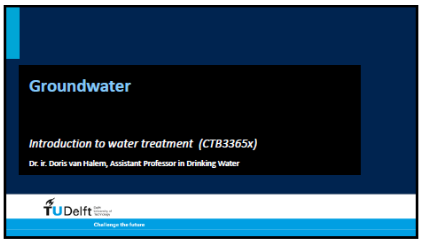
CTB3365x – Introduction to Water Treatment

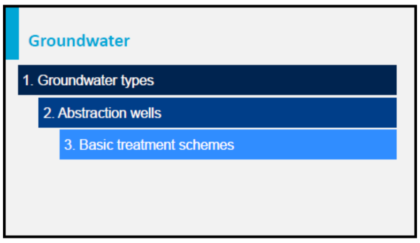
D4a – Groundwater treatment

Doris van Halem

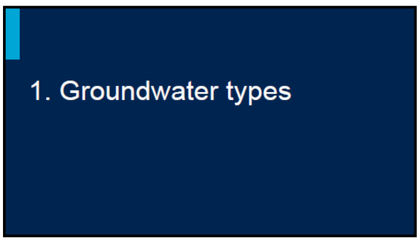
Ever wondered where your drinking water comes from? Well, chances are that you are sitting on it as we speak.



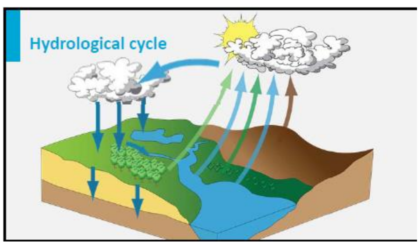
Welcome to the water treatment lecture about Groundwater.My name is Doris van Halem and I am an Assistant Professor in Drinking Water. In this lecture I will introduce you to the basics of groundwater abstraction and treatment.



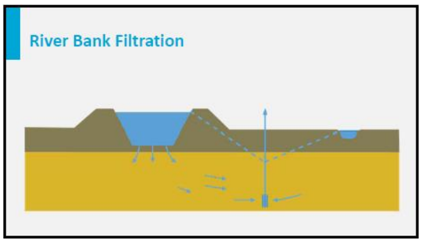
After this lecture you should be able to explain different types of groundwater, groundwater abstraction wells and basic groundwater treatment schemes.



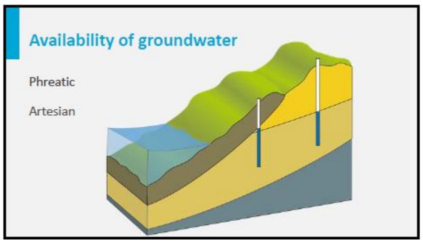
Groundwater is considered a safe and reliable source for drinking water. Groundwater is constant in water quality and typically free of suspended solids and pathogenic microorganisms. It is noteworthy, though, that groundwater abstraction can negatively influence the surrounding environment. For example agriculture and nature can be negatively influenced due to lowering of the groundwater table.



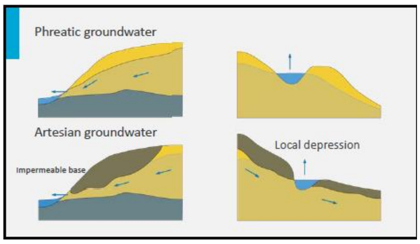
Before we can discuss water treatment schemes, I will provide a short overview of different groundwater sources. Groundwater is always connected to surface water. After all, groundwater eventually becomes surface water within the hydrological cycle (in seas, lakes or rivers).



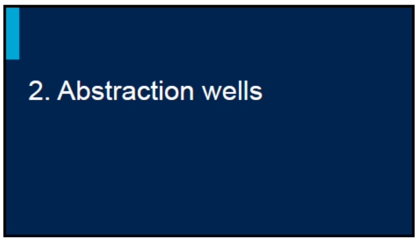
This interaction can also be accomplished artificially when groundwater is abstracted close to surface water, for example during river bank filtration, or when surface water is transported to groundwater systems, like during managed aquifer recharge.



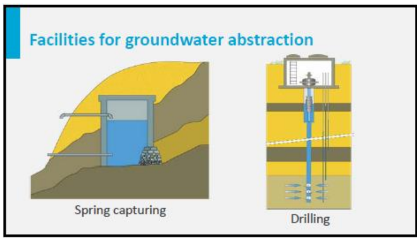
The availability of groundwater is strongly tied to the local situation.
An important division can be made between the abstraction of phreatic groundwater, which has a free water table, and confined, artesian groundwater, which is enclosed by a non-permeable layer.



