Home Water Plant

THE SCIENCE OF LIMESCALE FORMATION and HOME WATER PLANT™ SCALE REMOVAL & PREVENTION [1]

It All Starts with Hard Water

Hard water is created by the chemical weathering or dissolving of rocks in lakes, rivers, reservoirs, and wells. This process begins with carbon dioxide from the atmosphere dissolving in surface waters. Atmospheric carbon dioxide reacts with water in solution to form a weak acid, carbonic acid. (Carbonic acid is harmless; it is more popularly known as soda water, which adds carbonation to soft drinks.) This weak carbonic acid reacts with carbonates[2] in rocks and silicates[3] to form soluble calcium, magnesium and manganese ions[4] and other minerals, the components of hard water. As the water runs over and through cracks in these rocks (for example, limestone), these soluble ions get into the water supply.

Other weak acids, such as acid rain, get into the water supply and dissolve rocks further contributing to the creation of hard water.

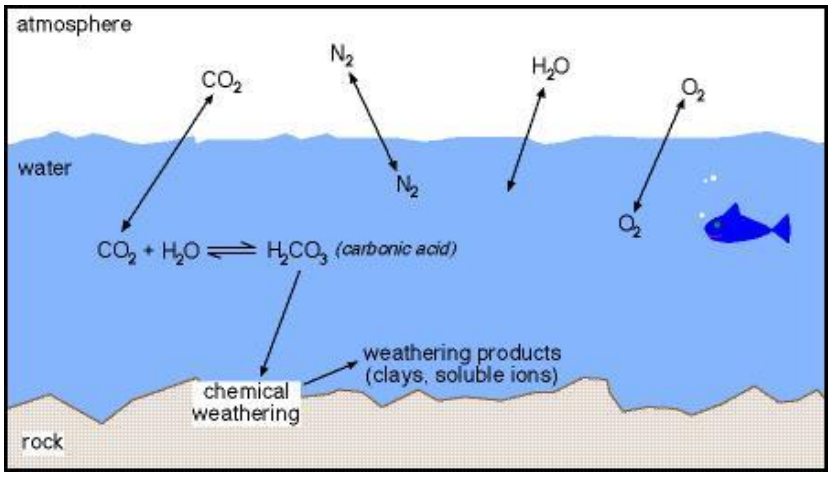

Figure 1[5]

[1] © Sharon Laska, 2018.
[2] Salts (see footnote 8) composed of metal ions and carbonate ions.
[3] Similar to limestone, in that they contain positive calcium or magnesium ions, but different negative ions.
[4] Atoms which have gained or lost electrons, resulting in either a net positive or negative charge.
[5] Picture provided by Columbia University, http://www.columbia.edu/vjd 1/carbon. htm

The reactions for dissolving rocks (weathering) are these:

Reaction 1: Carbon dioxide is removed from the atmosphere by dissolving in water and forming carbonic acid

$$\underset{\text{carbon dioxide}}{CO_2} + \underset{\text{liquid}}{H_2O} \longrightarrow \underset{\text{carbonic acid}}{H_2CO_3}$$

Reaction 2: Carbonic acid dissolves (weathers) rocks, yielding soluble bicarbonate ions, other soluble ions, and clays:

$$\underset{\text{carbonic acid}}{H_2CO_3} + \underset{\text{water}}{H_2O} + \text{mineral salts} \rightarrow \underset{\text{bicarbonate ion}}{HCO_3^-} + \text{cations } (Ca^{++}, Mn^{++}, Mg^{++}, \text{etc.}) + \text{clays}$$

Calcium and magnesium are the most common soluble ions in hard water and the amounts of these two ions are measured to determine water hardness. Iron and manganese ions are also found in some water supplies.

How does limescale form in your pipes & appliances?

LIMESCALE IN PIPES

LIMESCALE ON APPLIANCE HEATING ELEMENTS

The three carbonates that form from the most common soluble metal ions are calcium carbonate, magnesium carbonate, and manganese carbonate. These three carbonates are very insoluble in water, tend to fall out of solution, and deposit as white to off-white crystals in pipes and on heating elements in hot water heaters, dishwashers, instant hot water heaters, and coffee makers.

