Water Analysis

Understanding Water Constituents

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For You and Planet Blue.

BWT BEST WATER TECHNOLOGY

Why water analysis?

Water analysis is needed to . . .

- determine the water is safe for human drinking
- determine if water treatment is needed
- determine if the water has corrosive properties
- determine if the water is suitable for certain processes e.g. boiler water, water for cooling tower, etc.
- solve water related problems e.g. lime scale in piping and warm water systems, corrosion, etc.

Water analysis has to be done . . .

- Upfront a system installation being base of a adequate design
- With the treated water to validate if design and installation is done correctly

SAFE CONTAMINANT LEVELS

For every contaminant there is a level at which they are considered safe.
Every country has an agency which fixes the Maximum Contaminant Level MCL.

- **Primary Drinking Water Standards**
  For contaminants which constitute a health hazard

- **Secondary Drinking Water Standards**
  For contaminants that do not constitute a health hazard

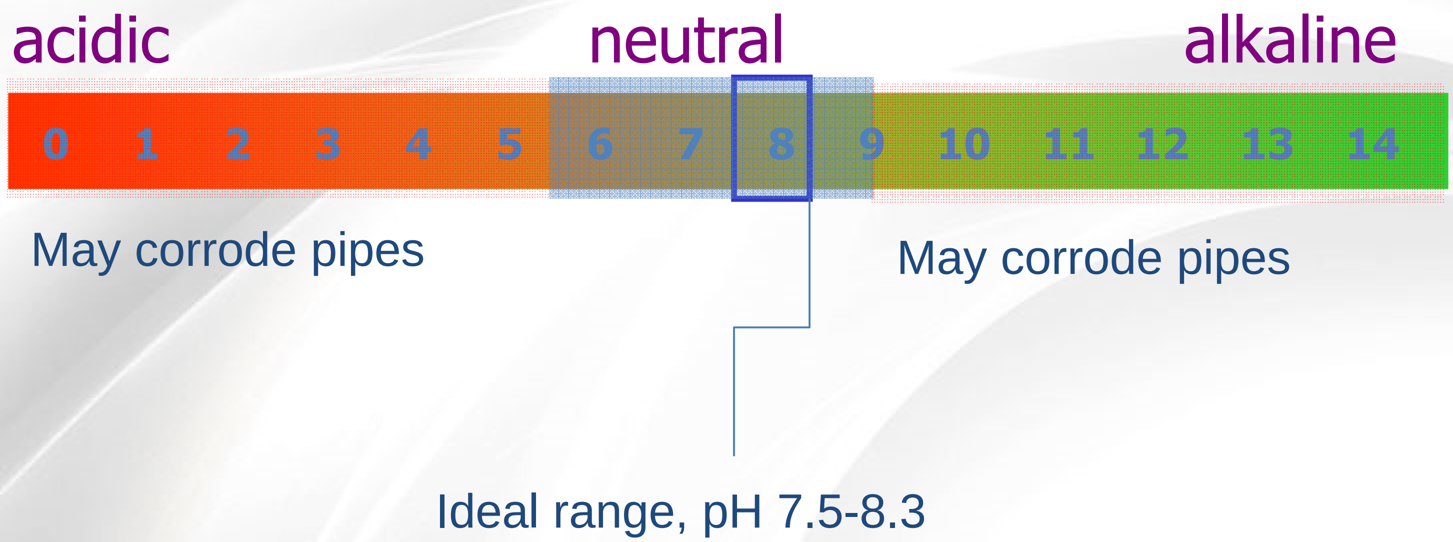
Physical Parameters

pH value

The pH is a measure of the acidity or alkalinity of an aqueous solution.

Pure water is said to be neutral, with a pH close to 7.0 at 25 ℃.

Solutions with a pH less than 7 are said to be acidic and solutions with a pH greater than 7 are basic or alkaline. **The pH-value gives an indication on the corrosion behaviour.**



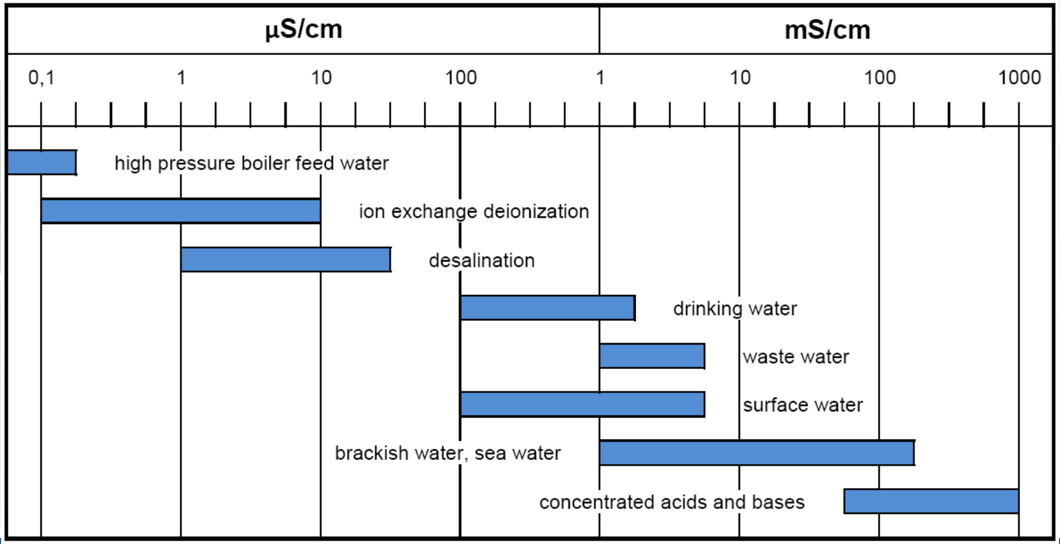
Conductivity

The conductivity (or specific conductance) of an electrolyte solution is a measure of its ability to conduct electricity with the unit Microsiemens per centimeter (µS/cm) or Milisiemens per meter (mS/m).

