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Scale-Forming Tendency of Water

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One common concern we hear is: "We have hard water at our facility. Will it form scale deposits inside our automated watering system?" The white solid scale that can appear on plumbing components is calcium carbonate or $CaCO_3$. If water is supersaturated with calcium carbonate, then hardness scale can precipitate.

What problems can scale cause in an automated watering system?

- *Drinking valves may leak if tiny calcium carbonate salt crystals develop inside the valve, preventing it from sealing properly.*
- *Solenoid valves can leak when scale forms inside. If the pressure reducing station's flush solenoid valve leaks, you will get a high water pressure condition.*
- *Scale buildup inside flow switches makes them stick. This can cause actual leaks to go undetected or false alarms when there is no leak.*
- *Drain valves on rack manifolds do not close easily.*
- *Aesthetically, hard water deposits leave stains and build-up on the outside of drinking valves and rack manifold piping.*

This document describes how the scale-forming tendency can be calculated and how scaling problems can be avoided. If you have any further questions or concerns about water quality, contact Edstrom Industries at 800-558-5913.

What is Hardness?

Hardness is a chemical parameter of water that represents the total concentration of calcium and magnesium ions. It is called hardness because if calcium and magnesium are present in your water, making a lather or suds for washing is hard to do. Another negative characteristic of hard water is its capacity to produce scale, which is primarily caused by calcium and magnesium salts. Hardness is usually expressed in grains per gallon or parts per million (ppm) as calcium carbonate equivalent. The degree of hardness standard as developed by the Water Quality Association (WQA) is shown below.

WATER HARDNESS SCALE		
Term	**Grains / gallon**	**mg / L or ppm**
Soft	Less than 1.0	less than 17.1
Slightly Hard	1.0 to 3.5	17.1 to 60
Moderately Hard	3.5 to 7.0	60 to 120
Hard	7.0 to 10.5	120 to 180
Very Hard	10.5 and above	180 and above
Note: 1 grain per gallon hardness = 17.1 milligram per liter (mg/L)		

Table 1. Water Hardness Scale.

Just knowing that your water supply is defined as moderately hard or very hard is not enough to determine whether it will cause scaling problems in your automated watering system. However, the scale-forming tendency can be predicted by calculating the Langelier Saturation Index (LSI).

Langelier Saturation Index (LSI)

The Langelier Saturation Index (LSI), also called the Langelier Stability Index, is a calculated number used to predict the calcium carbonate stability of water; that is, whether water will precipitate, dissolve, or be in equilibrium with calcium carbonate. Langelier developed a method for calculating the pH at which water is saturated in calcium carbonate. This pH is called the saturation pH, or pH_S. The LSI is expressed as the difference between the actual system pH and the saturation pH: **LSI = pH – pH_S**.

If the actual pH of the water is below the calculated saturation pH, the LSI is negative and the water has a very limited scaling potential. If the actual pH exceeds pH_S, then the LSI is positive, and because the water is supersaturated with $CaCO_3$, the water has a tendency to form scale. At increasing positive index values, the scaling potential increases.

LSI	Scale Potential
– negative (less than zero)	No scale potential. Water will dissolve $CaCO_3$.
+ positive (greater than zero)	Scale can form. $CaCO_3$ precipitation may occur.
close to zero	Borderline scale potential. Water quality and temperature changes, or evaporation, could change the index.
Note that the LSI only indicates the presence of a driving force; it does not guarantee that the tendency to scale will actually occur.	

Table 2. Scale Potential, based on LSI.

Calculating LSI

In order to calculate the LSI, it is necessary to know the alkalinity (mg/l as $CaCO_3$), the calcium hardness (mg/l Ca^{+2} as $CaCO_3$), the total dissolved solids (mg/l TDS), the actual pH, and the temperature of the water (°C). These values get plugged into the following equations:

$$LSI = pH - pH_S$$

$$pH_S = (9.3 + A + B) - (C + D)$$

where:

$$A = (\log_{10}[TDS] - 1) / 10$$

$$B = -13.12 \times \log_{10}(°C + 273) + 34.55$$

$$C = \log_{10}[Ca^{+2} \text{ as } CaCO_3] - 0.4$$

$$D = \log_{10}[\text{alkalinity as } CaCO_3]$$

You can also use the LSI calculator on the Edstrom Industries Web site. Go to **www.edstrom.com/lsicalc.htm**, click on the link for the LSI calculator, and we'll do the calculation for you.

