32] or whether divalent ions are preferred for removal by the CDI process.[33]

Despite its wide-ranging ion removal, CDI is not effective at removing neutrally charged constituents, such as radon and organic compounds, which will pass through the deionization chamber and enter the plumbing system. CDI systems are effective at reducing hardness to less than 87 mg/l as $CaCO_3$, however CDI can struggle to achieve truly low hardness level of less than 17 mg/l as $CaCO_3$ or lower and may not be able to deliver fully softened water. CDI systems can achieve scale reduction of around 80 percent.[34,35] Operationally, a power source is required to generate the potential difference between the electrodes. The process also generates a waste brine flow containing the removed ionic constituents, meaning a drain connection is required.

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[30] *A. Kalfa, B. Shapira, A. Shopin, I. Cohen, E. Avraham, D. Aurbach, "Capacitive deionization for wastewater treatment: Opportunities and challenges",* Chemosphere*, 241(125003), 2020.*

[31] *Nebraska Extension, "Drinking Water Treatment: Salt-Free Water "Softener" Options", May 2016.*

[32] *C.J. Gabelich, T.D. Tran, and I.M. Suffet, "Electrosorption of inorganic salts from aqueous solution using carbon aerogels",* Environmental Science & Technology*, 36(13): 3010-3019.*

[33] *P. Xu, J.E. Drewew, D. Heil, and G. Wang, "Treatment of brackish produced water using carbon aerogel-based capacitive deionization technology",* Water Research*, 42(10-11): 2605-2617.*

[34] *Nebraska Extension, 2016,* op. cit.

[35] *L. Shen, 2019,* op. cit.

A key advantage of CDI is its low environmental impact: no chemical or salt inputs are used, and no chloride is generated in the process. Because of this, CDI can be a suitable softening alternative in locations that have restrictions on chloride-containing water softening brine. Further research and development is needed for CDI to become used more widely.

Considerations for Emerging Technologies

While emerging water softening and conditioning technologies can offer benefits over conventional ion exchange water softeners, each technology has its own set of considerations. Table 4.Water Treatment Technology Summary summarizes the various considerations for the traditional, alternative, and emerging technologies for water softening and water conditioning discussed in this Chapter.

In general, alternative and emerging water softening and conditioning technologies do not use softening salts and thus do not yield chloride as a byproduct. This makes them attractive candidates for chloride reduction at the household level as well as a means for reduction of chloride delivered to waterways from wastewater treatment plant effluent. Similarly, these technologies can be good alternatives for geographic locations that have initiatives to reduce brine discharge from conventional water softeners.

Some alternative technologies offer installation flexibility because they do not require a drain connection for waste discharge or an electrical power source. This offers a higher degree of flexibility as to where in the home the system can be operated. For example, if the system is not being used as a whole house treatment system, the device could be located near specific appliances or taps that need treated water without the need for extensive new plumbing or an accessible drain connection. This could also be beneficial for use in individual apartment units. Furthermore, eliminating the waste stream can be particularly beneficial for use in areas that have water use restrictions, as no water is consumed during the treatment processes.

While emerging water conditioning and softening technologies hold promise to reduce chloride pollution, these technologies are not yet widespread in the market at the time of writing. Further research and development and increased familiarity among professional plumbers and water treatment specialists is needed before these technologies can gain a larger market share. Because these technologies are still in early stages of development and not widely commercially available, sufficient cost data was not available in the literature or from suppliers to present a meaningful cost comparison among the technologies discussed.

4.3 FACTORS INFLUENCING PRIVATE WATER SOFTENING

There are numerous factors that can influence the performance of private water softening systems. These include the use of iron filters, low water use appliances, and blending valves, as well as calibration of the equipment and information and educational programs. WWTPs with chloride variances have implemented some of these strategies to achieve chloride reduction within their service areas.

Iron Filters

The presence of iron in water generally does not pose a health risk, however untreated iron in source water can lead to unsightly staining of sinks and toilets, stain laundry, and cause an undesired taste. There are three types of iron that can be present in water: ferrous iron, ferric iron, and iron bacteria. Ferrous iron, or clear water iron, is soluble and does not change the color or appearance of the water. When ferrous iron comes into contact with air, it oxidizes into ferric iron, or red water iron. Ferric iron will turn water into a reddish-brown color and is insoluble. Iron bacteria is less common in water supplies than ferrous or ferric iron, but it can cause major problems in plumbing. This bacteria naturally occurs in soils, groundwater, and surface waters, and feeds on iron. It produces reddish-brown slime buildups that can clog pipes, pumps, and other plumbing fixtures.

Traditional ion exchange water softeners can remove low to moderate concentrations of ferrous iron but cannot remove ferric iron. There is a risk that the ferrous iron that enters a water softener can come into contact with air in the system and become ferric iron. Once ferric iron attaches to the exchange resin in traditional softeners, it can be difficult to remove. The regeneration backwash cycle does not cleanse the resin beads of ferric iron, and over time the ferric iron buildup accumulates. This can reduce the hardness removal capacity of the softener, potentially leading to an increase in the amount of salt used in the softener, more water waste containing higher levels of chloride, and higher energy consumption.

To prevent against appreciable amounts of iron entering the water softener, an iron filter can be operated upstream of the water softener unit. Iron filters contain a media bed that oxidizes the iron, converting the ferrous iron into ferric iron. The insoluble ferric iron particles can then be filtered out of the water, preventing it from entering the water softener and leading to the issues previously described.

Iron filters do not remove hardness from water, but they can reduce the salt needed in homes that operate a water softener when iron is present in the source water. Preventing iron from entering the softener and potentially building up ferric iron deposits can maintain the water softener hardness removal capacity and efficiency. In the absence of an iron filter, the water softener efficiency may decrease over time and lead to more frequent regeneration cycles and excess salt use to achieve the desired level of softening.[36]

Impact of Low Water Use Appliances

Low water use appliances are designed to use less water while maintaining the utility of conventional appliances. Devices such as high-efficiency washing machines and dishwashers, low flow showerheads and toilets, and faucet aerators are common low flow appliances. While the reduction in water consumption is the main advertised benefit of low water use appliances, they can also reduce water softening by decreasing the amount of flow passing through the softener. This in turn can reduce the amount of salt used in the softener and lessen the amount of chloride produced. This reduction in salt use can be most readily experienced in households that use a demand-based water softener, however homes that use an older timer-based system can also realize salt use reduction once the softener is recalibrated in response to the implementation of low water use appliances.