In many cases, conductivity is linked directly to the total dissolved solids (TDS).

[conversion rate conductivity in µS/cm to TDS in ppm ~ 1/0.64]

A normal conductivity value is roughly twice the total hardness (in ppm) in unsoftened water samples. If the conductivity is much greater than two times the hardness, it may indicate the presence of other ions such as chloride, nitrate, or sulfate which may be human-influenced or naturally occurring.

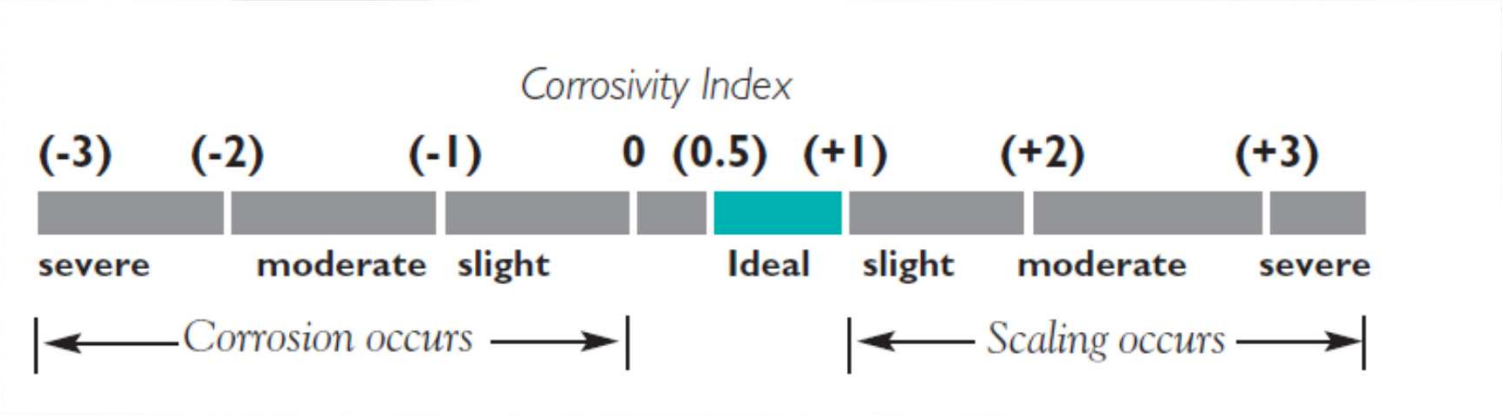


Corrosivity Index (also called Saturation Index, Stability Index, Langelier Index)

Corrosivity index is a measure of the tendency for lime (calcium carbonate) to precipitate (form a solid and settle out) from water. **It is calculated from pH, alkalinity, calcium hardness and conductivity data**.

Lime precipitate (scale) from hard water is a natural protection against corrosion. Too much scale, however, will partially plug pipes and water heaters, decreasing their efficiency. Water softeners prevent scale buildup, but also decrease any protection from corrosion the water may have provided.

Water with an LSI below -0.5 tends to exhibit noticeably increased dissolving abilities while water with an LSI above +0.5 tends to exhibit noticeably increased scale forming properties.



Temperature

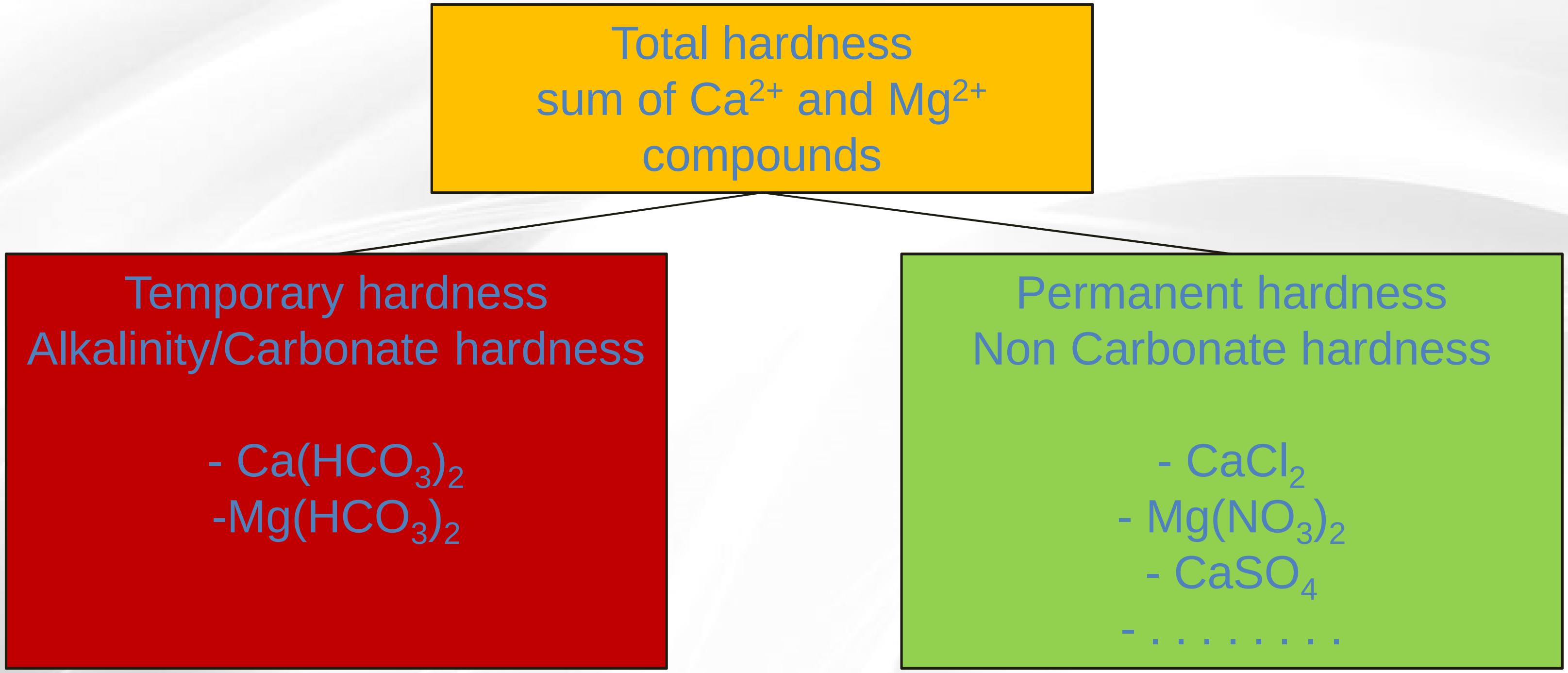
Cool water is generally more palatable than warm water, and temperature will have an impact on the acceptability of a number of other inorganic constituents and chemical contaminants that may affect taste.