Reactions 3, 4, and 5 show the formation of each carbonate from each soluble metal ion and the bicarbonate ions in water. Carbon dioxide gas is also produced and becomes dissolved in

the water. These three reactions all absorb heat energy. Thus, they all make more solid crystal carbonates at higher temperatures. The "descaler energy" notation for each of these reactions is discussed later in this paper.

Reaction 3: Formation of calcium carbonate (white solid/crystal) limescale

heat energy **Calcium Carbonate**

$Ca^{+2} + 2HCO_3^{-1}$ ⇌ $CaCO_3 + CO_2 + H_2O$

(dissolved ions) descaler energy (solid/crystal) (gas) (liquid)

Reaction 4: Formation magnesium carbonate (white solid crystal) limescale

heat energy **Magnesium Carbonate**

$Mg^{+2} + 2HCO_3^{-1}$ ⇌ $MgCO_3 + CO_2 + H_2O$

(dissolved ions) descaler energy (solid/crystal) (gas) (liquid)

Reaction 5: Formation Manganese Carbonate (white/pink solid crystal) limescale

heat energy **Manganese Carbonate**

$Mn^{+2} + 2HCO_3^{-1}$ ⇌ $MnCO_3 + CO_2 + H_2O$

(dissolved ions) descaler energy (solid/crystal) (gas) (liquid)

Reaction 6:

In the presence of oxygen, Fe ions (iron) form rust, which precipitate out of water and combine with the calcium or magnesium or manganese carbonate formations. This may give limescale a reddish-brown color.

$2Fe^{+3} + 3O^{-2}$ → Fe_2O_3

Iron oxygen rust

How do the different metal ions in hard water affect users?

Calcium, magnesium, manganese, and iron are all needed by the human body. These minerals are found at varying amounts in hard water supplies, as well as in many different foods.

Calcium and magnesium, as the main components in hard water, adversely affect the user by producing limescale build-up in pipes and on dishwasher and hot water heater elements. This limescale causes appliances to work less efficiently and lowers water flow (from reduced interior diameter pipes). Descaling removes the limescale. The freed calcium and magnesium ions pose no health or aesthetic problems to users; the minerals are necessary to health.

Manganese and iron are found less frequently in water supplies. They also form precipitates and attach to calcium and magnesium carbonates in limescale, often contributing a reddish-brown color. However, manganese and iron are an additional nuisance for the user, considered aesthetic contaminants. Each gives a disagreeable metallic taste to water and imparts a brownish stain to laundry and plumbing fixture.[6] When pipes and heating elements are descaled, manganese and iron salts flake off as the calcium and magnesium salts are dissolved. Descaling, itself, does not get rid of the smell and stains caused by manganese and iron. But Home Water Plant phase 2, Aquasorb, treatment does (presuming the source of manganese and iron is the city's water supply, not deteriorated in-home piping).

How is limescale dissolved in pipes and appliances?

The Home Water Plant Descaler uses the carbonic acid already in the water.

Limescale is composed mainly of calcium carbonate, plus smaller amounts of magnesium, manganese, or iron salts[7]. Calcium, magnesium, and manganese carbonates are all insoluble in water, but are soluble in weak acids.

Looking back at figure 1, one sees that atmospheric carbon dioxide dissolves in water making a weak acid, carbonic acid. This carbonic acid weathers the rocks on earth and slowly dissolves them. Carbon dioxide is also byproduct of limescale formation itself (reactions 3, 4, and 5) ultimately forming further carbonic acid.

Carbonic acid contains two hydrogen ions. Descaler electrical energy frees one of these hydrogen ions in carbonic acid via an electrochemical reaction.[8]

Reaction 7: formation of hydrogen ions

[6] https://water.usgs.gov/edu/groundwater-contaminants.html.
[7] Positive metal ions combined with negative ions in a crystalline structure.
[8] "Electrochemical reactions" encompasses both facilitating electrical reactions chemically (e. g., deriving electricity from a battery) and facilitating chemical reactions through the introduction of electrical energy. In this instance, the latter type of reaction is meant.