Blending Valves

Homeowners can also reduce the amount of salt used in their water softener by installing a blending valve, sometimes called a bypass or mixing valve, or by operating a built-in blending valve. A blending valve allows a portion of untreated source water to bypass the softener and be blended with the softened water, providing finished water with a certain amount of hardness. The amount of water that bypasses the softener is often measured in grains per gallon of hardness, which equates to the amount of hardness in the finished, blended water. The bypass valve can be operated to produce a blend that has a level of hardness that is acceptable to the homeowner while reducing the amount of salt used. For example, as most softeners fully soften water down to 0 mg/l as $CaCO_3$, if the water supply hardness for a home is 200 mg/l as $CaCO_3$ and a blending valve is operated to bypass 30 mg/l as $CaCO_3$, this would yield a 15 percent reduction in salt use.

Blending valves can vary in design, however most are located on the water softener at the point where the source water enters the system or are located along the water supply piping, just upstream of the tee that supplies the softener. Most blending valves are operated manually. The cost for a blending valve can vary among designs, but they are generally inexpensive and cost less than $100.

[36] *M.L. McFarland and M.C. Dozier, "Drinking Water Problems: Iron and Manganese", 2024.*

Calibration of Ion Exchange Water Softeners

For ion exchange water softeners, which are the most prevalent residential softeners in the study area, calibration is essential to optimizing salt use and reducing chloride waste production. To properly calibrate an ion exchange softener, the hardness of the source water and the capacity of the water softener must be known. The hardness of the source water can be determined using a test kit. If water is supplied by a municipal system, the hardness of the source water can often be obtained from the municipality. The softener capacity is defined in grains, or grains per pound of salt, and can be found on the softener label or in the specifications. For demand-based systems, the system capacity in grains can be divided by the water hardness in grains per gallon to give the number of gallons the system can treat between regeneration cycles. Calibrating timer-based systems requires an additional step of defining the amount of water used per person per day in the household. A generally accepted value for water use is 70 gallons per person per day.[37,38] To calibrate the softener, the per person water use is multiplied by the number of people in the household, giving the amount of water passing through the softener per day. That number is multiplied by the source water hardness to get the total grains of hardness passing through the system on a daily basis. Lastly, to provide the number of days to set the regeneration cycle, the softener capacity is divided by the grains of hardness that pass through the system per day.

Once a softener is properly calibrated, the hardness of the source water should be tested periodically and the softener should be recalibrated as needed in response to changes in hardness. Similarly, for timer-based softeners, the system should also be recalibrated when the number of people living in the household changes. Because the amount of salt used in a water softener depends in part on the raw water hardness, rate of water use, and the softener efficiency, there is no universal guidance for the amount of salt use per person.

Information, Education, and Policy

There can be various barriers that prevent homeowners from reducing their water softener salt use. Lack of information can be a common obstacle. Many homeowners are unaware of the harmful impacts of chloride pollution and the extent to which their water softener contributes. Homeowners may also not know how to improve the efficiency of their softeners or be aware of other ways to reduce their softener salt use. Financial

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[37] *Southeastern Wisconsin Regional Planning Commission, "A Regional Water Supply Plan for Southeastern Wisconsin," December 2010.*

[38] *This value could be refined based on actual water use in a given household. Households with young children, for example, may use more water than 70 gallons per person per day.*

considerations can also be a difficulty for homeowners, where they may not have the financial resources to upgrade their softener to a more efficient system or to hire a professional to calibrate their existing softener. Municipalities or utility districts can offer programs that provide homeowners with best management practice information for their water softeners as well as potentially offering financial assistance for system upgrades.

Municipalities can offer services or informational resources to assist residents in optimizing the efficiency of their softeners and determining the hardness of their water. This could be in the form of educational materials and hardness testing kits that can help homeowners properly calibrate their existing softeners or via professional recalibration services at low or no cost to homeowners. Often a utility district will inform residents of the hardness level in the supply water.

Incentives can assist in facilitating recalibration or removal of point-of-entry water softeners. Financial incentives could also be used to further encourage homeowners to optimize or remove softeners as appropriate. Some municipalities in the State have developed rebate programs for installation of higher efficiency softeners to help offset the cost to homeowners. Additionally, where homeowners are able to disconnect their softeners without jeopardizing the health of their plumbing and appliances, municipalities can offer free disconnection and pickup services for water softeners to alleviate cost and logistical considerations facing homeowners. Such programs could help overcome the financial barrier some homeowners face for improving softener efficiency. Incentive programs can be effective in reducing chloride, however they can be expensive to implement, prohibitively so for some communities.[39]

From a regulatory perspective, state plumbing code could mandate the installation of high efficiency softeners during new builds, sale of a home, and at the time of replacement. This would take older, less efficient softeners offline and ensure that more homes get upgraded to efficient softeners during these events, thus increasing the prevalence of efficient softeners throughout the community. Plumber training programs could also be required to assure that all plumbing professionals understand the best management practices for water softener use and efficiency. Plumber training programs can also provide training on reverse osmosis, nanofiltration/ultrafiltration, portable exchange softeners, and water conditioners to help plumbers be proficient with these alternative technologies.

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[39] *C. Harris, E. Jones, and K. Lake, "Household Water Softener Incentive Pilot Program," 2023.*

Homeowners can also adjust their expectations for the level of hardness in their water that is deemed acceptable. Many homeowners are accustomed to the fully softened water produced by most point-of-entry water softeners, however water in homes and businesses is considered ideally softened when hardness is between approximately 60 and 120 mg/l as $CaCO_3$.[40] To note, this increase in hardness is likely to be perceptible.[41] While these increased levels of hardness are still adequate for appliance health and soap lathering, some homeowners may require an adjustment period to adapt.

Not all household uses of water benefit from using softened water. Uses that do not require softened water include irrigation, hose bibs, utility sinks, toilets, and other cold water taps. When softening occurs at the point-of-entry, water for these uses can be plumbed to bypass the softener, resulting in softening only where required. Similarly, cold water pipes can be plumbed to bypass the softener, delivering cold water to faucets that is unsoftened. In addition to reducing softener salt use, a cold water supply that bypasses the softener will have less sodium than a softened water supply, which can be beneficial from a health perspective, especially for individuals with hypertension or on a low sodium diet. Retrofitting plumbing to have a portion of the water supply bypass the softener would likely be expensive in an existing home but could be more easily done during new construction. This plumbing separation will require additional piping which would increase construction costs.

