

PUROXI WATER SERIES

UNDERSTANDING WATER HARDNESS

What Calcium and Magnesium Mean
for Water Systems

PWS-009



Water Hardness Is Mainly Dissolved Calcium and Magnesium

Water hardness is a measure of dissolved multivalent minerals, principally calcium and magnesium. These minerals usually enter water as it moves through soil, limestone, dolomite and other mineral-bearing formations.

Hardness is not dirt, suspended sediment or a universal measure of water quality. It is a chemical property that can be useful, harmless or operationally troublesome depending on the concentration, temperature, pH, alkalinity and intended use of the water.

- Hardness is commonly reported as milligrams per litre as calcium carbonate, mg/L as CaCO_3 .
- The same hardness result can have different consequences in a household, hatchery, boiler, irrigation system or membrane plant.
- A hardness number should be interpreted with the rest of the water chemistry.

PUROXI INSIGHT Hardness is a mineral measurement, not a grade for whether water is good or bad.

CHAPTER 2

Where Hardness Comes From

Rainwater is naturally low in dissolved minerals. As it contacts rock and soil, carbon dioxide and natural acidity help dissolve calcium- and magnesium-bearing minerals. Groundwater often has more hardness than surface water because it remains in contact with geology for longer periods.

Hardness can also change when waters are blended, concentrated by evaporation, recycled through a process, or affected by chemical addition and precipitation.

Common geological sources

Limestone contributes calcium carbonate chemistry; dolomite contributes both calcium and magnesium; gypsum can contribute calcium and sulfate. Local geology strongly influences the final water composition.

PUROXI INSIGHT The hardness of source water often tells part of the story of the geology it has contacted.

CHAPTER 3

How Hardness Is Measured and Reported

Laboratories commonly determine hardness by titration or calculate it from measured calcium and magnesium. Results are usually expressed as an equivalent concentration of calcium carbonate so different mineral contributions can be compared on one basis.

Field test kits can support routine monitoring, while laboratory analysis is preferable when treatment design, regulatory decisions or unusual chemistry require greater accuracy.

Hardness as CaCO ₃	General description
0–60 mg/L	Soft
61–120 mg/L	Moderately hard
121–180 mg/L	Hard
More than 180 mg/L	Very hard

PUROXI INSIGHT Units matter. A number without “as CaCO₃” or another stated basis may be misinterpreted.

CHAPTER 4

Total Calcium and Magnesium Hardness

Total hardness combines the contributions of calcium, magnesium and, in some waters, smaller contributions from other multivalent ions. Calcium hardness and magnesium hardness can be reported separately.

Two waters with the same total hardness may not behave identically if the calcium-to-magnesium balance, alkalinity, sulfate, chloride, silica or dissolved organic matter differs.

- Calcium hardness describes the calcium contribution on a CaCO_3 -equivalent basis.
- Magnesium hardness describes the magnesium contribution on the same basis.
- Total hardness is approximately the sum of calcium and magnesium hardness when other contributors are minor.

PUROXI INSIGHT Equal total-hardness numbers do not guarantee equal water chemistry.

CHAPTER 5

Carbonate and Noncarbonate Hardness

Carbonate hardness is the portion associated with bicarbonate and carbonate alkalinity. It is often called temporary hardness because heating or pH change can promote carbonate-scale formation under suitable conditions.

Noncarbonate hardness is associated with other anions such as sulfate, chloride or nitrate. It is sometimes called permanent hardness because simple boiling does not remove it.

- Carbonate hardness cannot exceed total hardness.
- When total hardness is greater than alkalinity, the difference is commonly treated as noncarbonate hardness, provided both are expressed as CaCO_3 .
- The terms are useful for treatment and scaling analysis, but they do not replace a complete ionic analysis.

PUROXI INSIGHT Hardness and alkalinity are related in many natural waters, but they measure different properties.

CHAPTER 6

Hardness Is Not pH Alkalinity Conductivity or TDS

Several water measurements are connected, but none is interchangeable with hardness. pH describes acidity or basicity at the moment of measurement. Alkalinity measures acid-neutralizing capacity. Conductivity reflects the water's ability to carry electrical current through dissolved ions. Total dissolved solids estimate or measure the broader dissolved mineral content.

A water can be hard while having moderate conductivity, or show high conductivity because of sodium and chloride while having relatively little calcium and magnesium hardness.

