Non-salt Conditioning Alternatives

Template Assisted Crystallization (TAC)

Template Assisted Crystallization is a relatively new mode of water conditioning. TAC was primarily developed to prevent scaling from hard water. In a TAC system, hard water passes through polymeric beads acting as catalytic nucleation sites for the formation of crystals. [1] As the water passes through the beads, the ions fall into the nucleation sites and grow into microscopic crystals, which are then released back into the water. [1] Refer to Figure 1, for the catalytic nucleation sites employed by a TAC system. These microscopic crystals act as better deposition environments than the piping walls, in scale-growing environments. [1] TAC system is a physical process since the hardness is converted from an ionic aqueous state to a solid crystalline state. The pros and cons of this technology are in Table 1.

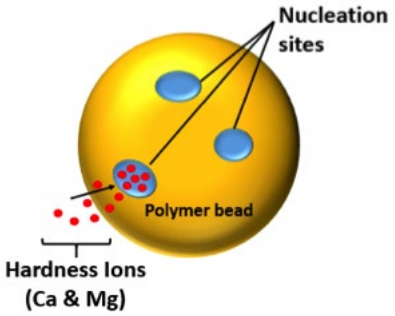

Figure 1: The polymeric nucleation catalyst important to TAC. Image from Heger. [2]

Table 1: Advantages and Disadvantages of a TAC system [1]

Pros	Cons
• No additional chloride loading • No water usage (since no regeneration process) • Smaller operation and maintenance costs • Comparable scale reduction capabilities to Ion-exchange softeners	• Hardness is not removed but transformed – soft scale formation possible • Catalyst media replaced every 3-4 yrs • Ineffective on standing water systems • Aesthetically unpleasant • Technology still developing – unsure of industrial capabilities

Magnetic Water Treatment (MAG)

Magnetic Water Treatment is a physical separation process. MAG systems employ a wire coil around a pipe connected to a transformer. Refer to Figure 2, for a schematic of a MAG system. When current is passed through the wire, a magnetic field either oriented with the flow or against the flow of the pipe is created which will cause the cations to move to the center of the pipe and the anions to move to the wall of the pipe. [1] When the current direction is changed the field direction is switched, causing the cations and anions to collide with each other at a higher frequency and energy allowing the formation of minute crystals. [1] The pros and cons of this technology are in Table 1.

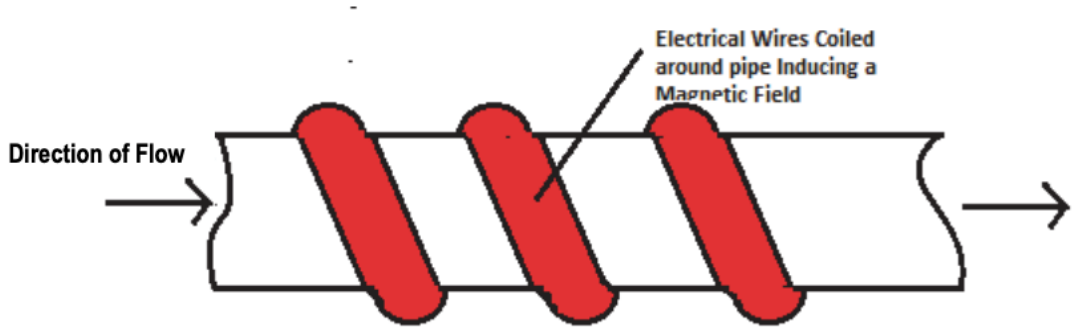

Figure 2: Schematic of the magnetic water treatment from Fox et al. [1]

Table 2: Advantages and Disadvantages of a MAG system [1]

Pros	Cons
• No additional chloride loading • No water usage (since no regeneration process) • Smaller operation and maintenance costs – extremely affordable	• Hardness is not removed but transformed – soft & hard scale formation possible • Can only reduce scale formation by 50% • Cannot be used independently for water conditioning

Electronically Induced Precipitation (EIP)

Electronically Induced Precipitation systems use the electromagnetic properties of hardness ions to condition water. Using an electric field, the hardness ions are precipitated on an electrode, which is then cleaned. [1] Microscopic particles also remain suspended in the water which act as better deposition environments than the piping walls, in scale-growing environments like high temperature environments. The pros and cons of this technology are in Table 3.

Table 3: Advantages and Disadvantages of an EIP system [1]

Pros	Cons
• No additional chloride loading • No water usage (since no regeneration process).	• Hardness is not removed but transformed – soft & hard scale formation possible • Can only reduce scale formation by 50% • Cannot be used independently for water conditioning • High capital, operational and maintenance cost

Capacitive Deionization (CDI)

Capacitive Deionization is relatively new technology in the field of water treatment and conditioning. In a CDI system, water is passed between two charged electrodes with high surface area and adsorption capabilities, so that the cations move towards the negative electrode and the

anions move towards the positive electrode and are absorbed into the electrode surface. [1] Once the electrode surface becomes saturated, a backwash phase occurs where the charge on the electrodes are reversed while the water flows through the system. This ensures that the adsorbed ions are repulsed by the electrode and carried away by the water into the wastewater discharge. [1] Refer to Figure 3, for an illustration of the conditioning process carried out in a CDI system. The pros and cons of a CDI system are in Table 4.

