Fundamentals

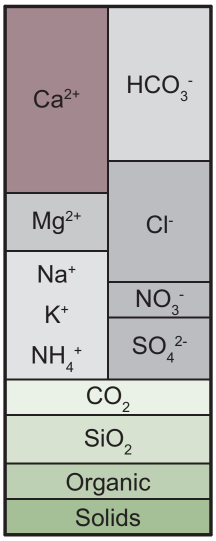
Water is a compound of hydrogen and oxygen that results from the combustion of hydrogen. It is an excellent solvent. For this reason, natural water does not exist as a chemically pure substance.
It contains dissolved minerals, salts and organic compounds and also disperse and colloid disperse substances, furthermore gases, in varying concentrations and compositions.

Ions Salts dissociate in water and form ions: Positively-charged ions are designated as cations, and negatively-charged ions are anions.

Water mainly contains different proportions of the following ions, depending on the source of the water:

Cations

- Calcium [Ca^{2+}]
- Magnesium [Mg^{2+}]
- Sodium [Na^{+}]
- Potassium [K^{+}]
- Ammonium [NH_4^{+}]
- Iron [$Fe^{2+/3+}$]
- Manganese [Mn^{2+}]



Anions

- Hydrogen carbonate [HCO_3^-]
- Chloride [Cl^-]
- Nitrate [NO_3^-]
- Sulphate [SO_4^{2-}]

Gases / Solids

- Carbon dioxide [CO_2]
- Oxygen [O_2]
- Silicate [SiO_2]

Traces of the following ions are also present:

- Cations: Strontium [Sr^{2+}], Barium [Ba^{2+}], Lithium [Li^{+}]
- Anions: Fluoride [F^-], Nitrite [NO_2^-], Phosphate [PO_4^{3-}], Bromide [Br^-], Iodide [I^-]

Organic All water also contains organic components with a non-ionic and ionic (mainly anionic) character.
These compounds are measured as total parameters

- TOC (**T**otal **O**rganic **C**arbon)
- DOC (**D**issolved **O**rganic **C**arbon)
- Oxygen consuming capacity
- COD (**C**hemical **O**xygen **D**emand)

Water also contains undissolved components of water, so-called disperse and colloid disperse substances.

Applications

The selection of an ion exchange process and the degree of demineralisation depend on the application in question and the additional operating and economical conditions.

Possible areas of use:

- **Steam generation:** steam for turbines and process steam for industrial applications etc.
- **The foodstuff industry:** the manufacture of fruit juices, beer, etc.
- **Industry:** the manufacture of technically high-quality and sensible goods, e.g. in the field of medicine or electronics. In the galvanisation industry for the reduction of back-flushing water consumption or decontamination of waste water etc.

Technologies for demineralisation

A variety of processes are used to remove ions from the water:

- Demineralisation based on the principle of **ion exchange** via adsorption at activated surfaces.
- Demineralisation via **membrane technologies** using semi-permeable membranes (reverse osmosis).
- Desalination via **distillation**.

Design

A complete water analysis with information on the pH level, the electrical conductivity and the temperature is required to design a demineralisation unit. Several analyses may be required, depending on the constancy of the raw water values, so that ranges of variation can be detected.

A water analysis can be verified via the ionic balance.
With a precise analysis, the amount of cations equals the amount of anions. Only small, single-digit percentage deviations are permissible.

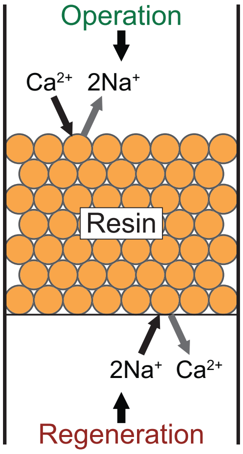
In addition to the specifications on the desired net volume flow, the requirements to be fulfilled by the demineralised water must be specified.

The requirements can also be defined by references to technical publications and guidelines.

Description of process

Ion exchangers are synthetic resins (organic polymers). Various exchange-active groups, at which ions accumulate, are built into the exchangers. In the exchange process, the ions of the solution to be treated are exchanged with accumulated ions with the same electrical charge on the resin.

Principle of ion exchange



Basically, a differentiation is made between cation and anion exchangers.

