Water hardness

1. Term for hardness

The hardness of water is caused by the contents of calcium and magnesium salts. Water with high calcium and magnesium content is characterised to be hard and such water with less calcium and magnesium content as being soft. In form of figures, the hardness is fixed by the hardness degrees, whereby 1 English hardness degree corresponds to a concentration of 1 part $CaCO_3$ in 70,000 parts water.

1 Engl. hardness degree H° = 14.3 mg/l $CaCO_3$

An international standardisation for the hardness degrees does unfortunately not exist. Nowadays, the hardness is indicated as “sum alkaline earths” in mmol/l with international regulation. (Strictly speaking, such elements as e.g. strontium and barium belong to the alkaline earths as well, the concentration of which in drinking water is however is negligible small compared with calcium and magnesium.)

2. Terms total hardness, carbonate hardness and non-carbonate hardness

2.1 Total hardness

Calcium and magnesium in natural water are mainly bound to carbon dioxide, i.e. in form of hydrogen carbonate. In most cases a small percentage of sulphuric acid (sulphate), hydrogen chloride (chloride), hydrochloric acid (nitrate), silicio acid (silicate) and phosphorous acid (phosphate). Some areas for example have real gypseous or brewing water in which calcium is exclusively or mainly existing in form of calcium sulphate.

The sum of all that calcium and magnesium compounds results in the total hardness measured in milligram calcium carbonate per litre. In order to determine the total hardness, the weight percentage of the magnesium compound is converted into the equivalent $CaCO_3$-quantity. The hardness in °H $CaCO_3$ or mg/l $CaCO_3$ or ppm $CaCO_3$ is therefore to be understood as reference figure and has nothing to do at all with the real contents of $CaCO_3$.

Conversion table:

1 mg/l Ca^{2+} = 2.50 mg/l $CaCO_3$ = 0.025 mmol/l $CaCO_3$ = 0.175 °eH
1 mg/l Mg^{2+} = 4.12 mg/l $CaCO_3$ = 0.0412 mmol/l $CaCO_3$ = 0.288 °eH
1 °eH = 14.3 mg/l $CaCO_3$ = 5.71 mg/l Ca^{2+} = 3.47 mg/l Mg^{2+}
1 mmol/l alkaline earth ions (Ca^{2+}, Mg^{2+}) = 100 ppm $CaCO_3$ = 7.0 °eH
= 40 ppm Ca^{2+} = 24.3 ppm Mg^{2+}

2.2 Carbonate hardness

During longer boiling of the water, the content of calcium and magnesium bound to hydrogen carbonate are settled out almost totally except a small part as insoluble carbonates. This is thus called temporary hardness, i.e. carbonate hardness. Nor-

mally, the carbonate hardness is lower than the total hardness. Strictly speaking, the term „carbonate hardness“ is not quite correct and should rather be „hydrogen carbonate hardness“ . Since the term is well known in the water industry, this will be maintained.

Pure $CaCO_3$ is soluble at a water temperature of 20 °C to max. 14 mg/l only. With the aid and in the presence of carbonic acid however, $CaCO_3$ is dissolved to several 100 mg/l by the formation of calcium hydrogen carbonate that only exists in solution.

2.3 Non-carbonate hardness

The amounts of calcium and magnesium remaining in the solution after boiling as sulphate, chloride and nitrate (phosphate and silicate are not that important) cause the remaining/residual or permanent hardness and is now more exactly called non-carbonate hardness.

It is to be differentiated:
Total hardness TH: total of alkaline earths bound to carbonic acid, sulphuric acid, hydrogen chloride and nitric acid shown in mg/l $CaCO_3$.

Carbonate hardness: CH, also called carbonic acid hardness or temporary or transitory hardness, = amounts of calcium and magnesium bound to carbonic acid as part or amount of total hardness and shown in mg/l $CaCO_3$.

Non-carbonate hardness: NCH, earlier called remaining or permanent hardness, also inorganic acid hardness or sulphate hardness, = amounts of calcium and magnesium bound to sulphuric acid, hydrogen chloride or nitric acid as remaining part or amount of total hardness and shown in mg/l $CaCO_3$.

3. Classification of water hardness

The amount of hardness is sometimes expressed by descriptive words. The following table shows how these descriptions may be related to the numerical value of the hardness in common units.

Description	Hardness in mg/l as calcium	Hardness in mg/l as calcium carbonate
Soft	0 - 20	0 - 50
Moderately soft	20 - 40	50 - 100
Slightly hard	40 - 60	100 - 150
Moderately hard	60 - 80	150 - 200
Hard	80 - 120	200 - 300
Very hard	Over 120	Over 300

(mg/l = milligrammes per litre = 1 part per million)