Measurement	What it helps describe
Hardness	Primarily calcium and magnesium
pH	Current acidic or basic condition
Alkalinity	Capacity to neutralize acid
Conductivity	Combined ionic conductance
TDS	Overall dissolved solids

PUROXI INSIGHT Interpret related measurements together, but never substitute one for another.

CHAPTER 7

Why Scale Forms

Hardness does not automatically mean scale will form. Scale develops when dissolved minerals become supersaturated and precipitate onto surfaces. Heating, evaporation, pH increase, carbon dioxide loss and concentration cycles can all increase scaling potential.

Calcium carbonate is common, but calcium sulfate, magnesium compounds, silica and mixed deposits may also occur. A deposit should be identified before treatment is chosen.

- Heat exchangers and boiler surfaces can accelerate deposition.
- Low-flow areas and rough surfaces can encourage crystal attachment.
- Scale can reduce pipe diameter, heat transfer, nozzle performance and membrane recovery.
- A hardness result alone cannot predict every deposit.

PUROXI INSIGHT Hardness supplies scale-forming ions; the operating chemistry determines whether they remain dissolved.

CHAPTER 8

Hardness Corrosion and Water Stability

Soft water is not automatically corrosive, and hard water is not automatically protective. Corrosion depends on pH, alkalinity, dissolved oxygen, temperature, chloride, sulfate, flow velocity, materials and protective-film formation.

A thin mineral film may reduce metal contact with water in some systems, while uncontrolled scale can create under-deposit corrosion, flow restriction and maintenance problems in others.

- Do not use hardness as the only corrosion indicator.
- Review water stability and material compatibility together.
- Changes made to control scale can also change corrosion behaviour.

PUROXI INSIGHT Scale control and corrosion control must be evaluated as one water-chemistry problem.

CHAPTER 9

Hardness in Drinking and Domestic Water

Hardness commonly affects soap use, spotting, laundry performance, fixtures, heaters and appliances. It is generally treated as an aesthetic and operational matter rather than a direct health hazard at concentrations normally found in drinking water.

Calcium and magnesium are essential nutrients, but drinking-water mineral content should not be presented as a medical treatment. Local drinking-water requirements and the complete mineral composition remain important.

- Visible spots may be mineral residue left after evaporation.
- Soap scum forms because hardness ions react with some soaps.
- Water heaters often reveal scale problems earlier because heating changes mineral solubility.

PUROXI INSIGHT Household symptoms can suggest hardness, but testing is needed before selecting equipment.

CHAPTER 10

Hardness in Aquaculture Agriculture and Natural Waters

Calcium and magnesium support biological functions and can influence osmoregulation, shell or skeletal development, nutrient interactions and the response of aquatic organisms to other water conditions. Requirements vary greatly by species, life stage and system.

In irrigation, hardness itself is rarely interpreted alone. Calcium, magnesium, sodium, alkalinity, salinity, carbonate chemistry, soil conditions and crop sensitivity must be considered together. Mineral precipitation can clog emitters when water chemistry and operating conditions favour scale.

- Measure source and recirculating water where concentration can occur.
- Use species- and crop-specific guidance rather than a universal hardness target.
- Inspect emitters, heaters, pumps and aeration equipment for mineral deposition.

PUROXI INSIGHT Biological usefulness and mechanical scaling can occur in the same water system.

CHAPTER 11

Hardness in Industrial and Process Water

Hardness management is central to boilers, cooling towers, membrane systems, food processing, laundries, laboratories and many manufacturing operations. The acceptable level depends on temperature, pressure, recovery, cycles of concentration, product contact and equipment design.

Small residual hardness may be significant in high-pressure or high-temperature equipment, while other processes can tolerate much more. Treatment targets must come from process requirements, not a general household classification.

- Track feed, treated and recirculating water separately.
- Confirm hardness leakage after softeners.
- Use mass balance and operating trends to detect concentration or treatment decline.
- Identify deposit composition before changing chemistry.

PUROXI INSIGHT The correct hardness target belongs to the process—not to a universal chart.

CHAPTER 12

Sampling Monitoring and Trend Interpretation

A representative sample is essential. Flush stagnant lines when appropriate, use clean containers, record the sampling location and operating condition, and follow the laboratory's preservation and holding-time instructions.

For treatment systems, sample before and after each relevant process. A single result is a snapshot; trends can reveal seasonal source changes, resin exhaustion, blending shifts, evaporation or process concentration.

- Record units and reporting basis.
- Compare results from consistent locations and methods.
- Measure related parameters such as pH, alkalinity, conductivity, temperature and major ions.
- Investigate abrupt changes before assuming the source water changed.