These types are further differentiated regarding the exchange-active groups:

- Weak acidic / strong acidic
- Weak basic / medium basic / strong basic

Overview of processes

The various ion exchanger resin qualities are used for demineralisation in a variety of processes:

Co-current flow process

Very robust process technology, but requires relatively large amount of chemicals and offers moderate demineralisation rates. Only used in specific cases for these reasons.

Counter-current flow process

- **Floating bed process** (loading in up-current, regeneration in down-current)
  Very economical, very good demineralisation rates, similar process technology used: liftbed and rinsebed process.
- **Downflow counter-current process** (loading in down-current, regeneration in up-current)
  Larger regeneration water consumption, somewhat more complex process technology than the floating bed process.

Multi-step filter with integrated buffer filter

Speciality of the floating bed process, cation and anion exchanger in one filter, separated by additional nozzle plate.
Third chamber with additional cation exchanger possible.

Mixed bed filter

- **Fine-polishing mixed bed**
  The water output of a demineralisation plant is cleaned of remaining ionic traces.
- **Working mixed bed**
  Raw water is freed of ions.

Floating bed process

The floating bed process is often used because of the many advantages.

Advantages:
- Most effective regeneration agent utilisation with best possible demineralisation
- Most versatile with regard to resin selection
- Minimal water consumption caused by regeneration
- Very compact vessel size

Good pre-cleaning of the raw water is required for use of this process. The water must be free of iron, manganese and suspended substances.

Downflow counter-current process

The downflow counter-current process also offers these advantages, but to same extent to a lesser degree.

Both above-mentioned processes each contain a cation exchanger and an anion exchanger. This makes for very good purity of desalinated water, i.e. many ions have already been fully removed, and others with lower affinity for the respective ion exchangers are only present in very low concentrations.
Technical improvement regarding remaining ions is only possible with a second stage also containing cation and anion-exchanger resins. These two ion exchangers can be housed mixed in a single vessel.

Multi-step filter

Multi-step filters represent a type of intermediate solution between cation and anion exchangers with or without a fine-polishing mixed bed. Cation and anion exchangers are housed in a single column, but in separate chambers (i.e. multi-step filter). Since the ion leakage of a cation exchanger is always more clearly pronounced than that of an anion exchanger, an additional chamber with cation exchanger is often added.
An additional anion exchanger (as with the mixed bed) is not used, however. Residual conductivity is achieved with this three-chamber multi-step filter as in conjunction with a fine-cleaning mixed bed filter, except that its low residual concentration of silicate is not reached.

The above-mentioned types provide an initial overview of the **multitude of process-technical and instrument-based options** for demineralisation of water solutions via ion exchange.

RWT has many decades of experience in the field of water treatment and demineralisation technology. Our large number of great references attest to this.

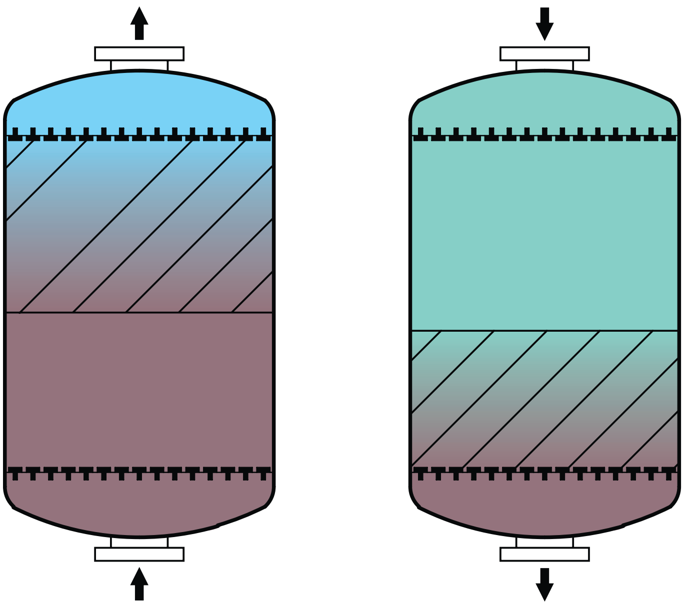
To you as a customer, this means optimised unit design under consideration of the most important features to be fulfilled (low investment, great operating safety, low operating costs).

Description of floating bed process

A full demineralisation unit consists of at least one cation exchanger and one anion exchanger.
The two exchangers are usually arranged in series in different vessels.