High water temperature enhances the growth of microorganisms and may increase problems related to taste, odour, colour and corrosion.

Chemical Parameters

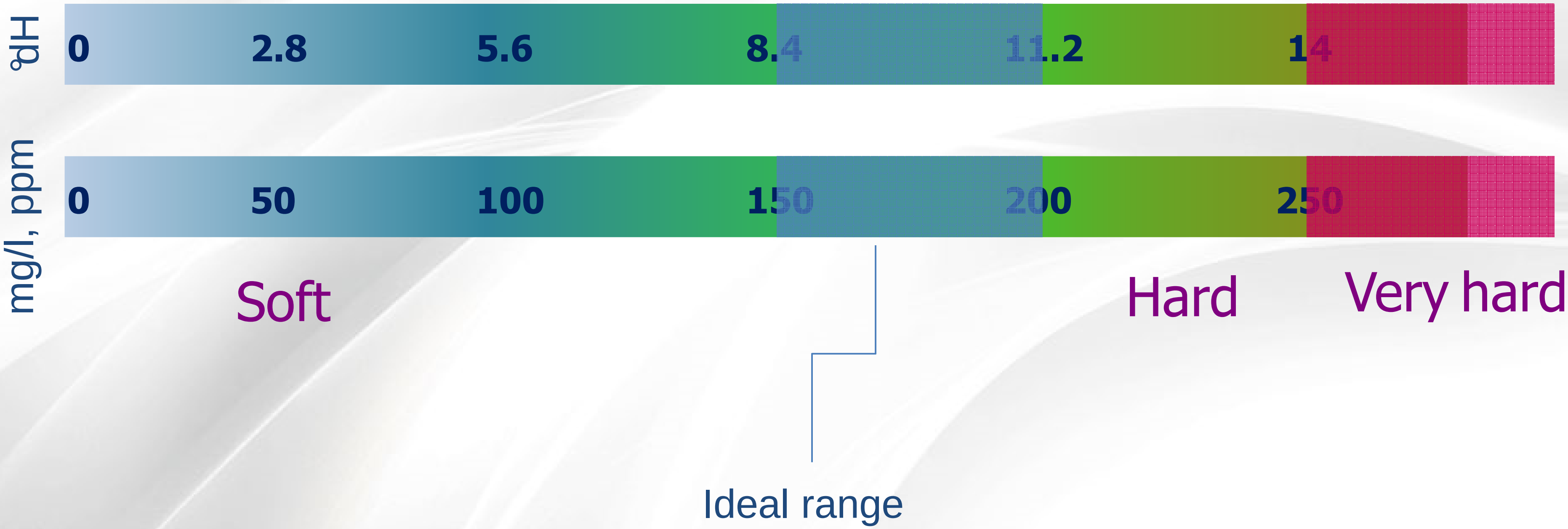
Hardness

The Total hardness is the sum of all compounds of Calcium and Magnesium in the water. It is divided into the Temporary hardness (also Alkalinity or Carbonate hardness) and the Permanent hardness (Non Carbonate hardness). **The Temporary hardness falls out as $CaCO_3$ and $MgCO_3$ at higher temperatures, also the Permanent hardness is still soluble.**



Hardness

Hard water is beneficial to health.
However, values near 150 mg/L are ideal from an aesthetic viewpoint, if the corrosivity index is satisfactory.



