Basic knowledge
Physical/chemical water treatment

Application of physical/chemical processes

Industrial wastewater often contains dissolved inorganic substances (e.g. heavy metals) or organic materials which cannot be biodegraded. This is also true of a lot of landfill leachate and contaminated groundwater. The use of physical/chemical processes is ideal in such cases. There is a variety of different processes in this field of water treatment. The most widely used processes include:

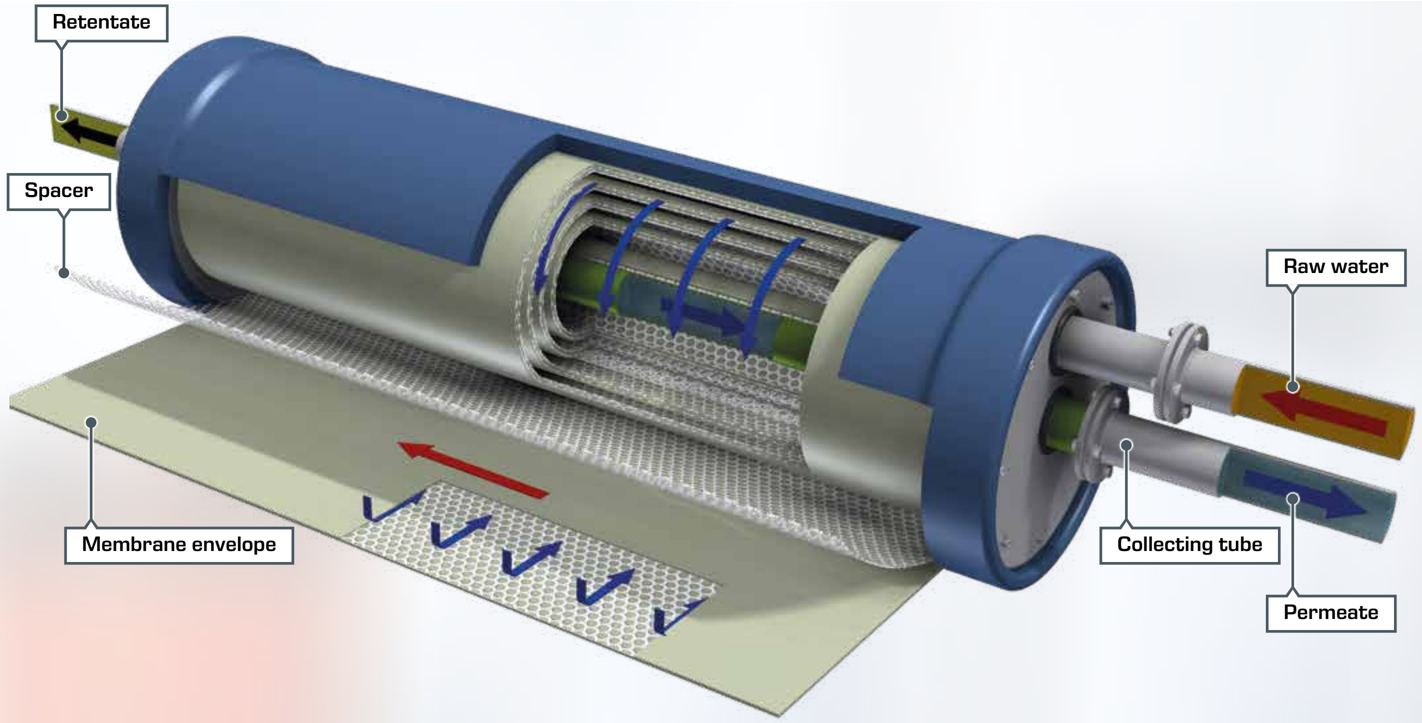
- Adsorption
- Reverse osmosis
- Ion exchange
- Precipitation
- Flocculation
- Oxidation processes


Continuous-flow adsorber in a water treatment plant

Adsorption

In adsorption, the material to be removed (adsorbate) is bonded to the surface of a solid (adsorbent). This bonding can be either physical or chemical. The adsorbent is predominantly granular activated carbon. This procedure can be used to reliably remove toxic, chlorinated hydrocarbon compounds from the water. Such substances are found in many places in landfill leachate and contaminated groundwater.

Adsorption is generally carried out with continuous-flow adsorbers. The adsorbers contain a fixed bed of granular activated carbon. After a certain period of operation, the adsorbate concentration in the outlet of an adsorber rises. This condition is referred to as breakthrough. If the adsorbate concentration in the outlet of an adsorber is plotted over time, it shows what is known as the breakthrough curve.



Reverse osmosis: membrane separation process for the strictest demands

The basic principle of reverse osmosis is quite simple. The natural tendency to bring about a concentration equilibrium between the two sides of a membrane (osmosis) must be countered. To do this, counter-pressure which is at least as high as the osmotic pressure is built up. The water then flows across the membrane in the direction of the concentration gradient, thereby sharply increasing the concentration on one side of the membrane (retentate) and decreasing it on the other side (permeate). To put it simply, reverse osmosis can be regarded as a dilution process.

Even dissolved substances such as ions can be removed from the water by reverse osmosis. This means ultrapure water, which is required in many sensitive industrial production processes, can be produced, for example in the pharmaceutical industry. Another application is the desalination of sea water.

Reverse osmosis uses what are known as spiral-wound membranes. One special feature of this design is the membrane envelope wound spirally around a central tube. The high pressure on the inlet side causes the water (permeate) to pass across the membrane and to flow spirally into the central collecting tube. The partial flow (retentate) retained by the membrane is removed via a separate tube.

