THE WATER MANAGEMENT SOCIETY

TOOLBOX TALKS

What is Water Softening?

Water softening is the process of removing calcium & magnesium salts from water to reduce its hardness and eliminate scale and its associated problems. This is done via resin beads in a softening unit which exchange the calcium or magnesium dissolved ions as the water flows through the softening unit.

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What is hard water?

Hard water is water that has high mineral content and is formed when water percolates through deposits of limestone & chalk etc. which are largely made up of calcium and magnesium carbonate, bicarbonate & sulphates.

There are two types of hardness, temporary & permanent. Temporary hardness is due to the presence of calcium hydrogencarbonate $Ca(HCO_3)_{2(aq)}$ & magnesium hydrogencarbonate $Mg(HCO_3)_{2(aq)}$. Both of these disassociate when heated to the original insoluble carbonate which is reformed and deposited. In hard water areas this is most often seen on the heating elements in kettles.

So softening removes calcium & magnesium ions (the hardness) from the water hence the term temporary hardness. It is a general rule that increasing water temperature increases the solubility of most salts but from the above there are exceptions, in this case $CaCO_3$ and $MgCO_3$.

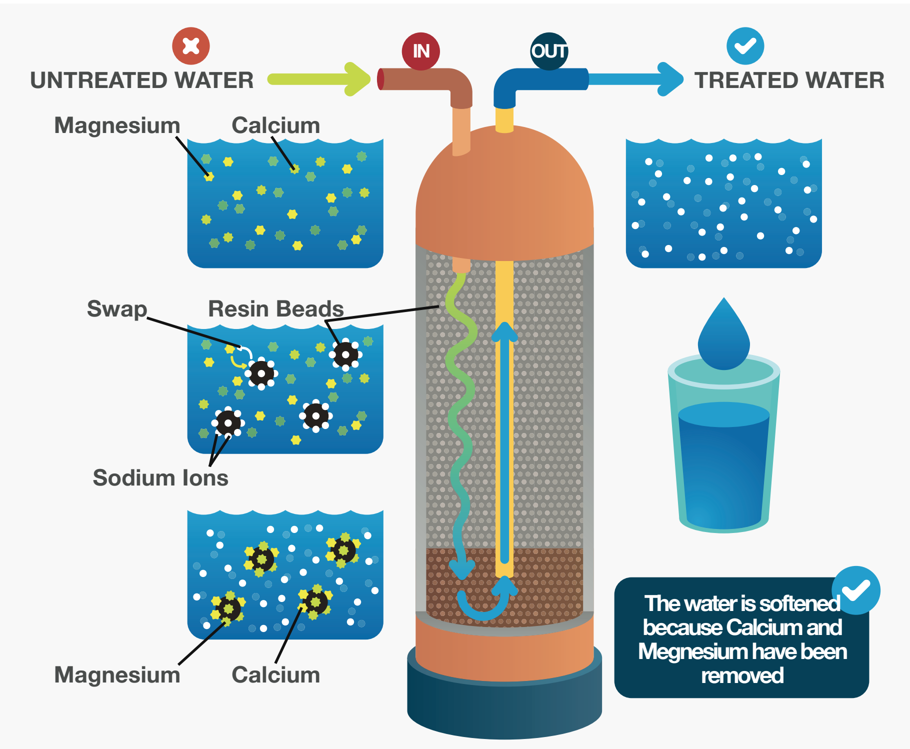
Permanent hardness of water is due to the presence of chlorides, nitrates & the sulphate of magnesium. These are not precipitated with rising temperature.

Associated Problems of Hard Water

The precipitation of scale* within domestic water systems can cause numerous problems - precipitation on the element of kettles, spotting on glasses coming from dishwashers, mineral stains, reduction in the lifespan of domestic appliances etc. Within steam boilers, heating systems, cooling systems & water systems scaling is potentially a major issue. Scaling causes the narrowing of pipes and, as such, increased pumping energy is required to move the water through the pipes and, in addition, scaling increases the thermal resistance to heat transfer. In other words, it requires more heat to boil the water or more cooling to reduce the temperature.
So the effect of scaling is to increase energy costs due to reduced energy efficiency (as a rule of thumb - 1mm of scale produces a 10% decrease in heat transfer). In extreme cases, scale on heat transfer surfaces in boilers can cause failure of the metal if it does not allow sufficient heat transfer away from the metal surface. The scale can also reduce flow rates and block system components, and provide a protective environment for harmful bacteria, such as legionella.