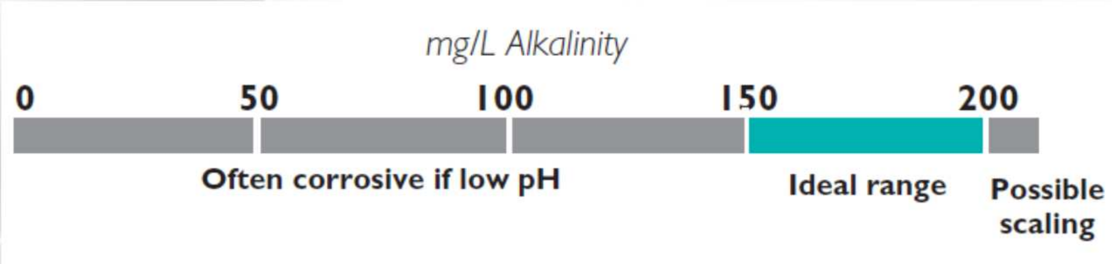
Alkalinity - Base and Acid capacity

Alkalinity is a measure of water's ability to neutralize acids, and so is related to pH. It results primarily from dissolving limestone or dolomite minerals in the aquifer.

Alkalinity and total hardness are usually nearly equal in concentration (if both in mg/L CaCO3) as they are formed from the same minerals.

- **alkalinity >> total hardness in an unsoftened sample → test for sodium**
- **alkalinity << total hardness → test for chloride, nitrate, and sulfate**

The lower the alkalinity, the more likely water is to be corrosive. High alkalinity water may contribute to scale buildup in plumbing.



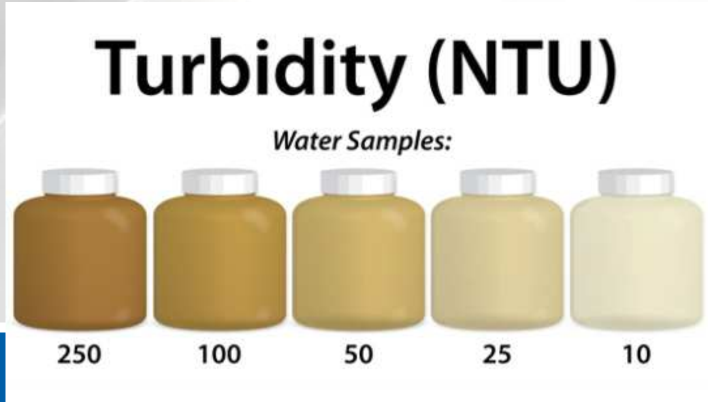
This is a test for overall water quality, there are no health concerns associated with alkalinity.

Turbidity – suspended solids

Turbidity is the cloudiness or haziness of water caused by individual particles (suspended solids) that are generally invisible to the naked eye. The measurement of turbidity is a key test of water quality.

Fluids can contain suspended solid matter consisting of particles of many different sizes. While some suspended material will be large enough and heavy enough to settle rapidly to the bottom of the container if a liquid sample is left to stand (the settable solids), **very small particles will settle only very slowly or not at all if the sample is regularly agitated or the particles are colloidal. These small solid particles cause the liquid to appear turbid.**

According to the European Union drinking water standard the Turbidity should be below 1NTU (Nephelometric Turbidity Units). Especially for the effectiveness of disinfection should be preferably lower.



Total dissolved solids

Water is a good solvent and picks up impurities easily. Pure water -- tasteless, colorless, and odorless -- is often called the universal solvent**. Dissolved solids" refer to any minerals, salts, metals, cations or anions dissolved in water.** Total dissolved solids (TDS) comprise inorganic salts (principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides, and sulfates) and some small amounts of organic matter that are dissolved in water.

The presence of high levels of TDS may also be objectionable to consumers, owing to excessive scaling in water pipes, heaters, boilers and household appliances. No health-based guideline value for TDS has been proposed.

The presence of dissolved solids in water may affect its taste. The palatability of drinking water can be rated according to TDS level as follows:

Excellent	< 300 mg/L
Good	300 - 600 mg/L
Fair	600 - 900 mg/L
Poor	900 - 1200 mg/L
Unacceptable	>1200 mg/L

Chemical Parameters - Cations

Calcium Ca^{2+}

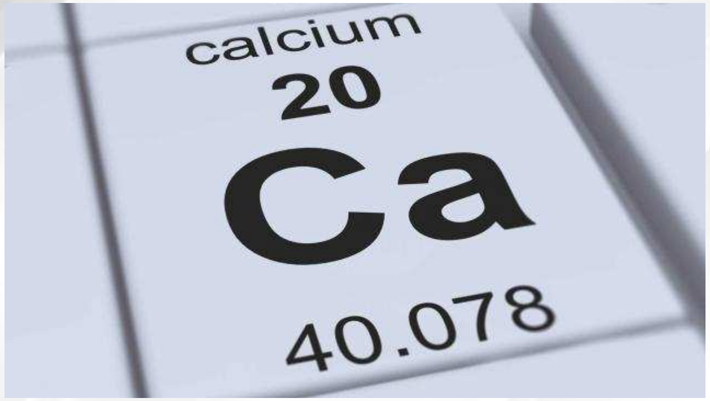
Calcium is a soft gray alkaline earth metal, and is the fifth-most-abundant element by mass in the Earth's crust.

Calcium is essential for living organisms, in particular in cell physiology, where movement of the calcium ion Ca^{2+} into and out of the cytoplasm functions is a signal for many cellular processes.

Calcium carbonate ($CaCO_3$) is one of the common compounds of calcium. Chalk, marble, and limestone are all forms of calcium carbonate.

Together with Magnesium, Calcium is responsible for the total hardness in the water.

Calcium is found in almost every kind of native water and is harmless to the human organism.