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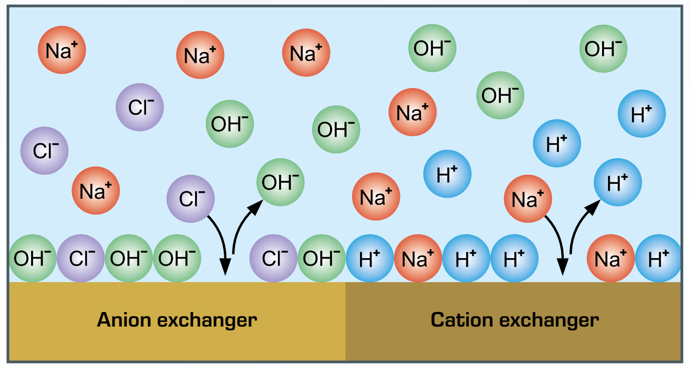
Ion exchange

Ion exchange is a physico-chemical process in which a solid absorbs ions from a liquid, and in exchange emits an equivalent amount of equally charged ions to the liquid. If positive ions are exchanged (e.g. sodium Na+), the process is called cation exchange. In contrast, anion exchange is where negatively charged ions are exchanged (e.g. chloride Cl-).

Ion exchangers are used primarily for desalination and softening. Heavy metals contained in a lot of wastewater from the metal-working industry can be removed by ion exchange.



Desalination by anion exchange followed by cation exchange

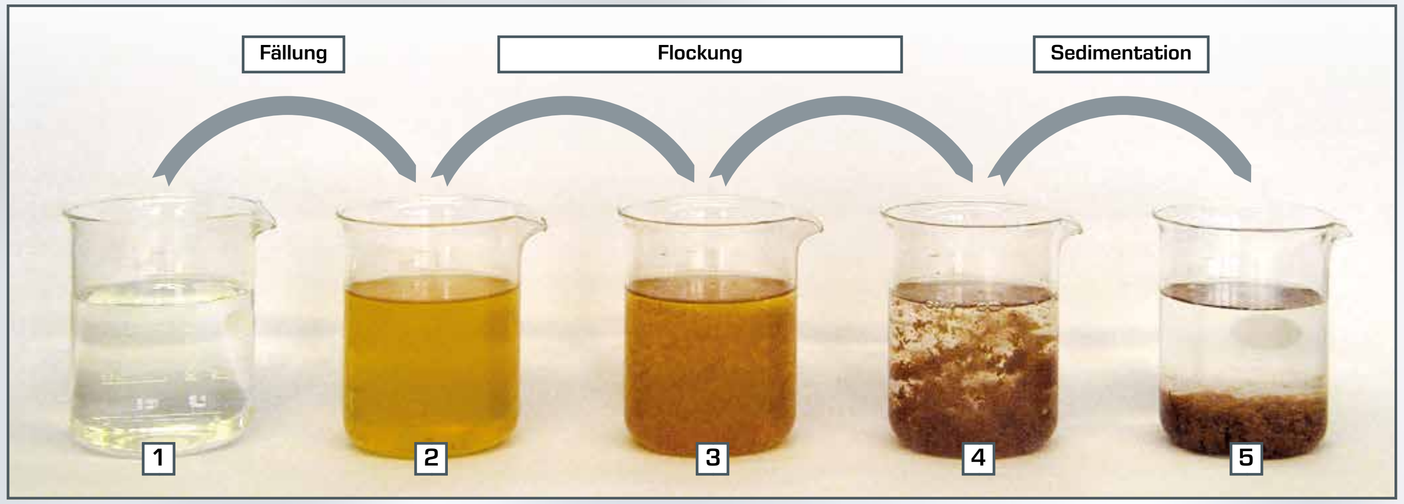
Precipitation

Precipitation is a chemical process in which a dissolved substance is transformed in an insoluble form (solid) by reaction with another substance. Precipitation is suitable for removing dissolved metals, for example. In addition, precipitation is also used for phosphorus elimination in wastewater treatment plants.

In practice, precipitation is often followed by flocculation in order to increase the size of the solids which are formed. This eases the subsequent mechanical separation of the solids (for example by sedimentation).

Flocculation

To add certain chemicals the electrostatic repulsive forces between the individual solid particles have to be removed first. As a result, the particles combine to form small flocs (coagulation). To increase the size of the flocs even further, a flocculant (e.g. polymer) is added to the water. This results in flocs several millimetres in diameter, which can easily be separated subsequently by mechanical means.



Precipitation and flocculation of dissolved iron:
By adding caustic soda, the dissolved iron (1) first precipitates as insoluble and yellow iron hydroxide (2). Adding other chemicals causes large iron hydroxide flocs (3 to 4) to form, which can then easily be separated by sedimentation (5).

Oxidation processes

Many organic contaminants are not biodegradable and therefore cannot be eliminated by biological processes. These include many chlorinated hydrocarbons. Improper handling of these materials allows them to enter the groundwater where they pose a threat to humans and the environment. An effective method of removing such materials from the water is with oxidation processes.

There is a variety of different oxidation processes in the field of water treatment. The importance of those referred to as "advanced oxidation processes" has increased in the past few years. The main feature of these processes is the formation of highly reactive OH radicals. These radicals are some of the strongest oxidants and thus are able to oxidise almost any substance.

OH radicals can be produced with UV light, for example by irradiation of hydrogen peroxide (H_2O_2). UV-C radiation with a wavelength of 254 nm is mainly used for this purpose.