Water Softener Chloride Reduction Strategies by WWTPs with Chloride Variances

Due to increasing chloride concentrations in waterways and the harmful impacts chloride has on freshwater ecosystems, wastewater treatment plants are subject to water quality-based effluent limitations (WQBELs) for chloride, among other pollutants. WQBELs restrict the allowable chloride concentration in effluent based on the environmental standards of the specific receiving waterbody and the extent to which the discharge will impact the compliance of a waterbody with the water quality criteria.[42] WWTPs that are unable to attain their WQBEL within the permit term can apply for a temporary water quality standard variance to receive additional time to meet their discharge limit. A chloride variance requires the WWTP to develop and implement a plan to reduce chloride discharges through means such as source reduction and operational

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[40] *United States Department of Energy, "Understanding and Dealing With Hard Water," www.energy.gov/energysaver, accessed on April 16, 2024.*

[41] *Minnesota Pollution Control Agency, December 2018,* op. cit.

[42] *The acute toxicity criterion sets a daily chloride maximum concentration of 757 mg/l that is not to be exceeded more than once in a three year period. The chronic toxicity criterion sets a four-day average of the daily maximum concentration of 395 mg/l that is not to be exceeded more than once in a three year period.*

changes. During the variance period, incremental progress must be made towards meeting the WQBEL. Table 3.1 in Chapter 3 of this Report lists the 14 wastewater facilities in the study area that have chloride variances.

Because treatment process upgrades to remove chloride at a WWTP are often cost prohibitive, source reduction is frequently a significant part of a chloride reduction plan. Chloride from ion exchange water softeners is commonly the largest source of chloride to WWTPs and as such is often targeted for chloride source reduction. Programs can be implemented to provide chloride reduction informational material or to improve the efficiency of water softeners via system calibration services or system upgrades to more efficient demand-based softeners. These initiatives can be in the form of rebates and incentives or can be mandated through ordinances. The following are measures taken by WWTPs in the Region that have chloride variances to reduce the amount of chloride produced by water softeners.

- Ordinances that require new softeners to be demand-based systems
- Ordinances that require a bypass to be installed to supply outdoor hose bibs with unsoftened water
- Inspections to document whether residential water softeners are timer-based or demand-based and provide homeowners with information on efficient softener use and maintenance
- Surveys to collect data on the existing water softeners, operating conditions, and motivation for softening within the service area
- Educational outreach for homeowners, commercial entities, and installers on salt reduction methods
- Incentives for softener tune-ups and upgrades to high efficiency softeners

4.4 SOFTENING IMPACTS ON PRIVATE ONSITE WASTEWATER TREATMENT SYSTEMS

Homes and businesses that are not connected to a municipal sanitary sewer system often have private onsite wastewater treatment systems (POWTS) to treat wastewater. Typically water softener regeneration flow discharges to the POWTS. While further research is needed to fully understand the impacts of elevated chloride and sodium concentrations on POWTS, maintaining the efficiency of a water softener can mitigate the impacts of water softening on the POWTS.

Private Onsite Wastewater Treatment Systems

POWTS treat all wastewater generated in a house and generally consist of a septic tank that removes solids via settling or floatation and digests organic matter. After preliminary treatment in the septic tank, the wastewater gets discharged to the drainfield. The drainfield contains perforated piping surrounded by filter medium such as gravel. Effluent passes through the stone medium into the underlying soils. Microorganisms in the soil further treat the wastewater, removing coliform bacteria, viruses, and nutrients. Ultimately, the treated wastewater percolates through the ground and enters the groundwater. There are numerous POWTS designs and configurations, but the most common types are conventional systems and mound systems.

Conventional Systems

Conventional private onsite wastewater treatment systems are comprised of a septic tank and an at grade drainfield as described above. Gravity is typically used in conventional systems to convey the wastewater from the septic tank to the drainfield. As such, sufficient topographic relief is required on the site for a conventional system to facilitate the gravity flow. The drainfield is located in a trench and is surrounded by stone or gravel, as shown in Figure 4.Conventional Septic System. A geotextile is typically placed on top of the trench to prevent dirt and other sediment from entering the trench and fouling the system. Adequate depth to the groundwater table is needed to provide sufficient space for the drainfield layers. Conventional POWTS require a larger lot size to be able to fit the expansive drainfield system.

Mound Systems

Mound systems function similar to conventional systems in that they contain a septic tank that provides preliminary treatment via settling and flotation as well as digestion of organic materials along with a drainfield that distributes the partially treated wastewater through a gravel and sand medium into soils beneath. In mound systems, however, the drainfield is located in an above grade mound that is built up to accommodate the gravel and sand layers as well as the perforated piping, as shown in Figure 4.Mound Septic System. A pump is needed between the septic tank and the drainfield to lift the wastewater up into the mounded drainfield. As the wastewater passes through the drainfield and percolates through the native soils beneath, it is further treated by microorganisms in the soils, as occurs in conventional systems. Mound systems can be a viable alternative on sites with shallow soil depth, high groundwater, or shallow bedrock that does not have adequate subsurface depth to fit a conventional system.

Impacts of Water Softening on POWTS

Septic systems typically receive all wastewater generated in a house. This includes water from toilet flushing, bathing, laundry, and water softener regeneration. When assessing the impacts of water softening on septic systems, there are four main points of consideration: the effect of softened water and regeneration waste on septic tank treatment process, the effect of softened water and regeneration waste on the drainfield, the impact of softening on tank corrosion, and the impact of the hydraulic load from the water softener.

Septic tank microbiology is essential to the treatment of wastewater, and therefore it is important to understand the impact of elevated sodium and chloride concentrations from softening on microbial treatment performance in the septic tank. Researchers disagree on the effect of water softening on septic tank treatment. While some studies purport that the heightened chloride and sodium concentrations can reduce the treatment performance of the microorganisms in the tank,[43] other studies conclude that water softening activity has no negative impacts.[44] Softener efficiency is likely key to septic tank performance. Efficiently operated softeners may actually improve settling in the tank, while inefficient water softeners may decrease treatment performance.[45] Inhibited septic tank performance can result in higher levels of solids being discharged to the drainfield, increasing the risk of fouling the system with sediment buildup. Additionally, some experts debate whether the saline backwash from softeners may create stratification in the septic tank, which could reduce the separation of solids.[46]

Partially treated wastewater from septic tanks discharge into the drainfield to be infiltrated into the soil. The primary concern for systems treating softened water is the potential for reduced soil hydraulic conductivity due to higher sodium concentrations in the wastewater. The higher sodium concentration can cause more water to migrate into the soil structure causing the soil to swell. This can result in less void space and reduced hydraulic conductivity, potentially reducing the infiltration rate of the wastewater into the underlying soils. Whether a given POWTS drainfield experiences reduced soil hydraulic conductivity and reduced infiltration depends on the specific soil types onsite as well as the specific water chemistry of the wastewater.