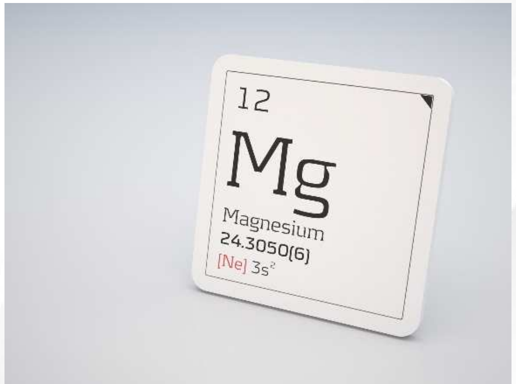
Magnesium Mg^{2+}

Magnesium is an alkaline earth metal and the eighth most abundant element in the Earth's crust.

Due to magnesium ion's high solubility in water, it is the third most abundant element dissolved in seawater.

The proportion of Magnesium in the total hardness varies for well water between 10-25% . Due to different solubility conditions in seawater the percentage of Magnesium in the total hardness lies between 75-80%.

Magnesium is a vital component of a healthy human diet. Adult human bodies contain about 24 grams of magnesium, with 60% in the skeleton, 39% intracellular (20% in skeletal muscle), and 1% extracellular.



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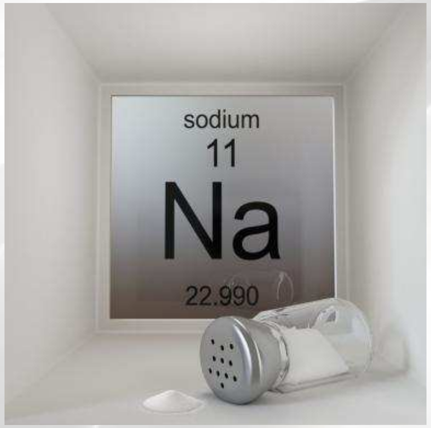
Sodium Na^+

Sodium is a soft, silvery-white, highly reactive metal and is a member of the alkali metals. It is an abundant element that exists in numerous minerals such as feldspars and rock salt. Many salts of sodium are highly soluble in water and are thus present in significant quantities in the Earth's bodies of water, most abundantly in the oceans as sodium chloride.

Sodium is not harmful to the human body, but should not exceed certain quantities in the drinking water.

Limits according to European Union drinking water standard ***>200mg/l.***

Limits according to WHO At room temperature, the average taste threshold for sodium is about 200 mg/l. No health-based guideline value has been derived



Iron Fe^{2+}/Fe^{3+}

Iron is found in traces in almost every native water. In well water it is normally dissolved as Fe^{2+}salt (Iron(II)hydrogen carbonate, Iron(II)sulfate) and can usually be oxidized by aeration to insoluble Iron(III)hydroxide. The separation from water is normally done by filtration.

Iron form very stable complex compound with organic substances as humic acid. These compounds are very complicate to separate from the water and need advanced treatment processes.

High concentrations of iron in the water (>0,3mg/l) increase the risk of corrosions.

Precipitations caused by oxidation to Iron(III) result in sedimentation of iron ochre.

Iron concentrations above 0,3mg/l may also cause a metallic taste of the water.

The limit for Iron according to European drinking water standard is 0,1mg/l.

Manganese Mn^{2+}

Manganese has similar properties like Iron.

It is harder to oxidize to brownstone (MnO_2) and needs, especially when Iron is present, a multi staged water treatment system.

High concentrations of Manganese in water result in sedimentations and an unwanted inky taste.

The limit for Manganese according to European drinking water standard is 0,05mg/l.

According to WHO:

< 0.1 mg/l	usually acceptable to consumers
> 0.1 mg/l	undesirable taste in beverages and stains sanitary ware and laundry, deposits in the distribution system
>=0.2 mg/l	manganese often forms a coating on pipes
0.4 mg/l	health-based value

Copper Cu^{2+}

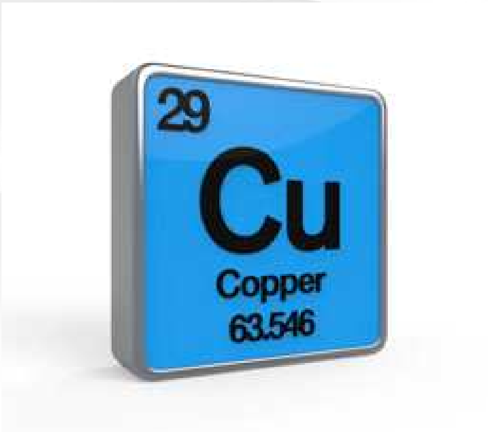
Copper is geologically present in native waters up to a concentration of approximately 0.05mg/l. Higher concentrations of copper are caused by industrial waste water, corrosion from copper pipes and valves or by pesticides and herbicides.

For living organisms copper is an essential trace element and indispensable for cellular respiration.

The limit for copper according to European drinking water standard is 2mg/l.

WHO:

> 1 mg/l	Staining of sanitary ware and laundry may occur
> 5 mg/l	Imparts a colour and an undesirable bitter taste to water



Zinc Zn^{2+}

Zinc is geologically present in native waters up to a concentration of approximately 0.02mg/l. Higher concentrations of Zinc are caused by corrosion from galvanized pipes and valves.

For the human body Zinc is needed as an enzyme component and for the immune defense.

