The Basics – Water Softening by Ion Exchange

What is "hard" water?

Water described as "hard" contains elevated levels of dissolved calcium and magnesium. Groundwater dissolves these metals from surrounding soil and rock.

What problems are caused by hard water?

Hard water can cause costly breakdowns in boilers, cooling towers, and plumbing, as well as making soap less effective. When hard water is heated, the carbonates precipitate out of solution forming a scale in pipes and on surfaces composed of mostly calcium carbonate, calcium sulfate, magnesium carbonate, and magnesium sulfate.

The resulting scale can end up completely plugging pipes and restricting flow. In boilers, the scale prevents efficient heat transfer, effectively insulating the heating elements, forcing the boiler to use more energy to provide hot water and causing metal boiler components to overheat. Hard water makes soap less effective because the suspended minerals react with the soap's organic acid to form calcium or magnesium salts.

How is hard water treated?

Water is made soft with ion exchange resin in a water softener. Troublesome calcium and magnesium ions in the hard water are exchanged for sodium, which is more soluble and does not precipitate out to form scale or interfere with soap.

Ion exchange resins are very small, porous, round plastic beads. For water softening applications, the resin beads' polymer structure contains a permanently attached, fixed negative ion that cannot be removed. In simple terms, the resin bead has a fixed negative charge. Each negatively charged exchange site can hold a positively charged ion. In this case, sodium (which has a positive charge) is attached to the exchange site (negative and positive charges attract – think of magnets!). So, mobile sodium ions are attached to each of the fixed negative charges on the resin beads.

The calcium and magnesium ions suspended in the water have stronger positive charges than the sodium ions. When hard water passes through the resin beads, the calcium and magnesium's strong attraction to the negatively charged resin beads "kick" the sodium ion off so the calcium and magnesium can take its place (and remain attached to the bead). As a result, the less desirable calcium and magnesium ions are exchanged for the more desirable sodium ions.

It's important to note that the salinity of the water does not actually change; the softening process simply exchanges one salt for another.

Eventually, the resin beads become saturated with hardness, mostly calcium and magnesium, and there are no more exchange sites left to produce soft water. The resin beads have reached exhaustion and must be regenerated.

How does regeneration work?

In simple terms, the ion exchange resin is soaked in a strong sodium chloride solution (brine) where the sheer volume of brine dislodges the calcium and magnesium ions in the resin beads. At the same time, the sodium in the brine solution affixes to the resin beads. After regeneration, the excess brine and hardness ions are rinsed to drain, and the resin beads are ready to use again.

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