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[43] *A. Howes, "Water Softeners and Septic Systems", undated.*

[44] *C. Kinsley, A, Crolla, and D. Joy, "Impact of Water Softeners on Septic Tanks Field Evaluation Study", January 2006.*

[45] *Water Quality Research Foundation, "Environmental Impact Study: Water Softener Effects on Septic System Performance", 2013.*

[46] *Ontario Onsite Wastewater Association, "Water Softener & Onsite Sewage Systems" August 2020.*

In addition to potential impacts on the treatment processes, another area of potential concern is the impact water softeners may have on the physical materials of the treatment system. The saline backwash of water softeners has been thought to contribute to corrosion of septic tank concrete, however empirical evidence is lacking to support this claim. Additionally, the anaerobic digestion of organic materials in the sludge layer in septic tanks naturally produces hydrogen sulfide, which becomes sulfuric acid when it reacts with oxygen in the air space within the tank. Sulfuric acid can leach calcium from the concrete, corroding the tank and leading to structural weakening and potentially structural failure of the tank. As such, it is likely that most septic tank corrosion is due to the naturally occurring sulfuric acid rather than the chloride in the softener backwash. While chloride has not been shown to corrode septic tank concrete or expedite the corrosion from sulfuric acid, it can corrode any rebar that has been exposed in the tank due to the corrosion from sulfuric acid.

A water softener will contribute a certain hydraulic load to an onsite wastewater treatment system, requiring adequate system sizing. A typical water softener regeneration cycle will discharge approximately 50 gallons of wastewater,[47] which is roughly equivalent to one extra load of laundry.[48] This discharge represents only approximately 6.2 percent of the total flow to a septic tank,[49] and regeneration cycles often are run overnight when household water demand is low. Using properly calibrated water softeners optimizes the frequency of regeneration cycles, minimizing the amount of wastewater generated over time and reducing the hydraulic loading to the onsite wastewater treatment system. Most modern POWTS are designed to comfortably handle this extra hydraulic loading.

While the impacts of water softeners on private onsite wastewater treatment systems are still in question, homeowners can nonetheless take measures to reduce the amount of chloride entering the system. Beyond potentially benefiting the functionality and longevity of the POWTS, reduction in household chloride production can decrease the amount of chloride pollution to groundwater and native soils as well as potentially save money due to less salt and energy used. Homeowners can reduce chloride discharge by calibrating their ion exchange water softener as discussed previously in this Chapter.

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[47] Ibid. (in reference to Ontario Onsite Wastewater Association 2020)

[48] *C. Kinsley, A. Crolla, and D. Joy, 2006,* op. cit.

[49] *R. Seigrist, M. Witt, and W.C. Boyle, "Characteristics of Rural Household Wastewater", 1976.*

4.5 CHAPTER SUMMARY

Key conclusions for this Chapter include:

- High hardness in water can cause scale buildup in pipes and appliances, reduce soap lathering and its effectiveness, and leave a film on glasses and other surfaces. Overall the Region has high groundwater hardness, which impacts those users with groundwater as their drinking water source.

- Hardness is typically removed by ion exchange water softening in homes. This process generates chloride as a waste product, which typically discharges to the municipal sanitary sewer system or a POWTS. Traditional wastewater treatment processes do not remove chloride.

- Water softener optimization and upgrading to more efficient systems can reduce chloride generation. This can be supported by public outreach and education programs, free or reduced cost optimization services, and financial incentives for upgrading to a more efficient softener.

- Homeowners can adjust their expectations for an acceptable level of hardness in their water. Water softener bypass valves can be installed and operated to adjust the hardness level in the finished water, which can reduce salt usage.

- Alternate water softening technologies can remove hardness without generating chloride onsite. These technologies are available for both residential and commercial use and include:

    - Portable exchange water softeners

    - Reverse osmosis

    - Nanofiltration

- Emerging water softening and conditioning technologies may reduce the buildup of scale without generating chloride, however more research and development is needed for these technologies to become more widespread. These technologies include:

    - Template assisted crystallization

    - Magnetic treatment
    - Electrically induced precipitation
    - Capacitive deionization

- Costs for emerging water softening and conditioning technologies are not widely available.
- Septic systems often receive water softener waste brine. The impact of these chlorides on the septic system components and function is unknown.

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Chapter 4

PRIVATE WATER SOFTENING AND TREATMENT

TABLES

Table 4.Water Treatment Technology Summary
Summary of Considerations for Private Water Conditioning and Softening Technologies

Technology	Traditional	Alternate			Emerging			
Consideration	Ion Exchange	Portable Exchange	Reverse Osmosis	Nanofiltration	Template Assisted Crystallization	Magnetic Treatment	Electrically Induced Precipitation	Capacitive Deionization
Produces chloride onsite	X							
Produces sodium in finished water	X	X						
Uses salt onsite	X							
Suitable for locations with brine discharge restrictions		X	X	X	X	X	X	X
Removes contaminants other than hardness[a]			X	X				X
Produces wastewater and requires a drain connection	X		X	X			X	X
Suitable for locations with water use restrictions		X			X	X		
Uses energy/requires an electrical connection	X		X	X		X	X	X
Suitable as a whole-house water softener/conditioner	X	X			X	X	X	X
Can remove existing scale					X		X	