Operation

A floating bed has one upper nozzle plate and one lower nozzle plate. In the demineralisation process, the resin is passed through upward. The resin floats up and is pressed against the upper nozzle plate.
To avoid shifting during operation, a minimum flow is required. It can be forced by circulation of the water to ensure the hydraulic requirements for maintenance of the floating bed.



Demineralisation operation   Standby mode / Regeneration

Regeneration

The exchanger material must be regenerated when fully exhausted.
In general, the following regeneration chemicals are used:

- Hydrochloric acid 30 - 33% pursuant to DIN EN 939 for the cation exchangers
- Sodium hydroxide 45 or 50% pursuant to DIN EN 896 for the anion exchangers

When regeneration is complete, the plant is ready/operation starts again.

Larger concentrations of carbon dioxide can be removed economically in a spray tower. This allows the anion exchanger to be considerably smaller. The chemical and regeneration water consumption for regeneration of the anion exchanger is thus much less than in a unit without a carbonic acid spray tower.

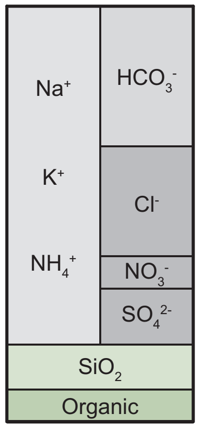
Applications

Softening

The alkaline earths calcium, magnesium, strontium and barium dissolved in water are designated as water hardness. Strontium and barium play a subordinate and negligible role.

With ion-exchange softening, the calcium and magnesium ions are exchanged for sodium ions. For this purpose, the water is passed over a strongly acidic cation exchanger loaded with sodium ions.

Regeneration occurs with a common salt solution of an elevated concentration.The total salt content of water remains unchanged with this process.



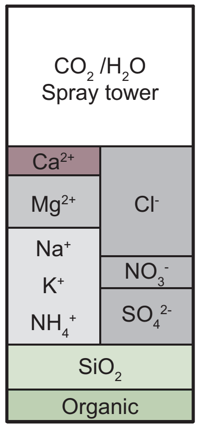
Water composition after softening

Decarbonisation

With softening, only the ions of the water hardness are exchanged. With decarbonisation, on the other hand, the hydrogen carbonate salts of the calcium and magnesium, the so-called carbonate hardeners, are removed.

This process results in partial demineralisation of the water. Decarbonisation occurs via filtration using a weakly acidic cation exchanger loaded with hydrogen ions. Regeneration primarily occurs with hydrochloric acid.

Carbon dioxide results from decarbonisation and can be removed in a spray tower. To obtain fully-softened water, softening has to occur downstream.



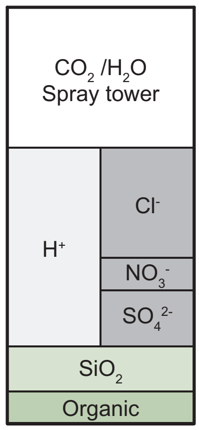
Water composition after decarbonisation

Demineralisation

With complete demineralisation, all salts dissolved in the water are removed through a combination of strongly acidic cation exchanger and strongly basic anion exchanger.

In the first demineralisation stage, all cations are exchanged for hydrogen ions. The concentrations of anions remain unchanged, i.e. strong acids such as hydrochloric acid HCl, nitric acid HNO_3 and sulphuric acid H_2SO_4, in addition to CO_2, arise. This process is also called decationisation for this reason.

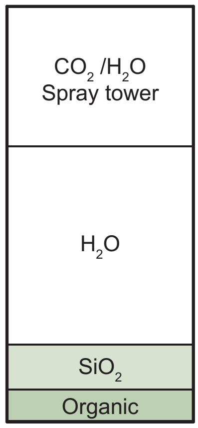
Regeneration of cation exchangers primarily occurs with hydrochloric acid.



Water composition after cation exchanger

The acidic discharge from the cation exchanger is passed over an anion exchanger in the second stage.

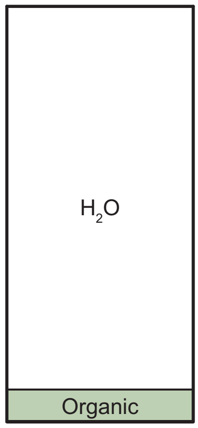
If a weakly basic exchanger is used, only mineral acids (HCl, H_2SO_4, HNO_3) are removed.



Water composition after anion exchanger

If, on the other hand, a strongly basic exchanger is used, silicon acid (SiO_2) and carbon dioxide can also be removed. Organic substances can be reduced up to 90% both in the weakly basic and strongly basic exchanger.
The result is demineralised water.