Water Softening

Water softening is the process of removing calcium & magnesium salts from the water using ion-exchange resin beads, in a suitable pressure vessel tank. An ion-exchange material is an insoluble substance containing anions or cations which



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are exchangeable with ions in a surrounding solution without physical change in the structure of the ion-exchange material. Certain naturally occurring alumino-silicates, the zeolites, show this property. Of course these days synthetic zeolites are used in water softeners and in its base state, the negatively charged resin beads hold positively charged sodium ions.

The process of exchange takes place according to:

$$Ca^{2+} + 2Na^{+}(Z^{-}) \leftrightarrow 2Na^{+} + Ca^{2+}(Z^{-})_2$$

Where (Z^{-}) represents the zeolite. Magnesium ions are replaced by a similar reaction. Eventually all the resin exchange sites on the resin have been replaced by calcium & magnesium ions and no further softening can take place. The resin may then be regenerated for further water softening by washing with a concentrated solution of sodium chloride (brine).

Softener Regeneration

1. Backwash – Regeneration starts with a backwash, which reverses a flow of water normally up through the resin bed which displaces any accumulation of suspended solids. This backwash is typically able to expand the resin bed by 50%.

2. Brine draw – Once the backwash is completed a brine solution is directed through the resin bed. The high concentration of sodium ions in the brine causes the calcium and magnesium ions to be replaced with sodium ions (a reversal of the softening process detailed above).

3. Slow rinse – Once regeneration of the bed is complete, clean, fresh water is run through the softener which finalises the ion-exchange process and the excess brine is flushed to drain.

4. Fast rinse – The final phase in the regeneration process is a fast rinse of fresh water which serves to flush any remaining brine from the system.

Selecting a Water Softener

Water softeners are of two basic types, time clock and water meter controlled.

Time clock controlled:

The more basic water softeners are time clock controlled whereby the softener is set to regenerate at a setdate and/or time. This is normally calculated by the hardness of the water supply, the capacity of thewater softener and the demand for softened water within the property or the industrial process. In most domestic and office type properties thesoftener is normally set to regenerate at 02:00 when demand is likely to be very low as, during regeneration of a single softener unit, the incoming hard water is delivered to outlets and/or the industrial process.

As the softener will regenerate at a set time irrespective of usage there will be occasions when the resin bed has been exhausted or, on the contrary, has hardly been used. An example would be in a school during the holiday periods. It can be argued that this is an unnecessary waste of salt and water.

Water meter controlled:

Water meter controlled can be considered the most economical method of water softening as they regenerate based on the water usage overcoming changes in demand for softened water.

In the two situations above, using a single resin bed supply (a simplex unit) of softened water means that there will be times, during regeneration, that softened supply will cease. If continuous supply is considered critical a duplex softener system is employed. As the name suggest this consists of two resin beds and as one is in service the other is regenerated and then on standby such that continued supply is maintained.
It is important to note, that when using a duplex system the standby vessel is stagnant for the period it is not in use, so it is important to only have duplex units for critical systems or when the standby unit is only in standby for short periods. A full legionella risk assessment should include the potential risk associated with water softeners and associated bypass pipework.

Maintenance & disinfection

Water softeners like all equipment requires regular maintenance to operate effectively and safely. Typically the requirement is to service the units twice per annum, one being a ‘major’ service and one being a ‘minor’ service.

Depending on what the softener feeds, domestic hot & cold services, cooling towers or process systems The HSE’s HSG 274 parts 1,2,3 requires disinfection of the resin bed, and brine system to the manufacturers recommendations (annually in the case of HSG274 part 2), the disinfectant should be selected to the efficacy of the disinfectant and inline with the ion exchange resin manufacturers method statement. Servicing and disinfection should be carried out by a trained/skilled person who is competent to do so, and have a task specific risk assessment in place.

Other considerations

For health reasons there is set limit on the recommended level of sodium ion concentration in drinking water (200mg/l). For some parts of the UK softened water would not exceed that level however there are parts of the UK where that limit would be exceeded and a bypass should be installed to supply mains to drinking water outlets e.g. the kitchen. There are also other specialised installations where lower sodium levels are required and direct mains supply should be provided e.g. preparation of formulas for children or infirm, sick & elderly people on low sodium diets, dialysis water.

When installing a water softener you need to take into account a number factors such as the location, available space, supply from the incoming mains, electrical supply and suitable drainage.

Note – Scale precipitation reaction chemistry:

$$Ca(HCO_3)_{2(aq)} \rightarrow CO_{2(g)} + H_2O_{(l)} + CaCO_{3(s)}$$

$$Mg(HCO_3)_{2(aq)} \rightarrow CO_{2(g)} + H_2O_{(l)} + MgCO_{3(s)}$$

***For more details see Scale toolbox talk.**

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