[a] *Not including manganese or ferrous iron.*

Source: SEWRPC

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Chapter 4

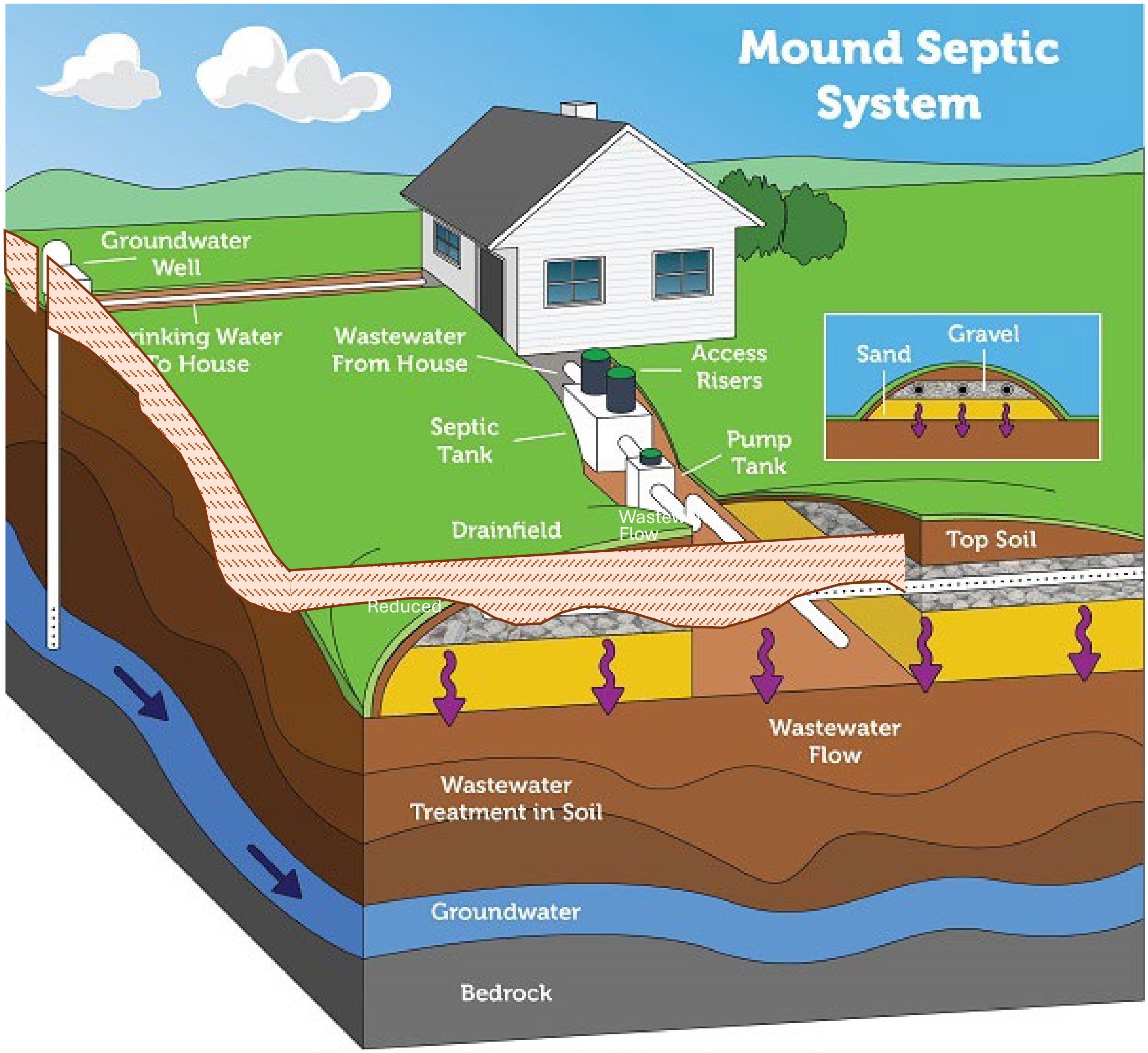
PRIVATE WATER SOFTENING AND TREATMENT

FIGURES

Figure 4.Whole Home RO
Whole Home Reverse Osmosis System

Source: Flicker User Lars Erikson

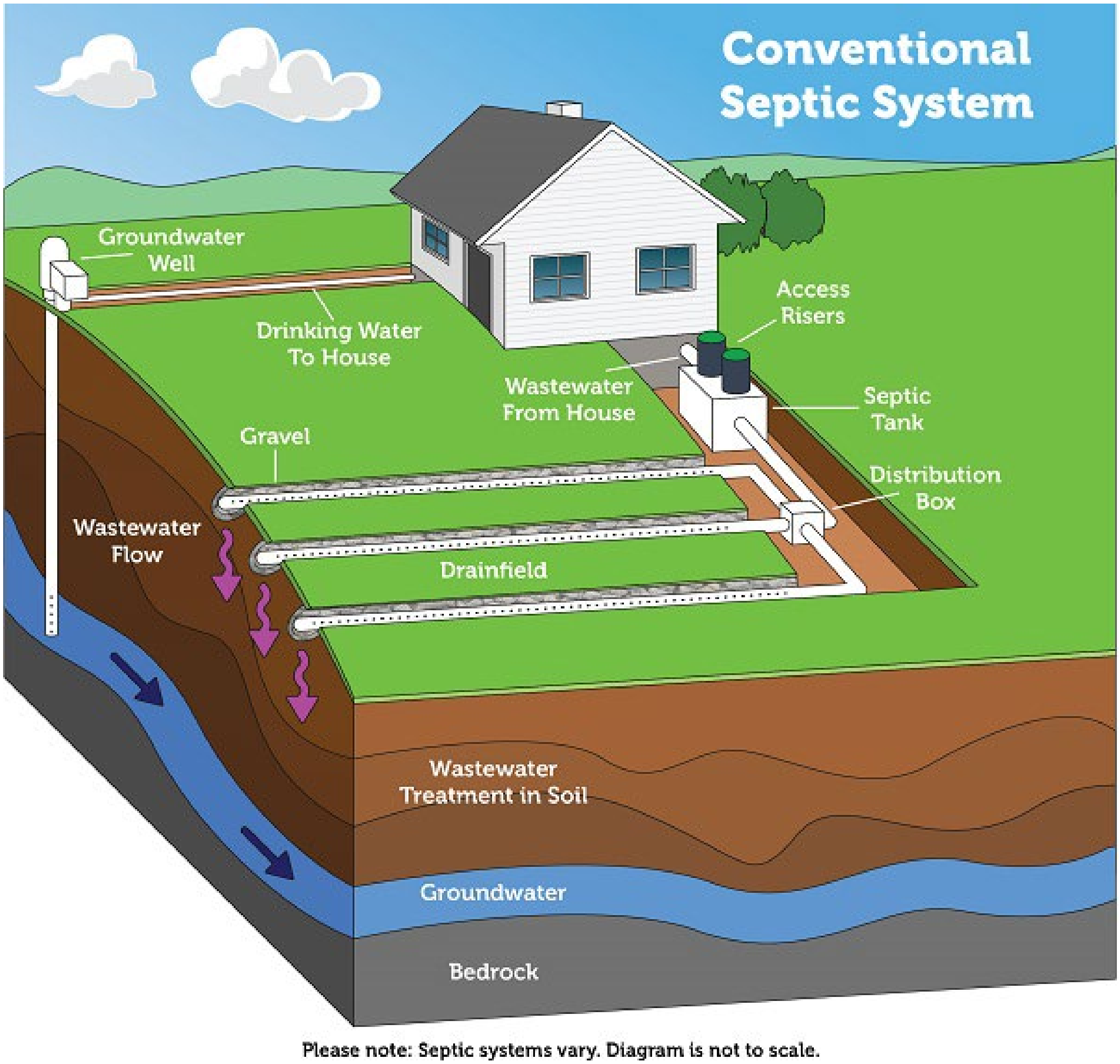
Figure 4.Mound Septic System
Mound Septic System



Please note: Septic systems vary. Diagram is not to scale.