Zinc imparts an **undesirable astringent taste to water at a taste threshold concentration of about 4 mg/l (as zinc sulfate). Water containing zinc at concentrations in excess of 3–5 mg/l may appear opalescent and develop a greasy film on boiling.**

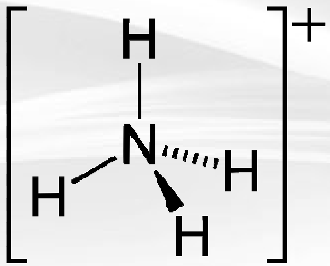
WHO: No health-based guideline value has been proposed for zinc in drinkingwater

Ammonium NH_4^+ - Ammonia NH_3

Ammonium compounds found in the water are hygienically of high importance, since they are a sign for human or animal excrement decomposing (formed by Urea).

In dirty surface waters ammonia is found in concentrations of 0.1-10.0mg/l.

In clean well water Ammonium is normally not found. If there is Ammonium in wells, most probably there is a connection to surface water. Due to its hygienic importance, **Ammonium in drinking water is restricted to 0.5mg/l. Only if the water comes from deep wells, geologically caused Ammonium is allowed up to 5mg/l.**



Ammonium is an unstable compound:

pH > 7 -> Ammonium NH4+ -> Ammonia NH_3, which is soluble in water

In the presence of Oxygen and Nitrosomonas bacteria it oxidizes to the toxic Nitrite NO_2^-

WHO: threshold odour concentration at alkaline pH = 1.5 mg/l

taste threshold = 35 mg/l

No health-based guideline value has been proposed. ***However, ammonia does react with chlorine to reduce free chlorine and to form chloramines.***

Chloramines

WHO: **Chloramines, such as monochloramine, dichloramine and trichloramine, are generated from the reaction of chlorine with ammonia**. Among chloramines, monochloramine is the only useful chlorine disinfectant, and chloramination systems are operated to minimize the formation of dichloramine and trichloramine. Higher chloramines, particularly trichloramine, are likely to give rise to taste and odour complaints, except at very low concentrations.

For monochloramine, no odour or taste was detected at concentrations between 0.5 and 1.5 mg/l. However, slight organoleptic effects within this range and odour and taste thresholds of 0.65 and 0.48 mg/l have been reported. For dichloramine, the organoleptic effects between 0.1 and 0.5 mg/l were found to be “slight” and “acceptable”. Odour and taste thresholds of 0.15 and 0.13 mg/l were reported, respectively.

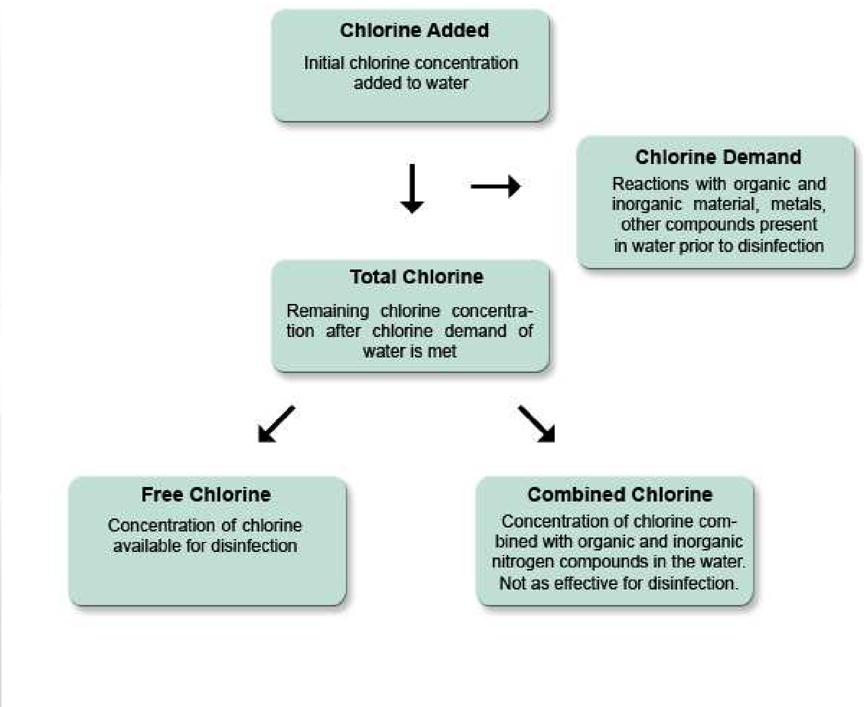
An odour threshold of 0.02 mg/l has been reported for trichloramine, and it has been described as “geranium”. A guideline value for monochloramine has been established

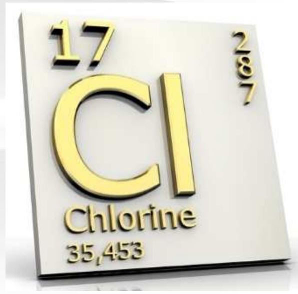
Free or Total Chlorine

WHO: Most individuals are able to taste or smell chlorine in drinking-water at concentrations well below 5 mg/l, and some at levels as low as 0.3 mg/l.

The taste threshold for chlorine is below the health-based guideline value of 5 mg/l

The guideline value for free chlorine in drinking-water is 5 mg/l





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other metals

-Potassium (K^+)

Potassium is as abundant in the earth's crust as Sodium. It is in strong compounds in minerals and due to that Potassium has a low solubility in water. Typical Concentrations of Potassium in water are 1-2mg/l.

-Lithium (Li^+), Rubidium (Ru^+), Cesium (Cs^+)

These metals are trace elements and also found in native water.

-Barium (Ba^+), Strontium (Sr^+)

These elements are mostly common in water with a high concentration of Sulfate. Since Barium and Strontium Sulfate have a low solubility in water, they may cause problems with Reverse Osmosis plants.