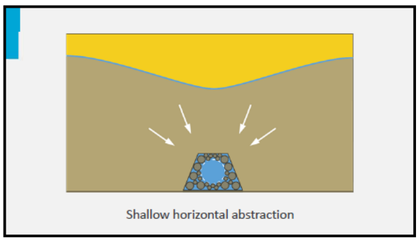
Phreatic groundwater is strongly influenced by in and out flows such as rainfall, so even without human interference the groundwater table will fluctuate significantly.
Artesian water is confined by an impermeable layer, resulting in the build-up of hydraulic pressure. This groundwater is also characterized by long residence times in the aquifer, resulting in changes in water quality, for example, improvement of microbial reliability, but also deterioration of quality by the dissolution of inorganic constituents.
So, groundwater is available under different circumstances, but how do we get it above ground?



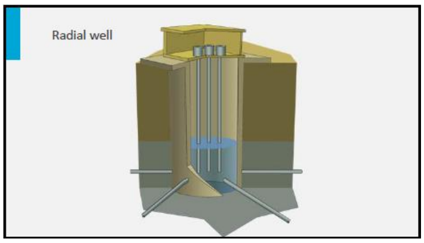
Sometimes, groundwater can surface spontaneously as a spring, and sometimes it has to be abstracted from great depths. For example in the Netherlands, wells go down to 200m, while in arid regions, wells are found deeper than 1,500m.



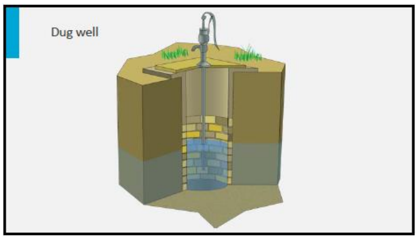
Facilities for groundwater abstraction can be relatively simple for freely discharging groundwater, called spring capturing, but also almost as complicated as oil drilling at extreme depths. Well types can be divided into horizontal and vertical wells, both can be applied for shallow and deep groundwater.



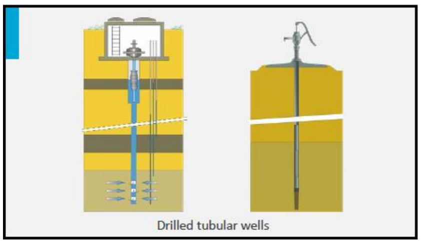
Shallow horizontal abstraction is very attractive in areas like the Dutch dunes, where the fresh water floats on top of the underlying salt water. Deep horizontal wells were found in Persia in ancient times, but still exist today.



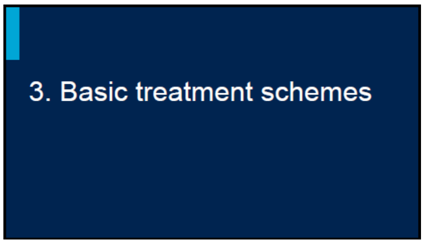
Nowadays, so-called radial wells are used for the abstraction of water from thin aquifers at greater depths. These wells are also called Ranney-wells, after their inventor Leo Ranney



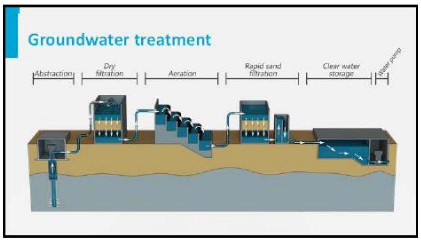
For the vertical abstraction of shallow groundwater, a dug well can be used, however, it is important to protect the water from its surroundings, such as feacal contamination by latrines or stock.



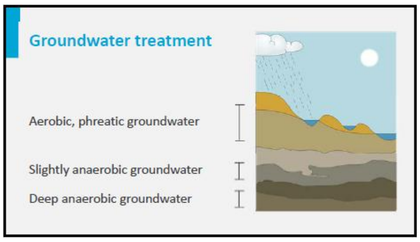
The most widespread method for vertical abstraction of groundwater is drilled tubular wells. Considering the required contact area with the aquifer, these types of wells can only be applied in cases where aquifers have enough thickness. A series of wells have to be constructed for larger capacities. Every well can be supplied with its own pump, or it can be centrally drained with a vacuum system.



Now you know the basics of groundwater abstraction, but what treatment is needed before groundwater is suitable for drinking?

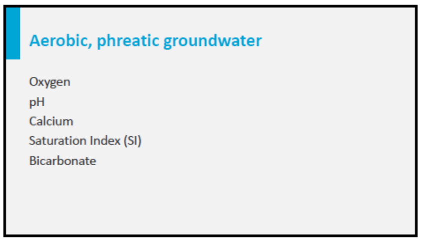


The extent of treatment required to convert the abstracted groundwater into drinking water can be determined based on the groundwater type and its water quality composition. In some cases, however, the groundwater is already suitable for drinking without any treatment.

