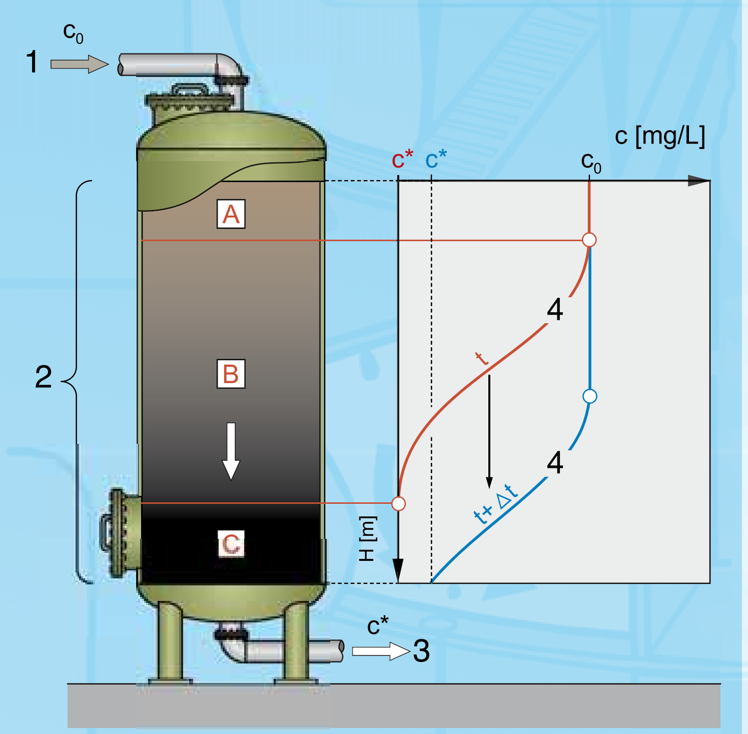
BASIC KNOWLEDGE

ADSORPTION

One method of removing dissolved substances from water is adsorption. This method is based on physical or chemical interaction between dissolved substances and a solid phase. The dissolved substances are bound to the solid phase.

The solid phase is referred to as the adsorbent, and the dissolved substance as the adsorbate. If adsorbent is brought into contact with adsorbate for long enough, an adsorption equilibrium is established. The adsorbent is then fully charged, and can absorb no more adsorbate. The adsorbent in most widespread use is activated carbon. Activated carbon has a very distinct pore system. One gram of activated carbon has a pore surface area of approximately 1000 m².



Concentration profiles in an adsorber:
***1** raw water, **2** fixed bed of activated carbon*
***3** treated water, **4** concentration profiles*
***H** fixed bed height, **t** time, **c** adsorbate concentration*
c_0 adsorbate concentration in inlet
c adsorbate concentration in outlet*

In water treatment, adsorption is mainly implemented with continuous-flow adsorbers. In this case, the concentration profile marked in red on the illustration is established after the time ***t***. It corresponds to the trend of the adsorbate concentration in the water along the fixed bed.

This concentration profile is divided into three zones:

- Zone A

The adsorbent is fully charged and can absorb no more adsorbate. So the adsorption equilibrium has been reached. The adsorbate concentration in the water corresponds to the inlet concentration (c_0).

- Zone B

The adsorption equilibrium has not yet been reached, so adsorbate is still being adsorbed. This zone is known as the **mass transfer zone**.

- Zone C

Since the adsorbate has been fully removed from the water in zone B, the adsorbent is still non-charged here, so the adsorbate concentration is zero.

Over time, the concentration profile moves through the fixed bed in the direction of the flow. At the time $t + \Delta t$ it corresponds to the blue curve. There is no longer any non-charged adsorbent remaining in the fixed bed. The adsorbate concentration in the outlet (***c****) is greater than zero. This state is termed the breakthrough, and the trend over time of the adsorbate concentration in the outlet is termed the breakthrough curve. The shape of the concentration profile indicates how well the capacity of an adsorbent is utilised before the breakthrough is reached. The narrower the mass transfer zone, the more effectively the capacity is utilised.

Applications

Adsorption on activated carbon is suitable primarily for non-polar dissolved organic substances with low water solubility. Examples include the chlorinated hydrocarbons DDT and lindane. These toxic substances often accumulate in ground water. To prevent them from entering the food chain, they must be removed in the course of remediation processes and treatment to meet drinking water quality.

