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Water qualities and ion exchange processes / 1

Water qualities

City water or tap water is supplied by local water supply systems. Typical ingredients of city water are dissolved mineral components such as calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), potassium (K^{+}), chloride (Cl^{-}), hydrogen carbonate (H^{CO3}-) and sulphate (S^{O4-}), which are present as charged ions. City water also contains organic compounds, bacteria and viruses. It is subject to legal framework conditions and regulations that ensure a certain quality.

Distilled water is produced by distillation. The distillation process removes all mineral components as well as bacteria and viruses. However, distilled water may still contain organic compounds.

Deionized water (DI-water) is produced by ion exchange processes. Depending on the type of ion exchange process, only certain mineral components are removed. DI-water can therefore still contain other specific mineral components, organic compounds, bacteria and viruses.

This soft water is produced by removing calcium (Ca^{2+}) and magnesium (Mg^{2+}) from the water and replacing them with sodium (Na^{+}) and potassium (K^{+}). This ion exchange process is also known as softening (see below).

Fully demineralized water (DM-water), sometimes also called DI-water, is also produced using ion exchange processes. This removes all mineral components. However, demineralized water can still contain organic compounds, bacteria and viruses.

Ultrapure water is also produced using ion exchange processes and is also treated intensively. Here all mineral components, organic compounds, bacteria and viruses are removed.

Overall, all types of treated water (distilled water, DI- and DM-water and ultrapure water) offer high levels of purity, although the specific degree of purity, i.e. the water hardness or electrical conductivity, the proportion of organic compounds and the presence of bacteria and viruses can vary.

Water hardness and electrical conductivity

Water hardness is a conceptual system of applied chemistry, determined by the content of so-called hardeners, i.e. the concentration of certain ions dissolved in the water. A distinction is made between two types of water hardness:

Temporal hardness, also known as **carbonate hardness**, mainly refers to the amount of calcium and magnesium carbonate in the water.

Permanent hardness, also known as **non-carbonate hardness**, refers to the amount of chlorides and sulphates in the water.

The **total hardness** is the sum of temporary and permanent hardness and correlates with the electrical conductivity of the water. **Electrical conductivity** is defined as the ability to conduct electrical current. The higher the concentration of ions dissolved in the water, the harder the water and the higher the electrical conductivity.

Water hardness and conductivity			
mmol/l	°dH	hardness	µs/cm
0 - 0,71	0 - 4	very soft	0 - 140
0,71 - 1,6	4 - 9	soft	140 - 300
1,6 - 2,67	9 - 15	light hard	300 - 500
2,67 - 3,39	15 - 19	moderately hard	500 - 640
3,39 - 4,46	19 - 25	hard	640 - 840
> 4,46	> 25	very hard	> 840

***Please note:** The results and data presented in this paper refer exclusively to processes in which **kolb** detergents are used in **kolb** cleaning systems. The use of **kolb** detergents in systems from other manufacturers or detergents from other manufacturers in **kolb** cleaning systems can lead to changed requirements for the rinsing process and thus to a necessary adjustment of the rinse water quality.

Fig. 1: Relationship between substance concentration, water hardness and conductivity

The table in Fig. 1 shows the relationship between the substance concentration (mmol/l) of the hardness constituents in the water, the water hardness (°dH) and the electrical conductivity of the water (µS/cm). The reciprocal value of the electrical conductivity corresponds to the specific resistance (Ω*m).

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Ion exchange processes for the production of deionized (DI) and demineralized (DM) water

Ion exchange processes for water treatment are processes in which the dissolved and charged ions in the water are exchanged for other ions in a solid material. This occurs through the interaction between the ions in the water and the ions in the solid material, which is referred to as an ion exchanger. Ion exchangers are usually in the form of resins. These ion exchange resins are often used in cartridges for use in water treatment systems. There are different types of ion exchange resins, which differ in their effect:

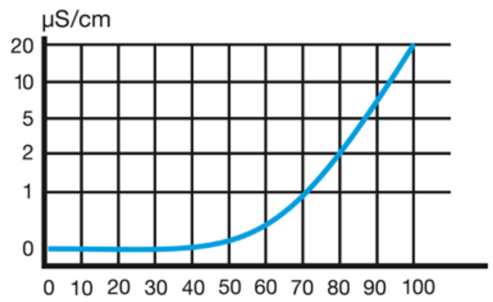
A **cation exchange resin** is a material that removes positively charged ions (cations), i.e. hardness formers such as calcium (Ca^{2+}) and magnesium (Mg^{2+}), from the water. The negatively charged functional groups of the cation exchange resin bind the cations from the water and release other cations instead. If the cations of the water are exchanged with sodium (Na^{+}), this is also referred to as **softening** (**reduction of the carbonate hardness**) or **decarbonization**. If the cations in the water are replaced by hydrogen ions (H^{+}), this is also referred to as **partial desalination**. The pH value of the water drops during partial desalination due to the CO_2 released.

An **anion exchange resin** is a material that removes negatively charged ions (anions) such as chlorides (Cl^{-}) and sulphates ($SO4^{-}$) from the water. The positively charged functional groups of the anion exchange resin bind the anions from the water and release other anions instead. If the anions released are hydroxide ions (OH^{-}), this results in an increase in the pH value of the water.

A **mixed bed (MB) of cation and anion exchange resin** removes both cations and anions from the water and exchanges them for other ions according to the processes described above.

This is often referred to as **full demineralization**. This type of ion exchanger is suitable for the production of demineralized water (DM-water), from which ultrapure water can subsequently be produced.

Mixed bed resin desalting performance to conductivity



ca. 100% under 20 µS/cm	ca. 90% under 10 µS/cm
ca. 70% under 1 µS/cm	ca. 50% under 0,2 µS/cm

Fig. 2: Relationship between the desalination performance of a mixed bed resin and the electrical conductivity of the water

In addition to the ion exchange processes described above, **reverse osmosis** can also be used to produce DI- or DM-water. In reverse osmosis, water is forced through a semi-permeable membrane under high pressure in so-called reverse osmosis systems, whereby dissolved ions, organic compounds, bacteria and viruses are retained.

Reverse osmosis is therefore suitable for the production of fully demineralized water (DM-water) from which ultrapure water can subsequently be produced. In some cases, pre-treated soft water is fed into reverse osmosis systems instead of untreated city / tap water, particularly when the aim is to extend the service life of the membranes.

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MB ion exchangers (cartridges) suitable for kolb cleaning systems

If the "clear rinse" process step is to be carried out in a **kolb** cleaning system, the system automatically treats city / tap water to demineralized- (or DI-) water before starting this process step. This is done using an MB ion exchange resin in a cartridge placed in the system.

In accordance with the various types of ion exchange resins described above, which differ in their effect, only cartridges with a mixed bed (MB) of cation and anion exchange resins are suitable for kolb cleaning systems, as these generate fully demineralized water. Therefore only certain MB ion exchanger cartridges are approved by kolb for use in kolb cleaning systems.

This ensures that the treated fully DM- (or DI-) water contains as few mineral components from charged cations and anions as possible, thus guaranteeing low residual ion contamination of the cleaning product.

More information on the "Rinse"-process step can be found in the white paper "The best rinsing process for cleanliness and efficiency". (Scan here)