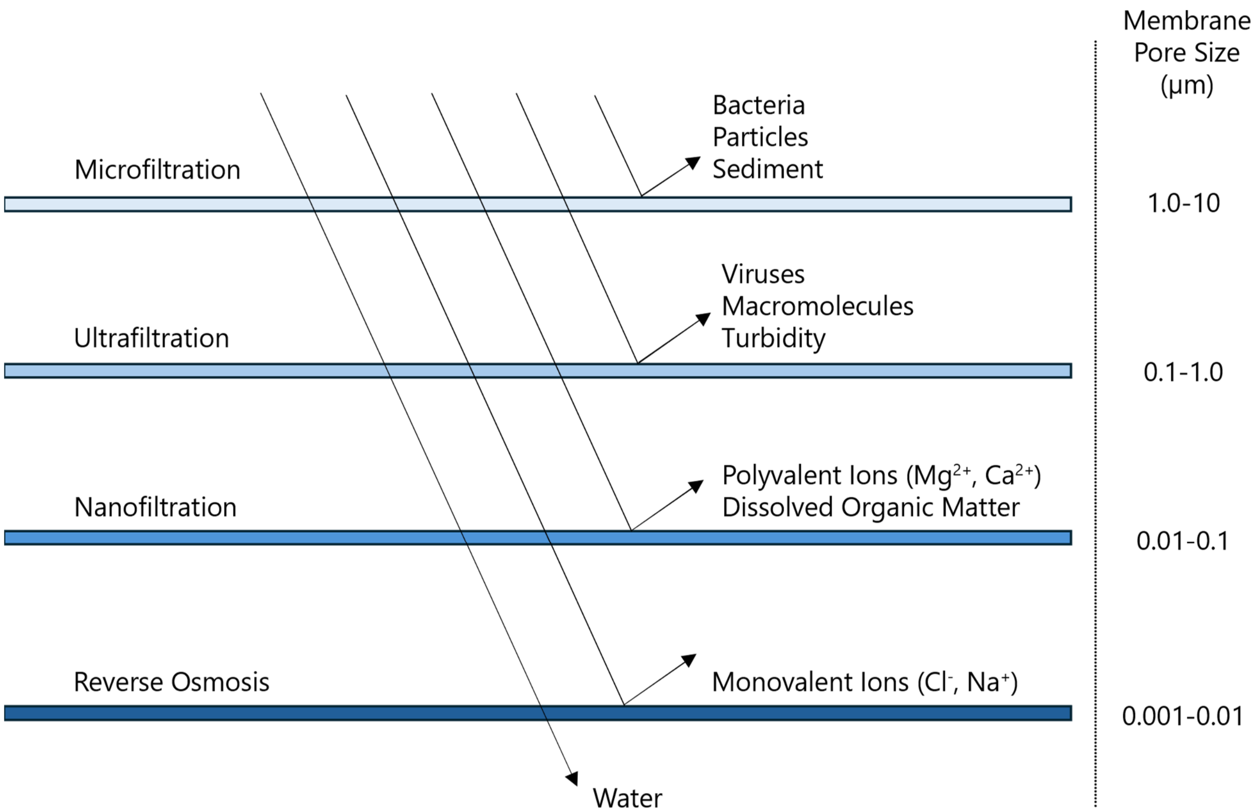
Source: USEPA

Figure 4.Conventional Septic System
Conventional Septic System



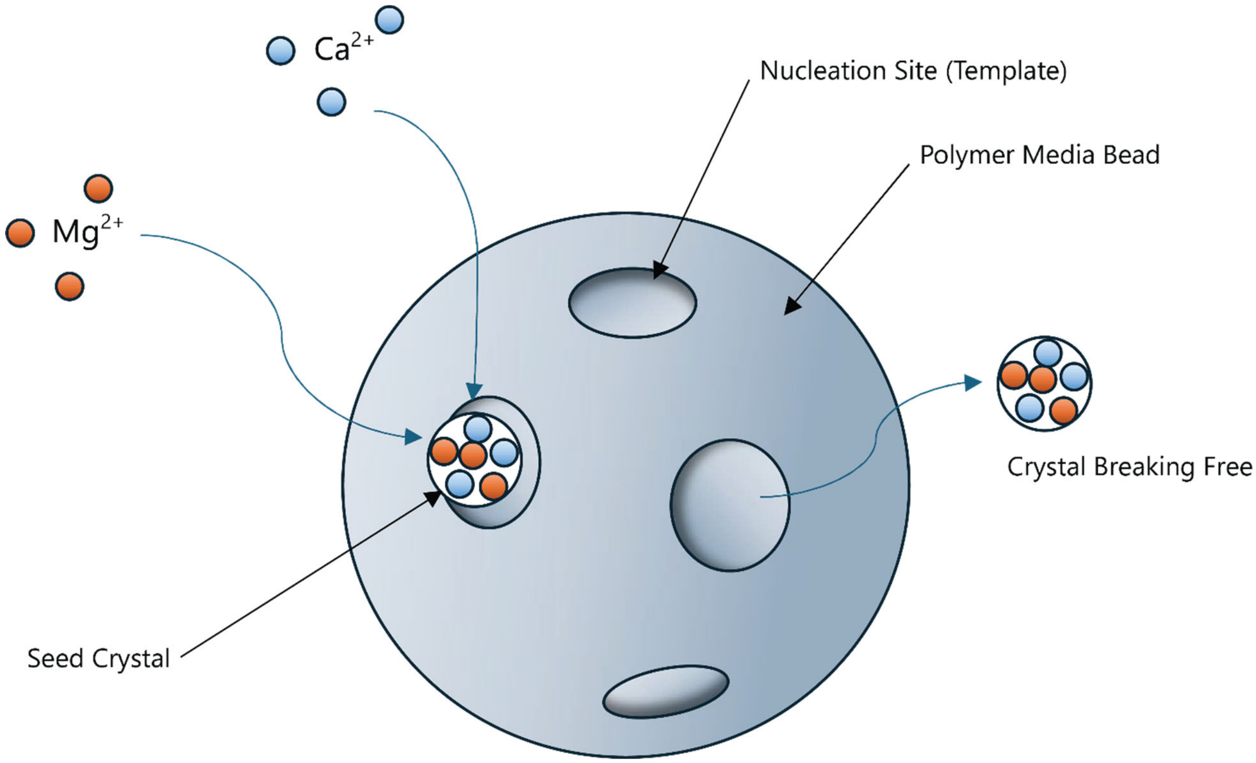
Source: USEPA

Figure 4.Membrane Treatment Hierarchy
Membrane Treatment Technology Hierarchy



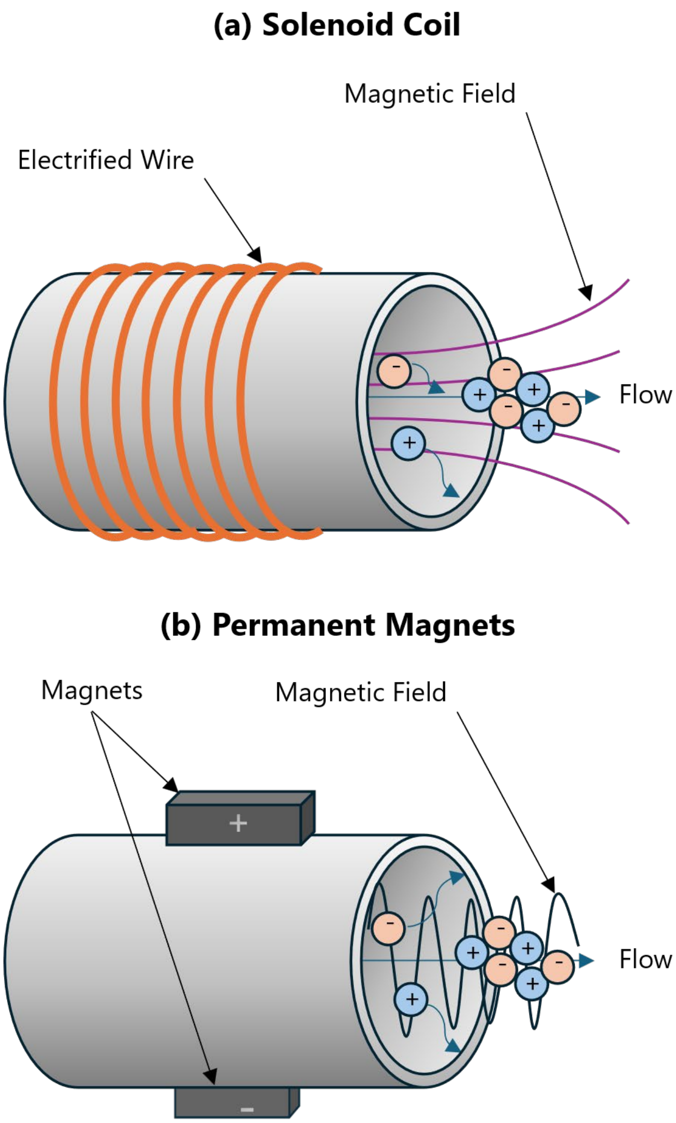
Source: SEWRPC

Figure 4.Template Assisted Crystallization
Template Assisted Crystallization Water Conditioning Process



