ION EXCHANGE WATER TREATMENT HISTORY

HOW IT STARTED

In 1905, Gans, a German chemist, used synthetic aluminosilicate materials known as zeolites in the first ion exchange water softeners. Although aluminosilicate materials are rarely used today, the term "zeolite softener" is commonly used to describe any cation exchange process.

The synthetic zeolite exchange material was soon replaced by a naturally occurring material called Greensand. Greensand had a lower exchange capacity than the synthetic material, but its greater physical stability made it more suitable for industrial applications. Capacity is defined as the amount of exchangeable ions a unit quantity of resin will remove from a solution. It is usually expressed in kilograins per cubic foot as calcium carbonate.

Figure 8-A. Microscopic view of cellular resin beads (20-50 mesh) of a sulfonated styrene-divinylbenzene strong acid cation exhcanger. (Courtesy of Rohm and Haas Company.)

The development of a sulfonated coal cation exchange medium, referred to as carbonaceous zeolite, extended the application of ion exchange to hydrogen cycle operation, allowing for the reduction of alkalinity as well as hardness. Soon, an anion exchange resin (a condensation product of polyamines and formaldehyde) was developed.The new anion resin was used with the hydrogen cycle cation resin in an attempt to demineralize (remove all dissolved salts from) water. However, early anion exchangers were unstable and could not remove such weakly ionized acids as silicic and carbonic acid.

In the middle 1940's, ion exchange resins were developed based on the copolymerization of styrene cross-linked with divinylbenzene. These resins were very stable and had much greater exchange capacities than their predecessors. The polystyrene-divinylbenzene-based anion exchan-ger could remove all anions, including silicic and carbonic acids. This innovation made the complete demineralization of water possible.

Polystyrene-divinylbenzene resins are still used in the majority of ion exchange applications. Although the basic resin components are the same, the resins have been modified in many ways to meet the requirements of specific applications and provide a longer resin life. One of the most significant changes has been the development of the macroreticular, or macroporous, resin structure.

Standard gelular resins, such as those shown in Figure 8-A, have a permeable membrane structure. This structure meets the chemical and physical requirements of most applications. However, in some applications the physical strength and chemical resistance required of the resin structure is beyond the capabilities of the typical gel structure. Macroreticular resins feature discrete pores within a highly cross-linked polystyrene-divinylbenzene matrix.

These resins possess a higher physical strength than gels, as well as a greater resistance to thermal degradation and oxidizing agents. Macroreticular anion resins (Figure 8-B) are also more resistant to organic fouling due to their more porous structure.

Figure 8-B. Microscopic view of a macroporous strong base anion resin. (Courtesy of Dow Chemical Company.)

In addition to polystyrene-divinylbenzene resins (Figure 8-C), there are newer resins with an acrylic structure, which increases their resistance to organic fouling.
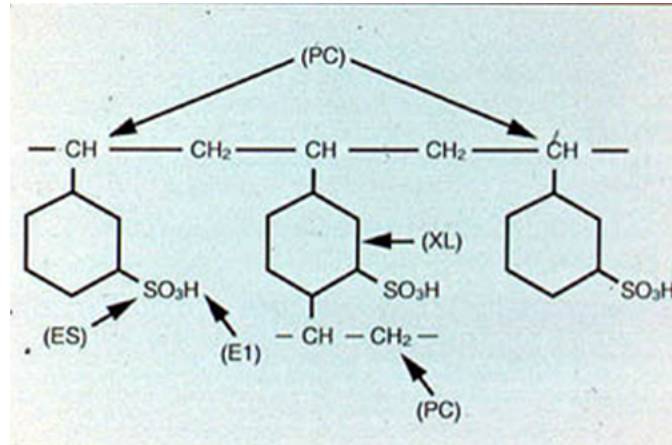

Figure 8-C. Chemical structural formula of sulfonic strong acid cation resin (Amberlite IR-120), (XL): cross link; (PC): polymer chain; (ES): exchange site; (EI): exchangeable ion.

In addition to a plastic matrix, ion exchange resin contains ionizable functional groups. These functional groups consist of both positively charged cation elements and negatively charged anion elements. However, only one of the ionic species is mobile. The other ionic group is attached to the bead structure. Figure 8-D is a schematic illustration of a strong acid cation exchange resin bead, which has ionic sites consisting of immobile anionic (SO_3^-) radicals and mobile sodium cations (Na+). Ion exchange occurs when raw water ions diffuse into the bead structure and exchange for the mobile portion of the functional group. Ions displaced from the bead diffuse back into the water solution.
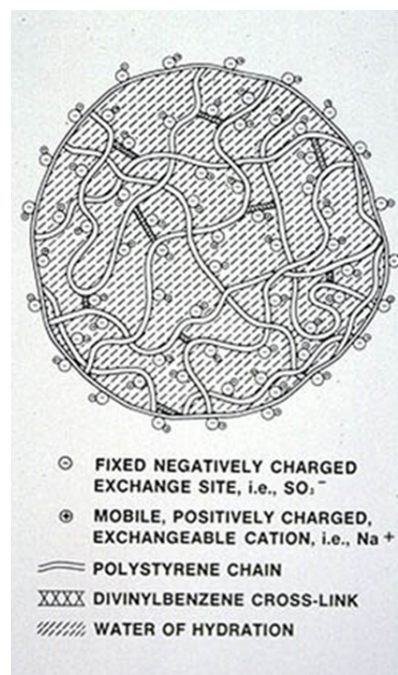

⊙ FIXED NEGATIVELY CHARGED EXCHANGE SITE, i.e., SO_3^-

⊕ MOBILE, POSITIVELY CHARGED, EXCHANGEABLE CATION, i.e., Na+

〜 POLYSTYRENE CHAIN

XXXX DIVINYLBENZENE CROSS-LINK

///// WATER OF HYDRATION

Figure 8-4. Schematic of hydrated strong acid cation exchanger. (Courtesy of Rohm and Haas Company.)

ADVANTAGES AND LIMITATIONS OF ION EXCHANGE

The ion exchange water treatment system is a widely used technology in various applications, including wastewater treatment, due to its numerous advantages and benefits. However, it also comes with certain limitations that need to be considered in specific contexts. Here are the advantages and limitations of the ion exchange process:

Advantages of ion exchange in water treatment:

- Efficient removal of dissolved ions and contaminants, leading to enhanced water quality.
- Versatile and applicable to a wide range of water treatment scenarios.
- Can be customized for specific ion removal needs, making it highly effective in targeted applications.

Limitations of ion exchange in water treatment:

- Limited capacity and lifespan of ion exchange resins, necessitating periodic replacement.
- High operational costs, particularly for large-scale applications or when treating highly contaminated water.
- Potential for regenerant chemicals used in the process to cause environmental concerns during disposal.

Overall, ion exchange remains a valuable and versatile tool in water treatment, but careful consideration of its advantages and limitations is essential for successful implementation in various contexts