-Radium (Ra^+)

This radioactive element is present in traces in certain thermal waters. Before human use (drinking, bathing) the Radium has to be separated from the water.

heavy metals

-Lead (Pb^{2+})

Lead is not present in native waters. Lead in the water is normally caused by Lead pipes (especially stagnating water). Since Lead is toxic to the human body the concentration is limited to 10µg/l in drinking water.

-Cadmium (Cd^{2+}), Chrome (Cr^{1-6+}), Mercury ($Hg^{+, 2+, 4+}$)

These heavy metals are highly toxic and never found in native water. Their presence show a contamination of the water with toxic waste. The limits for drinking water are 5µg/l for Cadmium, 50µg/l for Chrome and 1µg/l for Mercury.

-Arsenic (As^{+}), Antimony ($Sb^{3+, 5+}$)

Compounds of these toxic elements are in well water in partially high concentrations caused by leaching out from ore. Separation of Arsenic and Antimony is done by filtration over special filter material. The limits for drinking water are 10µg/l Arsenic and 5µg/l Antimony.

Chemical Parameters - Anions

Hydrogen Carbonate HCO_3^-

Hydrogen Carbonate HCO_3^- and Carbonate CO_3^{2-} are present in almost every native water.

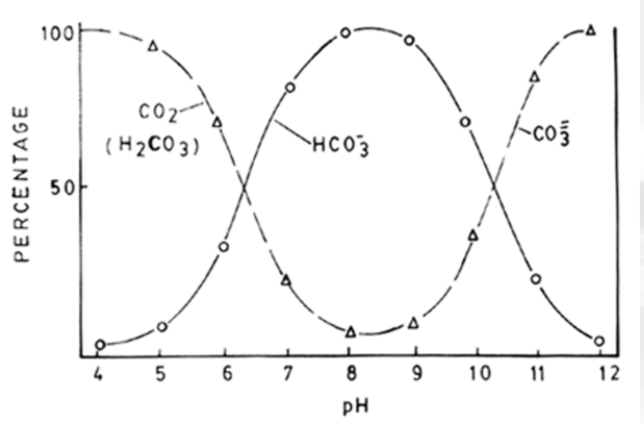
Hydrogen Carbonate and Carbonate are in a pH value dependent equilibrium with Carbon dioxide CO_2 which is always dissolved in water.

CO_2 is partly hydrated to H_2CO_3 which is dissociated to H^+ and HCO_3^-. The proportion of the different compounds is pH value dependent:

up to pH 4 only CO_2,

pH 7 to 10 mostly HCO_3^-,

above pH 11 mostly CO_3^{2-}.



Both compounds have a huge influence on the buffer capacity of the water.

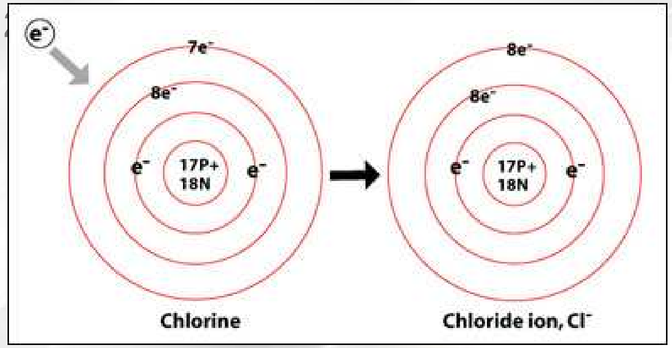
Hydrogen Carbonate is one main component of the Carbonate hardness.

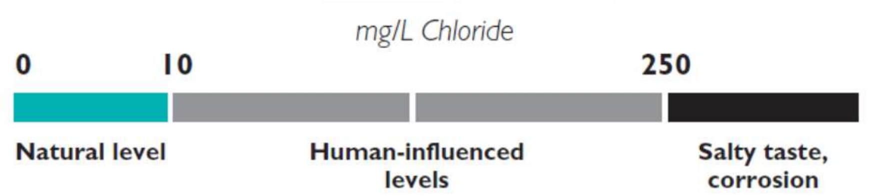
Chloride Cl^-

Chloride, the anion of the hydrochloric acid, is found in almost every native water. Depending on the geology, different concentrations of chloride in the water are occurring.

At a concentration of 200mg/l, Chloride supports the corrosion of ferrous materials. By alloying steels with Chrome, Nickel, Molybdenum, Copper, Titanium and by lowering the carbon concentration stainless steels are produced which withstand Chloride concentrations up to 25,000mg/l.

According to European Union drinking water standards the amount of Chloride should be below





Sulfate SO_4^{2-}

Sulfate is the anion of sulfuric acid H_2SO_4.

Normally the concentration of Sulfate in native water is below 50mg/l.

Sulfate often is one of the main components that for the non carbonate hardness or permanent hardness.

For the human body water with high concentrations of Sulfate, Sodium and Magnesium act laxative.

High concentrations of sulfate may support corrosions.

For waste water, a attack on concrete caused by Sulfate has to be taken into consideration. At a concentration of 400mg/l Sulfate in the water, the concrete is broken up by the formation of Ettringite.

According to European Union drinking water standards the amount of Sulfate should be below 250mg/l. Reported taste threshold concentrations in drinking-water are 250–500 mg/litre

Nitrate NO_3^-

Nitrate is the anion of the nitric Acid HNO_3 and is **detectable in low amounts in almost every native water.**

Wash out of fertilizers into the ground water cause higher levels of Nitrate in the water, especially in agricultural developed regions.