The effects of concentration and temperature on scaling potential

Higher concentrations of calcium, total dissolved solids, and alkalinity all promote a greater tendency for scale. This explains why scale or hardness spots form in areas where water has evaporated. Scaling potential increases with increasing temperature. This explains while water inside a manifold may not form scale at room temperature, but scale could deposit during a cage wash cycle.

Example LSI calculation

As an example, suppose the drinking water supplied to animals has the following analysis. The LSI index is calculated at two temperatures: 25°C (room temperature) and 82°C (cage wash cycle). The colder, incoming water will warm to room temperature in the manifolds. Residual water in the rack manifold can be heated to 82°C when the rack is in the cage washer.

Water Analysis:

pH is 7.5

TDS is 320 mg/L

Calcium is 150 mg/L (or ppm) as $CaCO_3$

Alkalinity is 34 mg/L (or ppm) as $CaCO_3$

LSI Formula:

$LSI = pH - pH_S$

$pH_S = (9.3 + A + B) - (C + D)$

where:

$$A = (\log_{10}[TDS] - 1)/10 = 0.15$$

$$B = -13.12 \times \log_{10}(^{o}C + 273) + 34.55$$

$= 2.09$ for water at 25°C, 1.09 for water at 82°C

$$C = \log_{10}[Ca^{+2} \text{ as } CaCO_3] - 0.4 = 1.78$$

$$D = \log_{10}[\text{alkalinity as } CaCO_3] = 1.53$$

Calculation at 25°C:

$pH_S = (9.3 + 0.15 + 2.09) - (1.78 + 1.53) = 8.2$

LSI = 7.5 – 8.2 = **-0.7**

Result: **No Tendency to Scale**

Calculation at 82°C:

$pH_S = (9.3 + 0.15 + 1.09) - (1.78 + 1.53) = 7.2$

LSI = 7.5 – 7.2 = **+0.3**

Result: **Slight Tendency to Scale**

LSI calculation conclusion

The LSI is negative for this water at room temperature, therefore scaling is not likely unless the water quality changes or evaporation occurs. The greatest potential for scale formation would be when the rack goes through a cage wash cycle. At high temperature, residual water inside the manifold and valves could be supersaturated in calcium carbonate and precipitation would occur.

Estimating LSI and total dissolved solids

If the calcium hardness is not known, but the total hardness is, you can assume that all the measured hardness is from calcium. This represents a worst case scenario. Actually, a typical water supply will have about ⅔ of the hardness from calcium and the other ⅓ from magnesium.

If the total dissolved solids is unknown, but conductivity is, you can estimate mg/L TDS using the following conversion table.

Conductivity (micro-siemans/centimeter (µS/cm))	**TDS (mg/L as $CaCO_3$)**
1	0.42
10.6	4.2
21.2	8.5
42.4	17
63.7	25.5
84.8	34
106	42.5
127.3	51
148.5	59.5
169.6	68
190.8	76.5
212	85
410	170
610	255
812	340
1,008	425

Table 3. Conversion Chart – Conductivity to TDS.

Avoiding Scale Problems

If the LSI calculation yields a positive index value for an animal drinking water supply, scaling problems can be avoided by demineralization, water softening, acidification, and avoiding high temperatures.

Demineralization

Reverse Osmosis, distillation, or deionization are all water purification methods that will remove dissolved minerals from water. Water purification will lower the TDS of the water supply.

Water softening

Water softening or cation exchange will reduce the calcium and magnesium concentrations in water.

Acidification

Lowering the actual pH of the water so it is below the saturation pH_s will prevent scale deposits.

Avoiding high temperature

Avoiding high temperatures (like in the cage wash) where scale formation is more likely will prevent scale deposits.

Reference

Byrne, W. *Reverse Osmosis: A Practical Guide for Industrial Users*, Tall Oaks Publishing Inc., Littleton CO, pp.111-114 (1995).

Kemmer, ed., *The NALCO Water Handbook*. McGraw-Hill, New York, NY, pp.4-13 to 4-14, (1979).

WQA Glossary of Terms. Water Quality Association, (1993).