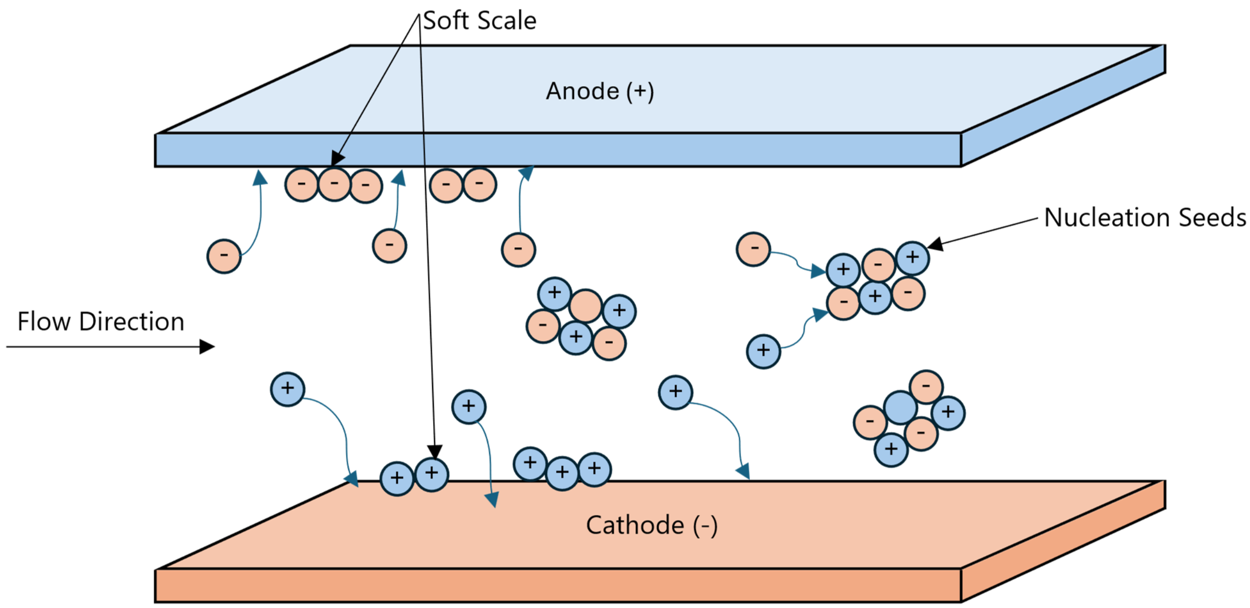
Source: SEWRPC

Figure 4.Magnetic Treatment
Magnetic Treatment Water Conditioning Process



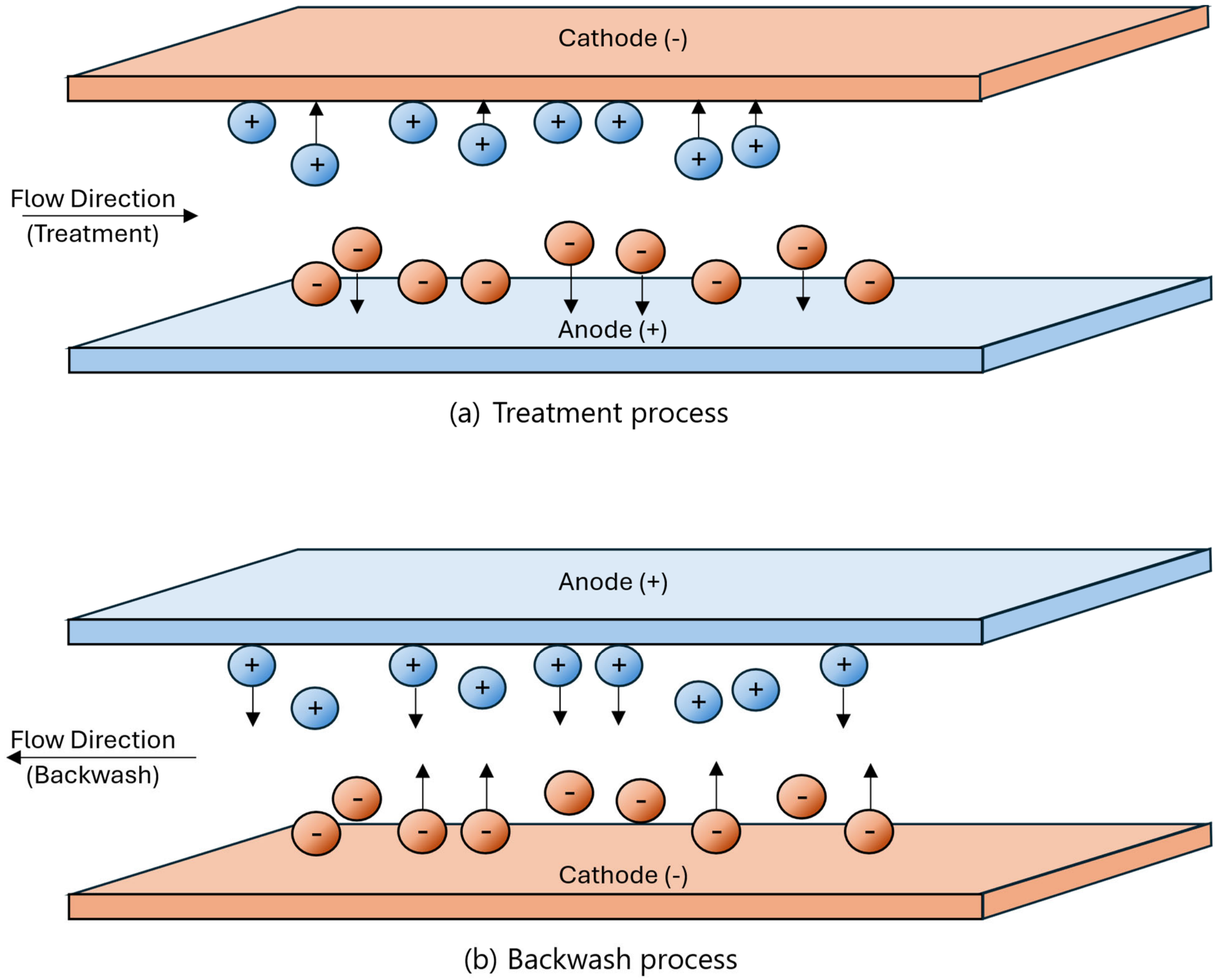
Source: SEWRPC

Figure 4.Electrically Induced Precipitation
Electrically Induced Precipitation Water Conditioning Process