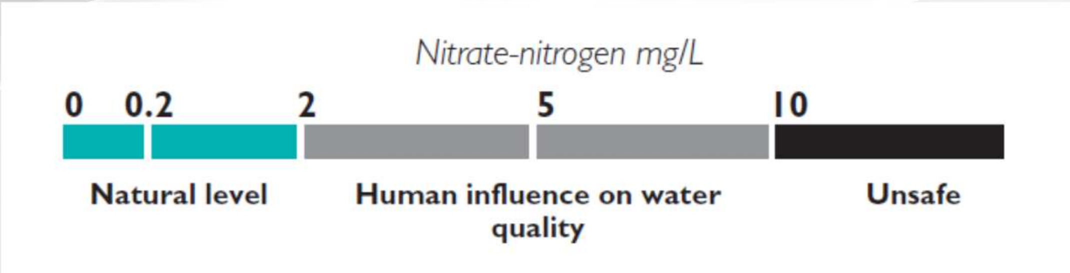
By bacteriological activity the Nitrate can be reduced to the more harmful Nitrite or even Nitrogen.

Nitrate may cause congenital cyanosis in toddlers by reduction to nitrite.

The limit for Nitrate according to the European Union drinking water standard is 50mg/l.

Because Nitrate can be easily reduced to Nitrite take also into consideration:

$$\frac{\text{Nitrate}}{50} + \frac{\text{Nitrite}}{3} < 1$$



Nitrite NO_2^-

Nitrite is the anion of the nitrous Acid HNO_2 and is **normally not present in native water.**

As intermediate product of natural bacteriological alternation and decomposition processes, **Nitrite indicates presence of contaminants in the water**. It also forms when water with Ammonium is aerated or transformed by Nitrosomonas bacteria to Nitrite. In the presence of Oxygen normally Nitrobacter bacteria form the less toxic Nitrate. In the absence of Oxygen this symbiosis does not work and can result in high concentrations of Nitrite.

Another source of Nitrite can be the reduction of Nitrate cause by new galvanized steel pipes.

In toddlers, Nitrite can obstruct the oxygen transportation in the blood and cause congenital cyanosis. **The limit for Nitrite according to the European Union drinking water standard is 0.5mg/l.**

Fluoride – The Ion of Flourine

-Fluoride (F^-)

Fluoride is an inorganic, monatomic anion of fluorine with the chemical formula F^-
Fluoride is the simplest anion of fluorine. In terms of charge and size, the fluoride ion resembles the hydroxide ion. Fluoride ions occur on earth in several minerals, particularly fluorite, but are only present in trace quantities in water.

Fluoride contributes a distinctive bitter taste. It contributes no color to fluoride salts. Fluoride is the anion of the fluoric acid H_2F_2 and is present in traces up to 0.5mg/l in almost every native water. Fluoride is an essential element for the human organism to prevent cavity and to form the skeleton. **A too high intake of Fluoride can be harmful and the concentration in the drinking water is limited to 1.5mg/l by WHO and European Union**. Calcium Fluoride is poorly soluble and may cause problems in membrane processes by scaling.

In groundwater, concentrations vary with the type of rock the water flows through but do not usually exceed 10 mg/litre; the highest natural level reported is 2800 mg/litre.

other Anions

-Bromide (Br^-), Iodide (J^-)

Bromide and Iodide are the anions of the Bromhydric acid and the Hydriodic Acid which are present in traces in native waters. Iodine is part of the thyroid hormone, an insufficiency induces goiter formation.

-Sulfide (S^{2-})

Sulfur as Sulfide in water is either formed by geothermic impacts, by Reduction of Sulfate in deeper layers or by bacteriological decomposition.
Dependent on the pH value Sulfur is dissolved as Hydrogen Sulfide H_2S, Hydrosulfide HS^- or Sulfide S^{2-}. Hydrogen Sulfite has the characteristic foul odor of rotten eggs and is unpleasant already in traces.

Taste and odour thresholds of hydrogen sulfide = 0.05 - 0.1 mg/l.

Sulfide is oxidized rapidly to sulfate in well-aerated or chlorinated water, and hydrogen sulfide levels in oxygenated water supplies are normally very low.

other Anions

-Phosphate (PO_4^-)

Phosphate is the anion of Phosphoric acid and is dissolve in native waters only in traces (0.1mg/l) since it is well adsorbed in the soil**. Higher concentrations normally origin from fertilizers, detergents or waste water.** Phosphor plays an important role in the human body used for several inorganic and organic compounds. **In water treatment Mono and Polyphosphate are used in small amounts to prevent corrosion and precipitation of lime scale.**

-Scilicic Acid (H_2SiO_3), Silicate (SiO_3^{2-})

Silicon is found in the nature mostly as Ortho Scilicic Acid or Ortho Silica. Silica is neither toxicologically nor hygienically harmful to the human body.
In water treatment Silicon compounds are use to prevent corrosion. For high pressure steam boilers and autoclaves all the Silicon has to be separated from the water to prevent precipitation on turbine blades or surgical instruments. **High concentrations of Silica in the feed water of Reverse Osmosis systems result in scaling.**

Bacteriological Parameters

Bacteriological Parameters

The minimum requirements for water for human use is that the water is free of any microorganisms, parasites and substances that could harm the human wellbeing.

To determine if water is contaminated with microorganism, so called indicator parameters (germs) are analyzed.

Parameter	Limit
Eschericha coli (e.coli)	0/250ml
Pseudomonas aeruginosa	0/250ml
colony forming units @ 22˚C	100/ml
colony forming units @ 37˚C	20/ml

Refer to your local authorities standards and regulations!

Thank You for your attention!