Softening Water Does Not Increase Corrosivity

Water that has been softened by ion exchange, is sometimes misrepresented to be more corrosive due to the softening process. This is usually because it is incorrectly associated with naturally soft water. Hard water which has been softened, and naturally soft water, are very different.

Softened water and naturally soft water. The main constituents of hard water are calcium and magnesium together with bicarbonate, sulphate, chloride, nitrate. When the water is passed through an ion exchange water softener, the calcium and magnesium ions are replaced by sodium ions; the anions (bicarbonate, chloride, sulphate, etc), and hence the alkalinity, remain unchanged.

Naturally soft water, on the other hand, contains very little dissolved solids; its pH is often low and buffering capacity is negligible. Hence, naturally soft water is often very corrosive to metals.

So ion exchange softened[1] water has not undergone any change which affects the parameters which might increase corrosivity[2], such as dissolved oxygen, pH, temperature, conductivity, chloride level, sulphate level, etc.

Historical Evidence. Water softeners have been used for many years. The technology dates back to 1903 when Robert Gans first patented the process. Softened water was necessary to protect steam engines against scale deposition in the engine boiler tubes. Similarly, water softeners have been used domestically since 1916 (link to advert – see below). For over 100 years, no specific mention, concern or requirements relating to increase in corrosivity have been found necessary for domestic or industrial softening applications.

The water softener industry, through trade associations such as the EWTA, UAE, Aqua Belgica, UKWTA and WQA, is alert to any operational issues which water softening may incur. Throughout the world, there is not one situation, of which these associations are aware, where water softening has been the proven cause of a corrosion failure. It should be borne in mind that the WQA (Water Quality Association, USA), with more than 2,400 members, represents about 50% of the world softener market.

The Misconceptions. Some boiler manufacturers are under the misapprehension that softened water is more corrosive. Situations have been encountered where a heating system has failed and the boiler manufacturer has negated its warranty because a softener was fitted to the premises. In all of these situations that have been investigated, the failure was eventually attributed to a cause other than softened water.

In addition, indiscriminate application of somewhat ageing prediction tools such as the Langelier Saturation Index, without taking account of more recent advances in the understanding of the factors that influence corrosion, can lead to misdiagnosis of corrosive conditions. The Langelier Index was developed to determine whether a water source is potentially scale-forming or scale-dissolving (agressive). Although it was not intended to be applied to softened or naturally soft water, its hypothesis was that a thin, uniform

[1] Note that water treated by reverse osmosis (RO) is termed demineralised because virtually all of the dissolved solids are removed. RO water is therefore corrosive to plumbing fittings and, for domestic applications, should only be fitted at point of use.

[2] Note: corrosivity and aggressivity are often confused; they are ***not*** the same. A corrosive water will attack metals and cause damage to plumbing systems. An aggressive water tends to dissolve scale (calcium carbonate) but is not necessarily corrosive.

layer of scale deposition can, under carefully controlled conditions, contribute to a protective barrier. However, in normal household plumbing applications, widely variable physical and chemical conditions render a deposit that is very variable in thickness, porosity, morphology, location, etc, such that reliable prediction of a beneficial effect is not possible. Deposition is usually restricted to the hottest parts of the boiler.
But, the scale can in fact exacerbate the corrosion problem in that formation of crevices, and/or bacteriological activity, can cause accelerated localised corrosion with consequent failure and property damage.

Investigation. Expert opinion has been sought internationally. NSF (National Sanitation Foundation, USA) provides an international testing and certification service for water treatment products and food. When questioned by WRc-NSF, its joint venture company in the UK, as to their awareness or possible concern about potential for increased corrosivity of softened water, its response (link to NSF reply) was that, in their international experience, they are not aware of any such issue and it would be addressed in product standards if they were necessity.

Chemical Inhibitors. Water treatment with a corrosion inhibitor is often advisable or necessary depending upon water quality parameters which are known to affect corrosion. In such circumstances, an appropriate inhibitor should be selected. Some inhibitors may increase the corrosivity of softened water and so selection should be based, not only on whether an inhibitor is required but whether the inhibitor is suitable for the quality of the water being used.

In the UK, chemical inhibitors are tested and certified by the BuildCert scheme which is operated by WRc-NSF (link to their website). The test process involves aeration procedures which result in displacement of carbon dioxide from the water and consequent rise in pH. This is significant with respect to aluminium as most aluminium components in a heating system will begin to corrode at a pH above 9. This evolution of carbon dioxide will not occur in a closed loop heating system because the carbon dioxide gas cannot escape (even in a vented tank system, the hot water is under the pressure head below the tank and the carbon dioxide is held in solution). Arguably, this challenges the representativeness of the test, but, even if it is over-excessive, an inhibitor which passes is more than capable of meeting the real-life conditions.

Definitive Experience. The predominant cation and anion in ion exchange softened water are usually sodium and bicarbonate, respectively, and sodium bicarbonate is used in closed circuit systems to assist in corrosion control by buffering (stabilising) the pH between 8.0 and 8.5.

Moreover, pitting corrosion of copper in hot water systems can be caused by localised deposits of iron, manganese or aluminium impurities in the water[3]. Ion exchange water softening will effectively remove these impurities at point of entry.

The positions of European trade associations (UAE, Aqua Belgica, UKWTA) and international (WQA) are clear and based on extensive experience and expertise.

[3] Harfst F.H., (1998). Corrosion in copper pipes can be prevented., *Water Technology*, Vol. 22 No. 3.

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Laboratory Evidence. Tests have been conducted which have compared the corrosivity of hard water before and after softening. A study by the USEPA (United States Environmental Protection Agency) was undertaken between 1994 and 1996 comparing the corrosion and corrosive properties of hard water with that after softening by ion exchange[4]. The results showed no pattern of higher leaching from lead, copper, brass and galvanised materials nor significant deterioration in the water quality parameters that influence corrosion rate. Similar results were obtained from tests in Belgium (click here to view report on Belgian corrosion study).

BSI Study on Corrosion in Hard and Softened Water

During 2011, a study was conducted by BSI on behalf of the UKWTA to investigate any difference in corrosion between two heating systems set up in BSI laboratory in Loughborough (click here for the full report); one system filled with hard water and the other with base exchange softened water. Each system was identical and comprised a gas fired boiler with 10 radiators and was operated on a 2 hours on and 2 off cycle over 6 months. Each system was fitted with corrosion coupons. No inhibitors were used.

The overall conclusion was that there was no significant difference in corrosion observed between the system operating on hard water and the one operating on softened water. The initial corrosion rate of aluminium was higher, over the first few weeks, in the softened water system but settled to an insignificant rate with the formation of a protective layer. The corrosion rate of steel was less in the softened water but insignificant in terms of system life (100 years for 5 mm wall thickness). The corrosion rate of copper was 3 to 5 time higher in hard water than softened – but, again, insignificant in terms of system life. Similar, although even less significant, results were observed for brass and stainless steel. Examination of the radiators and boiler by sectioning showed no significant corrosion for either system.

CONCLUSION Water softening by base exchange does not increase corrosivity.

[4] Sorg T. J., Schock M.R. and Lytle D.A., (April 1998). Leaching of Metals from Household Plumbing Materials: Impact of Home Water Softeners, *USEPA*.

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