Water softening

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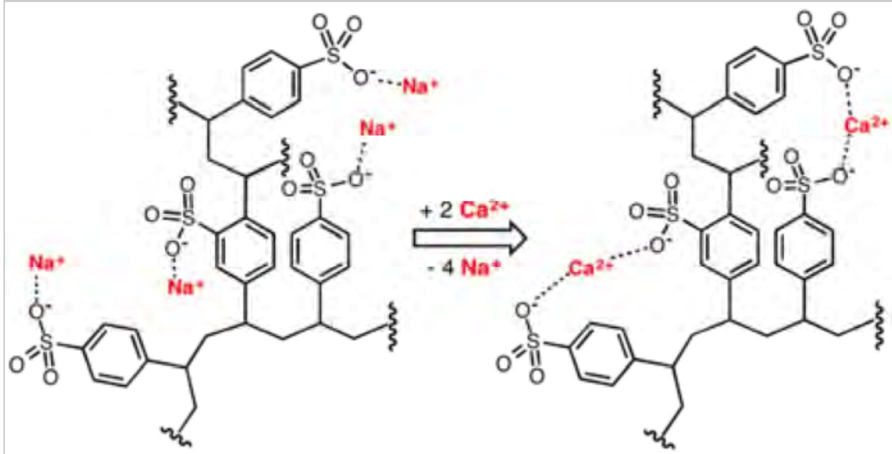
Water softening is the removal of calcium, magnesium, and certain other metal cations in hard water. The resulting soft water is more compatible with soap and extends the lifetime of plumbing. Water softening is usually achieved using lime softening or ion-exchange resins.



Idealized image of water softening process involving replacement of calcium ions in water with sodium ions donated by a cation-exchange resin.

Contents

Rationale

The presence of certain metal ions like calcium and magnesium principally as bicarbonates, chlorides, and sulfates in water causes a variety of problems.[1]

Hard water leads to the buildup of limescale, which can foul plumbing, and promote galvanic corrosion.[2] In industrial scale water softening plants, the effluent flow from the re-generation process can precipitate scale that can interfere with sewage systems.

The slippery feeling experienced when using soap with soft water occurs because soaps tend to bind to fats in the surface layers of skin, making soap molecules difficult to remove by simple dilution. In contrast, in hard-water areas the rinse water contains calcium or magnesium ions which form insoluble salts, effectively removing the residual soap from the skin but potentially leaving a coating of insoluble stearates on tub and shower surfaces, commonly called soap scum.[3]

Which of these effects is considered more or less desirable varies from person to person, and those who dislike the sliminess and difficulty of washing off soap caused by soft water may harden the water by adding chemicals such as baking soda, calcium chloride or magnesium sulphate.[4]

Methods

Lime scale in a PVC pipe

The most common means for removing water hardness rely on ion-exchange resin or reverse osmosis. Other approaches include precipitation methods and sequestration by the addition of chelating agents.

Ion-exchange resin devices

Conventional water-softening appliances intended for household use depend on an ion-exchange resin in which "hardness ions" - mainly Ca^{2+} and Mg^{2+} - are exchanged for sodium ions.[5] As described by NSF/ANSI Standard 44,[6] ion-exchange devices reduce the hardness by replacing magnesium and calcium (Mg^{2+} and Ca^{2+}) with sodium or potassium ions (Na^+ and K^+)."

Ion exchange resins, in the form of beads, are a functional component of domestic water softening units.

Ion exchange resins are organic polymers containing anionic functional groups to which the divalent cations (Ca^{++}) bind more strongly than monovalent cations (Na^+). Inorganic materials called zeolites also exhibit ion-exchange properties. These minerals are widely used in laundry detergents. Resins are also available to remove carbonate, bi-carbonate and sulphate ions which are absorbed and hydroxide ions released from the resin.

When all the available Na^+ ions have been replaced with calcium or magnesium ions, the resin must be re-charged by eluting the Ca^{2+} and Mg^{2+} ions using a solution of sodium chloride or sodium hydroxide depending on the type of resin used.[7] For anionic resins, regeneration typically uses a solution of sodium hydroxide (lye) or potassium hydroxide. The waste waters eluted from the ion-exchange column containing the unwanted calcium and magnesium salts are typically discharged to the sewage system.

Lime softening

Lime softening is the process in which lime is added to hard water to make it softer. It has several advantages over the ion-exchange method but requires full-time, trained personnel to run the equipment.[8]

Chelating agents

Chelators are used in chemical analysis, as water softeners, and are ingredients in many commercial products such as shampoos and food preservatives. Citric acid is used to soften water in soaps and laundry detergents. A commonly used synthetic chelator is ethylenediaminetetraacetic acid (EDTA).

Distillation and rain water

Since Ca^{2+} and Mg^{2+} exist as nonvolatile salts, they can be removed by distilling the water. Distillation is too expensive in most cases. Rainwater is soft because it is naturally distilled during the water cycle of evaporation, condensation and precipitation.[9]

Reverse osmosis

Reverse osmosis (RO) takes advantage of hydrostatic pressure gradients across a special membrane. The membrane has pores large enough to admit water molecules for passage; hardness ions such as Ca^{2+} and Mg^{2+} remain behind and are flushed away by excess water into a drain. The resulting soft water supply is free of hardness ions without any other ions being added. Membranes have a limited capacity, requiring regular replacement.

Non-chemical devices

Some manufacturers claim that their electronic devices affect the interaction of minerals with water so that the minerals do not bind to surfaces. Since these systems do not work by exchanging ions, like traditional water softeners do, one benefit claimed for the user is the elimination of the need to add salt to the system. While particle size reduction and plant growth promotion have been claimed, such systems do not remove minerals from the water itself. Rather, they can only alter the downstream effects that the mineral-bearing water would otherwise have. Examples are remediation of calcium scaling[10][11] and remediation of salt crusts in soil.[12] These systems do not fall within the term "water softening" but rather "water conditioning".

Similar claims for magnetic water treatment are not considered to be valid. For instance, no reduction of scale formation was found when such a magnet device was scientifically tested.[13]

Health effects

The CDC recommends limiting daily total sodium intake to 2,300 mg per day,[14] though the average American consumes 3,500 mg per day.[15] Because the amount of sodium present in drinking water—even after softening—does not represent a significant percentage of a person's daily sodium intake, the EPA considers sodium in drinking water to be unlikely to cause adverse health effects.[16]

For those who are on sodium-restricted diets, the use of a reverse osmosis system for drinking water and cooking water will remove sodium along with any other impurities which may be present. Potassium chloride can also be used as a regenerant instead of sodium chloride, although it is more costly. For people with impaired kidney function, however, elevated potassium levels, or hyperkalemia, can lead to complications such as cardiac arrhythmia.

Compared to reverse osmosis and distilled methods of producing soft water, hard water conveys some benefits to health by reducing the solubility of potentially toxic metal ions such as lead and copper, which are more soluble in soft water than in hard water.[17]

Environmental impact

Softened water (measured as residual sodium carbonate index) in which calcium and magnesium have been partly replaced by sodium is not suitable for irrigation use, as it tends to cause the development of alkali soils.[18] Non-chemical devices are often used in place of traditional water softening for this application.

See also

- Desalination
- Ion exchange
- Water purification

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