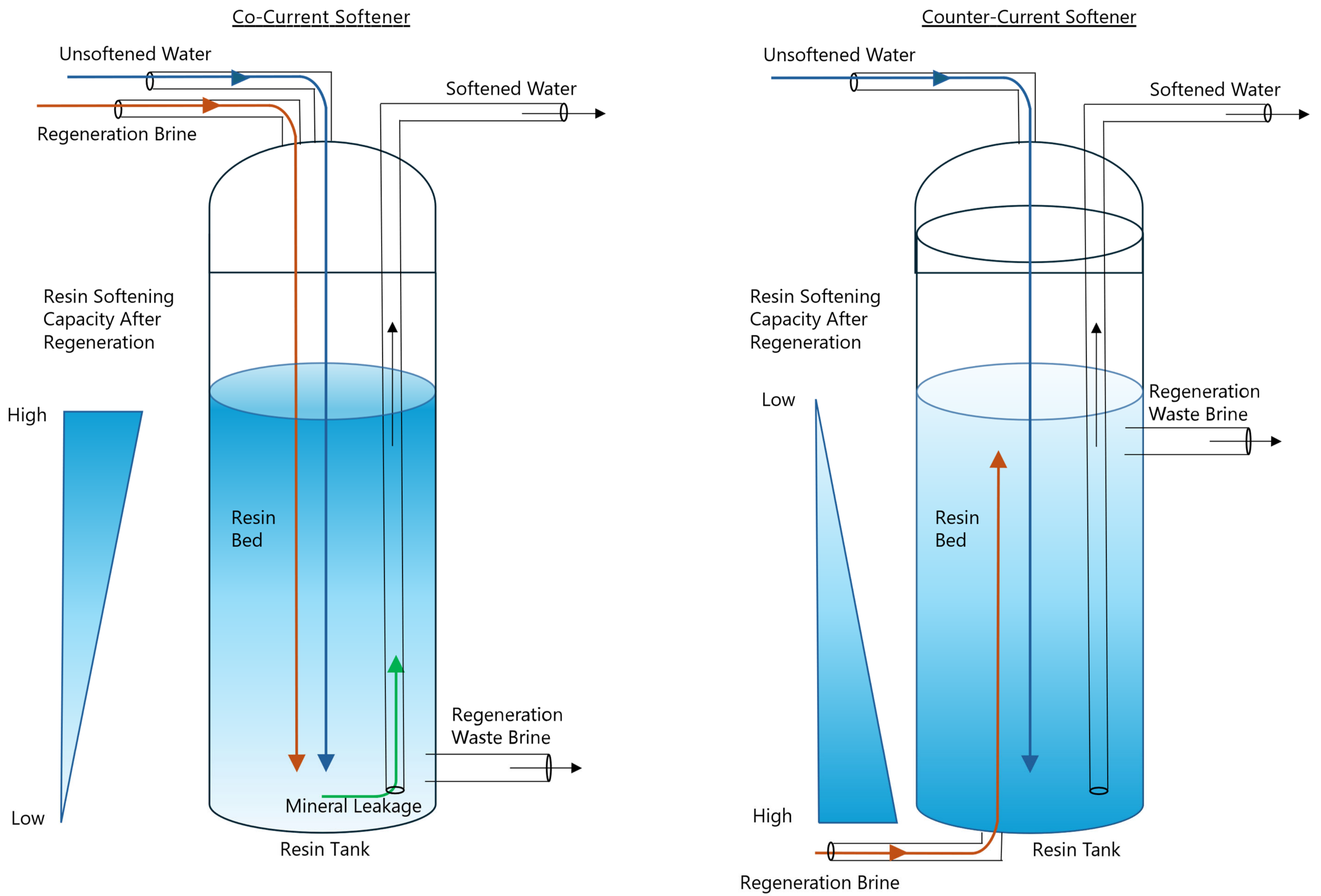
Source: SEWRPC

Figure 4.Capacitive Deionization
Capacitive Deionization Water Softening Process



Source: SEWRPC

Figure 4.Co-Current vs. Counter-Current
Co-Current and Counter-Current Water Softeners



Source: SEWRPC