The Hydrogen ions derived from the carbonic acid react with the solid calcium carbonate, limescale, to form soluble calcium and bicarbonate ions.[9]

Reaction 8: Reaction of hydrogen ions with limescale and formation of dissolved ions

$$H^{+} + CaCO_3 \rightarrow Ca^{+2} + HCO_3^{-1}$$

hydrogen ion | solid calcium carbonate | calcium ion | bicarbonate ion

The Home Water Plant Descaler sends out a continuous electrochemical signal that provides activation energy for separating a hydrogen ion from carbonic acid (reaction 7) already in the water. The freed hydrogen ion combines with the solid $CaCO_3$, limescale, and converts it into soluble ions (reaction 8). (See the "descaler energy" left-facing reaction arrows at reactions 3, 4 and 5.)

One overall reaction for the carbonic acid acting on the calcium carbonate can be written as:

Reaction 9:

$$H_2CO_3 + CaCO_3 \xrightarrow{\text{electrochemical signal}} Ca^{+2} + 2HCO_3^{-1}$$

carbonic acid | solid calcium carbonate | electrochemical signal | calcium ion | bicarbonate ion

Reactions 8 and 9 specifically apply to calcium carbonate, the most prevalent form of lime scale; similar reactions occur with magnesium and manganese carbonate.

How does the Home Water Plant Descaler prevent limescale formation?

The Home Water Plant Descaler's electrochemical signal also causes continuous movement of the dissolved ions in the water. The positive metal ions (Ca^{+2} and Mg^{+2}) and the negative ions (CO_3^{-2}) are kept moving in the water by the signal, thus preventing them from getting close enough to each other to precipitate as new calcium or magnesium carbonate (limescale).

$$Ca^{+2} + CO_3^{-2} \xrightarrow{\text{electrochemical signal}} \text{X} \rightarrow CaCO_3$$

[9] This is typical. The freed hydrogen ions from acids (weak or strong) are what dissolve carbonates and silicates.

Does all of the limescale dissolve and get washed away?

A byproduct of descaling limescale or dissolving limestone is a small amount of a white powdery substance. Any working descaler device has this same white powdery by-product, sometimes called lime dust. This white power does not clog pipes or attach to heating elements. In the Home Water Plant, any dish, silver or glassware spotting from lime dust is prevented by the phase 4 dishwasher-only filter.

ABSTRACT:

The limescale that clogs pipes and attaches to heating elements in hot water heaters and dishwashers is directly caused by metal ions (mostly calcium and magnesium) being deposited as carbonate crystals. Limescale ions come mainly from dissolved limestone. Limestone is slowly dissolved by carbonic acid formed when atmospheric carbon dioxide dissolves in surface water. The dissolved calcium and magnesium and other ions from dissolved limestone travel with water flow and are later re-crystalized as limescale on pipes and heating elements.

The Home Water Plant Descaler dissolves limescale without adding chemicals or salts. The Home Water Plant Descaler activates the carbonic acid, already in water, to eliminate limescale in pipes and appliances. The carbonic acid in water comes from the natural dissolving of carbon dioxide from the air at the citiy's water source (e. g., reservoir or well), and secondarily from the reactions that make carbonate salts (limescale). The Home Water Plant Descaler produces a constant electrochemical signal activating this carbonic acid to release hydrogen ions. These hydrogen ions combine with solid calcium carbonate, converting it into soluble ions that wash away. The electrochemical signal also generates movement of the dissolved ions in hard water to prevent the formation of new limescale.

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Abbreviated Curriculum Vitae

Education:

B.S. Biochemistry, University of Wisconsin

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Work History:

- 15 years at University of Washington in Clinical Chemistry, University Hospital.
- 5 years at the first Biotech Company in Seattle – Oncogen. Later Oncogen was purchased by Bristol-Meyers. Developed a diagnostic blood test for breast cancer.
- 4 years at Baxter Healthcare in Chicago. Developed an automated blood test for syphilis for the American Red Cross for blood banking.
- 5 years at a start-up biotech company. VP of Manufacturing and Customer Service. Responsible for all reagent manufacturing, including water quality and reagent shelf-life.
- 14 years teaching chemistry and advanced chemistry in Seattle area high schools.