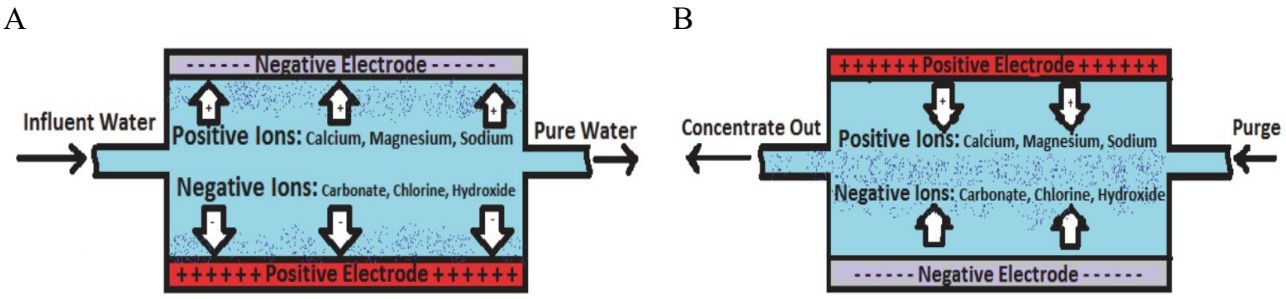

Figure 3: (A) The separation process performed by CID systems. (B) CID system backwash step from Fox et al. [1]

Table 4: Advantages and Disadvantages of a CDI system [1]

Pros	Cons
• No additional chloride loading • Minimal water usage (only backwash phase) • Removes hardness • Comparable scale reduction capabilities to TAC systems and Ion-exchange softeners	• High capital, operational and maintenance cost. • Lack of widespread data on performance in an industrial and commercial setting

Reverse Osmosis (RO)

A Reverse Osmosis (RO) system is one of the most widely known and used water conditioning systems. In a RO system, the raw incoming water is passed through a semipermeable membrane. The membrane is selectively permeable meaning it only allows water to pass through leaving the contaminants on the other side of the membrane. [3] Due to the selective nature of the membrane, it can filter out almost any, if not all, contaminants present in the feed water. This differs from an ion exchange softener which is specialized at exchanging ions, specifically cations. [3] Refer to Figure 4, for an illustration of this process. While there are different types of RO systems present, the central tenet revolves around the reverse osmosis membrane with variations arising due to additional filters being present in the system. The pros and cons of a RO system are in Table 5.

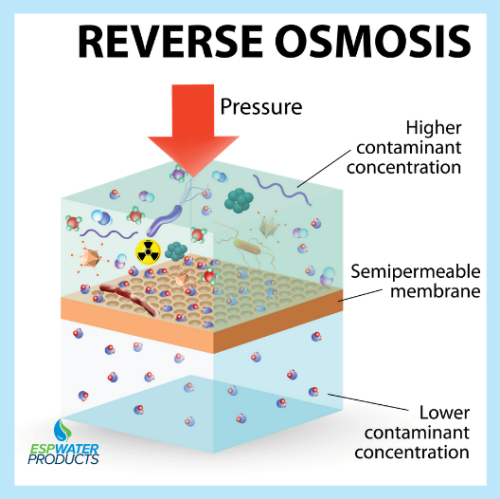

Figure 4: Illustration of a semi-permeable membrane in a RO system from ESP Water Products. [4]

Table 5: Advantages and Disadvantages of a RO system [3, 4]

Pros	Cons
• No additional chloride loading • Completely pure water supplied • Little to no scale growth	• High water and energy use • Periodic membrane cleaning and replacing • High capital, operational and maintenance costs • Implemented in conjunction with a water softener

Works Cited

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

[2] S. Heger, "Residential Water Softener Alternatives," Onsite Installer, 5 April 2019. [Online]. Available: https://www.onsiteinstaller.com/online_exclusives/2019/03/residential-water-softener-alternatives.

[3] K. Marshall, "Ion Exchange vs. Reverse Osmosis: Choosing the Best Treatment System for Your Needs," Samco Tech, 25 June 2018. [Online]. Available: https://www.samcotech.com/ion-exchange-vs-reverse-osmosis-choosing -best-treatment-system-needs/.

[4] ESP Water Products, "Understanding Reverse Osmosis (RO)," [Online]. Available: https://www.espwaterproducts.com/understanding-ro/.