BASIC KNOWLEDGE

MEMBRANE SEPARATION PROCESSES

Compared to filtration, membrane separation processes remove much smaller substances, such as viruses and dissolved ions, from the water. The driving forces of the separation process are for example differences in concentration or pressure between the two sides of the membrane. The following membrane separation processes are used in water treatment:

1. Microfiltration
2. Ultrafiltration
3. Nanofiltration
4. Reverse osmosis

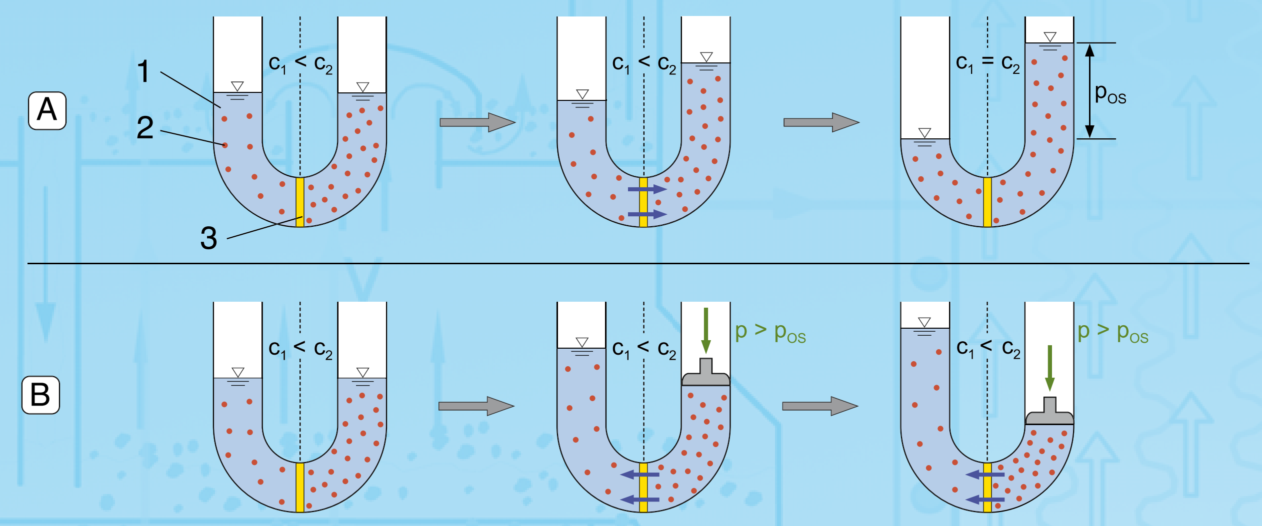
The pressure difference – the so-called transmembrane pressure – increases in the sequence indicated above. At the same time the separation limit – that is, the size of the smallest separable substances – decreases. The treated water is termed permeate, and the retained portion of the raw water is retentate.

Reverse osmosis

Reverse osmosis is particularly important. This unit operation enables high purity water to be produced. It is often required for many different processes in industry and for desalination of sea water.

To understand the reverse osmosis, the osmosis first has to be explained by an example (illustration). Two salt solutions with differing concentrations are separated by a semi-permeable membrane. The membrane is only permeable to water molecules. In trying to equalise concentrations on either side, water flows from left to right through the membrane. The water level rises on the right side until a state of equilibrium is established, the – so called – osmotic equilibrium. The same salt concentration now prevails on both sides of the membrane. The resultant hydrostatic pressure difference between the two sides of the membrane is termed the osmotic pressure.

To reverse the direction of flow of the water (reverse osmosis), the osmotic pressure must be overcome. To do so, a pressure greater than the osmotic pressure is applied to the right side of the membrane. The water then flows from right to left through the membrane. The retentate is produced on the right hand side, and the permeate on the left. In the applications mentioned transmembrane pressures up to 100 bars can be required.



Fundamental principle of osmosis (A) and reverse osmosis (B):
***1** water, **2** salt ions, **3** semi-permeable membrane, **p** pressure, p_{OS} osmotic pressure*
c_1 salt concentration on the left side of the membrane, c_2 salt concentration on the right side of the membrane