The regeneration of these exchangers occurs with strong bases, e.g. sodium hydroxide.



Water composition after complete desalination

Special applications

Organic substances are mainly taken up by anion exchangers.
Selectively-effective resins are also available for special applications.

RWT demineralisation units

Our units are distinguished by:

- Steel vessel with 3 mm-thick hard-rubber on interior, thus longer service life
- Coating with two-component PU resin (on sand-blasted surface with zinc priming)
- Sight glass for viewing resin (several sight glasses available as an option)
- Resin transport connection nozzles as standard for trouble-free resin transport
- Nozzle plates for best possible hydraulic properties of the resin bed (no distribution systems via nozzle stars!)
- Double nozzles for optimum flow against the resin bed
- Special chemical nozzles for the most efficient regeneration agent utilisation
- Optimum regeneration, and thus (technically) greatest possible elution of ions taken up via appropriate nozzle selection and chamber geometry, even in the fine-polishing zone
- Number of nozzles > 80 nozzles/m²
- Manholes with swivel arm in filter vessels with a 900 mm diameter and larger
- Filter vessel can also be designed for greater operating pressures and temperatures
- Best possible quality thanks to production at company headquarters (in Gütersloh, Germany))

Fittings/Valves

You'll find characteristic RWT quality here too:

- Clear fitting arrangement in a fitting schematic rack in front of the respective filter vessel.
- Clear pipeline guidance and thus good process control.
- Upright fitting arrangement with stable retainer providing good protection.
- Use of pneumatically-driven membrane valves, safety position is spring-forced closed, control air opened, includes visual position indication.
- With greater nominal widths (from DN 65 on), butterfly valves in end fitting design with pneumatically-operated, double-action swivel drive and visual position indication are used.
- Optionally, all automatic valves can be equipped with electrical position detectors

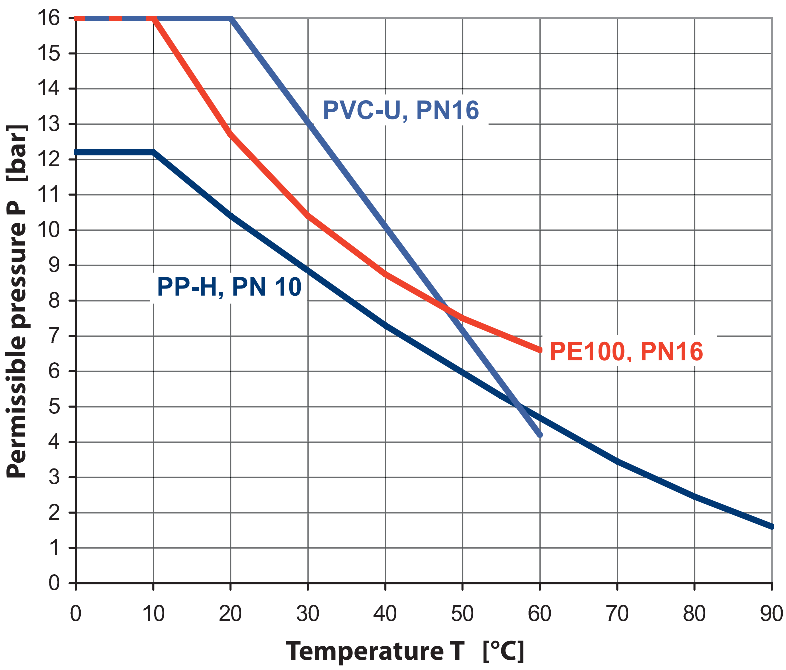
Piping materials

PVC and PP are normally used for pipelines.
Metallic pipelines are used for greater nominal widths (from approx. DN 125/150) on.
In principle, the following materials are possible:

- PVC-U, PN 16 (S6.3, SDR 13.6)
- PP-H, PN 10 (S5, SDR 11)
- PE 100, PN 16 (S5, SDR 11)
- Steel with rubber on interior
- Stainless steel 304, 321 or 316 Ti pursuant to DIN EN ISO 1127

Additional conditions, such as pressure, temperature and chemical composition of the medium, are authoritative for selection of the material.

Pressure/ Temperature diagram



Ion exchanger resins

We only use ion exchanger resins from leading German manufacturers. Imports from other continents with no competent manufacturer service and background are not used.