

6.10 Corrosion control

6.10.1 General

Corrosion is the partial dissolution of the materials constituting the treatment and supply systems, tanks, pipes, valves, and pumps. It may lead to structural failure, leaks, loss of capacity, and deterioration of chemical and microbiological water quality. The internal corrosion of pipes and fittings can have a direct impact on the concentration of some water constituents, including lead, copper and nickel. Corrosion control is therefore an important aspect of the management of a water supply system.

Corrosion control involves many parameters, including the concentrations of calcium, bicarbonate, carbonate, and dissolved oxygen, as well as pH. The detailed requirements differ depending on water quality and for each distribution system material. The pH controls the solubility and rate of reaction of most of the metal species involved in corrosion reactions. It is particularly important in relation to the formation of a protective film at the metal surface. For particular metals, alkalinity (carbonate and bicarbonate) and calcium (hardness) also affect corrosion rates.

6.10.2 Lead

Lead corrosion (plumbosolvency) is of particular concern. Lead piping is still common in old houses, and lead solders have been used widely for jointing copper tube. The solubility of lead is governed by the formation of insoluble lead carbonates. The solubility of lead increases markedly as the pH is reduced below 8 because of the substantial decrease in the equilibrium carbonate concentration. Thus, plumbosolvency tends to be at a maximum in waters with a low pH and low alkalinity, and a useful interim control procedure pending pipe replacement is to maintain pH in the range 8.0 to 8.5 and possibly to dose orthophosphate.

6.10.3 Copper

Copper tubing may be subject to general corrosion, impingement attack and pitting corrosion. General corrosion is most often associated with soft, acid waters; waters with pH below 6.5 and hardness of less than 60 mg/l CaCO₃ are very aggressive to copper. Impingement attack is the result of excessive flow velocities and is aggravated in soft water at high temperature and low pH. The pitting of copper is commonly associated with hard groundwaters having a carbon dioxide concentration above 5 mg/l and high dissolved oxygen. Surface waters with organic colour may also be associated with pitting corrosion. A high proportion of general and pitting corrosion problems are associated with new pipe in which a protective oxide layer has not yet formed.

6.10.4 Nickel

Concentrations of nickel up to 1 mg/l may arise due to the leaching of nickel from new nickel-chromium plated taps and from stainless steel pipes and fittings. Nickel leaching falls off over time. Increase of pH to control corrosion of other materials should also help to reduce leaching of nickel.

6.10.5 Concrete and cement

Concrete is a composite material consisting of a cement binder in which an inert aggregate is embedded. Cement is primarily a mixture of calcium silicates and aluminates together with some free lime. Cement mortar, in which the aggregate is fine sand, is used as a protective lining in iron and steel water pipes. In asbestos–cement pipe, the aggregate is asbestos fibres. Cement is subject to deterioration on prolonged exposure to aggressive water – due either to the dissolution of lime and other soluble compounds or to chemical attack by aggressive ions such as chloride or sulphate – and this may result in structural failure. Aggressiveness to cement is related to the ‘Aggressivity Index’, which has been used specifically to assess the potential for the dissolution of concrete. A pH of 8.5 or higher may be necessary to control cement corrosion.

6.10.6 Characterising corrosivity

Most of the indices that have been developed to characterise the corrosion potential of waters are based on the assumption that water with a tendency to deposit a calcium carbonate scale on metal surfaces will be less corrosive. The Langelier Index (LI) is the difference between the actual pH of a water and its ‘saturation pH’, this being the pH at which a water of the same alkalinity and calcium hardness would be at equilibrium with solid calcium carbonate. Waters with positive LI are capable of depositing calcium carbonate scale from solution.

There is no corrosion index that applies to all materials, and corrosion indices, particularly those related to calcium carbonate saturation, have given mixed results. The parameters related to calcium carbonate saturation status are, strictly speaking, indicators of the tendency to deposit or dissolve calcium carbonate (calcite) scale, not indicators of the ‘corrosivity’ of water. For example there are many waters with negative Langelier Index that are non-corrosive, and many with positive LI that are corrosive. Nevertheless there are many documented instances of the use of saturation indices for corrosion control based on the concept of laying down a protective ‘eggshell’ scale of calcite in iron pipes. In general waters with high pH, calcium and alkalinity are less corrosive and this tends to be correlated with a positive LI.

The ratio of the chloride and sulphate concentrations to the bicarbonate concentration (Larson ratio) has been shown to be helpful in assessing the corrosiveness of water to cast iron and steel. A similar approach has been used in studying zinc dissolution from brass fittings - the Turner diagram.

6.10.7 Water treatment for corrosion control

To control corrosion in water distribution networks the methods most commonly applied are adjusting pH, increasing the alkalinity and/or hardness, or adding corrosion inhibitors such as sodium polyphosphates or silicates and orthophosphate. The quality and maximum dose to be used should be in line with appropriate national specifications for such water treatment chemicals. Although pH adjustment is an important approach its possible impact on other aspects of water supply technology, including disinfection, must always be taken into account.

Treatment to reduce plumbosolvency usually involves pH adjustment. When the water is very soft (less than 50 mg/l CaCO₃), the optimum pH is about 8.0 to 8.5. Alternatively, dosing with orthophosphoric acid or sodium orthophosphate might be more effective particularly when plumbosolvency occurs in non-acidic waters. Wherever practicable, lead pipework should be replaced. Grants for pipe replacement may be available from the local authority and some water companies offer a lead pipe replacement service.