PUROXI INSIGHT Good interpretation begins with a sample that represents the water being managed.

CHAPTER 13

Treatment Options Must Match the Objective

Treatment depends on how much hardness must be removed, the water volume, competing ions, waste handling, energy use, discharge limits and the required finished-water quality. No single method is best for every application.

Approach	Primary role and caution
Ion exchange	Exchanges calcium and magnesium for sodium or potassium; requires regeneration, salt and brine management.
Lime softening	Promotes precipitation in larger treatment systems; requires chemical control and solids handling.
Nanofiltration or reverse osmosis	Can remove hardness and many other dissolved ions; requires pretreatment, pressure and concentrate management.
Sequestration or inhibition	May reduce deposition without removing hardness; effectiveness depends on chemistry, temperature and residence time.
Blending	Can achieve an operating target when both waters are compatible and blending is controlled.

PUROXI INSIGHT A treatment claim should distinguish between removing hardness and merely changing how scale forms.

CHAPTER 14

What Aeration and Nano Bubble Systems Can and Cannot Do

Aeration and nano bubble systems can improve gas transfer, circulation and oxygen distribution when properly designed. They do not directly remove dissolved calcium and magnesium and should not be described as water softeners.

Gas transfer can change dissolved carbon dioxide and pH, which may influence carbonate equilibrium and scaling conditions. That effect depends on the complete water chemistry and operating environment.

- Test hardness before and after treatment when removal is claimed.
- Monitor pH, alkalinity, temperature and deposit formation when gas transfer changes.
- Select softening or membrane treatment when dissolved hardness removal is the actual objective.

PUROXI INSIGHT Improving oxygen transfer is not the same process as removing hardness ions.

CHAPTER 15

Common Hardness Myths

Water hardness is easy to recognize operationally, but several common shortcuts lead to incorrect conclusions.

Myth	More accurate interpretation
Hard water is unsafe	Hardness alone is generally an aesthetic and operational property; safety requires broader testing.
Soft water is corrosive	Corrosion depends on the complete chemistry and materials, not hardness alone.
High conductivity means high hardness	Conductivity responds to all dissolved ions, including sodium and chloride.
Any scale is calcium carbonate	Deposits may contain sulfate, silica, metals, organics or mixed materials.
A conditioner removes hardness	Some devices alter deposition behaviour without lowering measured hardness.

PUROXI INSIGHT The correct question is not simply “Is the water hard?” but “What is the hardness doing in this application?”

CHAPTER 16

A Practical Hardness Decision Framework

Begin with the intended use, then connect the test result to the actual operating problem. Treatment should follow evidence, not assumptions.

- Define the application and acceptable finished-water condition.
- Measure total hardness and, when relevant, calcium, magnesium, alkalinity, pH, conductivity, temperature and major ions.
- Identify whether the concern is scale, soap performance, process compatibility, biological need or another issue.
- Review temperature, evaporation, pressure, residence time, materials and concentration cycles.
- Choose a treatment that achieves the objective and has manageable waste, energy and maintenance requirements.
- Verify performance with post-treatment testing and trend records.

PUROXI INSIGHT Understanding Always Comes Before Recommendation.

KEY LESSONS

- Hardness is caused mainly by dissolved calcium and magnesium.
- It is usually reported as mg/L as CaCO_3 so different mineral contributions share one basis.
- Hardness is not the same as pH, alkalinity, conductivity or TDS.
- Scale depends on saturation and operating conditions—not hardness alone.
- The correct treatment depends on the application and must distinguish removal from scale control.
- Aeration and nano bubble systems do not directly remove dissolved hardness.

The most useful hardness result is one interpreted within the complete water system.

TECHNICAL REFERENCES

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- Penn State Extension. Interpreting Irrigation Water Tests. <https://extension.psu.edu/interpreting-irrigation-water-tests>

Classification ranges and treatment information are general guidance. Site-specific design should use current analytical data, equipment requirements and applicable regulations.

ABOUT THE PUROXI WATER SERIES

The Puroxi Water Series is an educational publication created to improve understanding of water through science, practical experience and thoughtful discussion. Each edition focuses on one important measurement or process and explains what it means, what it does not mean and how it should be interpreted in real applications.

PWS-009 — Understanding Water Hardness continues the series by connecting calcium and magnesium chemistry with domestic, agricultural, aquaculture, environmental and industrial water management.

UNDERSTANDING ALWAYS COMES BEFORE RECOMMENDATION.

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