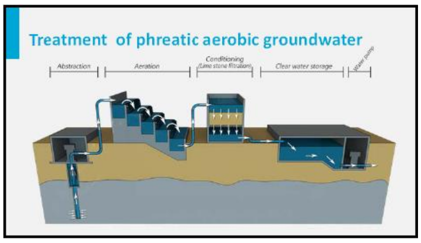


With respect to drinking water production, three different groundwater types can be roughly distinguished:
- Aerobic groundwater;
- Slightly anaerobic groundwater, and
- Deep anaerobic groundwater.

The type of groundwater can be identified by measuring parameters, such as oxygen concentration, redox potential, iron and methane concentrations. Each groundwater type has its own typical treatment scheme. Let's start with the treatment scheme for aerobic groundwater, which has an open groundwater table and is, therefore, connected to the atmosphere, and thus contains oxygen.

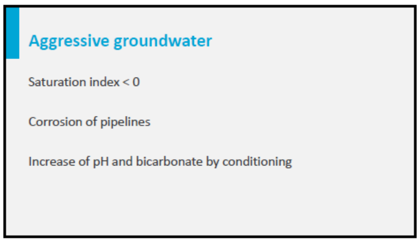


For aerobic groundwater only the parameters pH, calcium, saturation index and bicarbonate have to be taken into account. The other parameters generally comply with the legal requirements.

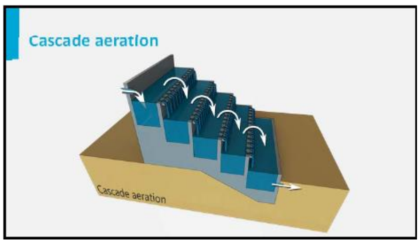


The treatment scheme of aerobic groundwater is generally very simple, and consists of aeration with optional subsequent conditioning or softening. The aeration phase will increase the oxygen concentration and at the same time reduce the carbon dioxide concentration.

Conditioning is desired when aerobic groundwater is abstracted from sandy soils where no calcium is available in the subsurface. The water is called soft or aggressive water.

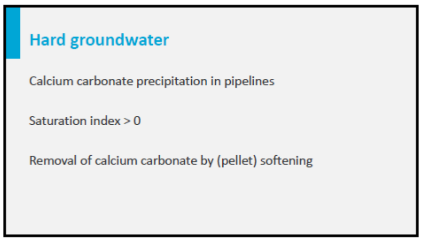


This is caused by a number of subsurface breakdown processes resulting in carbon dioxide in the water above the equilibrium concentration. With a saturation index below 0 the water can corrode the pipelines during distribution.



The saturation index, or SI, can be increased through aeration, but because of low bicarbonate concentrations it may still be recommendable to apply a conditioning step, such as limestone filtration.

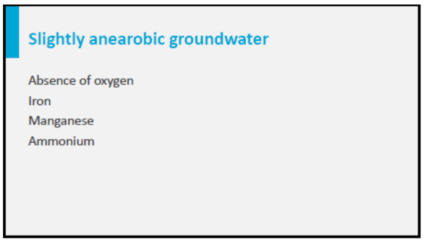
In cases where aerobic groundwater is abstracted from calcium-rich soils, carbon dioxide has dissolved bicarbonate and calcium in the groundwater,



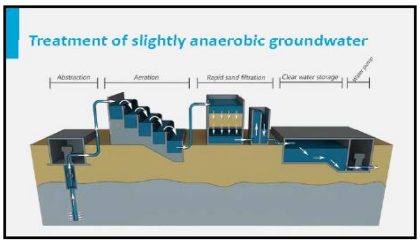
resulting in the abstraction of hard water.
After abstraction, hard water becomes supersatured

with respect to calcium carbonate, because of the loss of carbon dioxide. To prevent calcium carbonate precipitation in the distribution network or in consumers' washing machines and heaters, the water is softened.

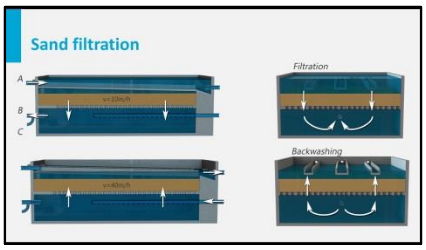
This softening can be done by dosing chemicals, such as caustic soda or lime, to increase the pH and cause an equilibrium shift in a pellet reactor. Softening can also be achieved by cation exchange resins.



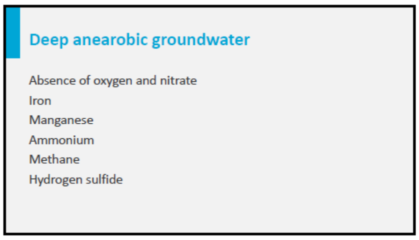
The water treatment scheme for slightly anaerobic groundwater differs from the scheme for aerobic groundwater. Slightly anaerobic groundwater is located under a confining layer, and is characterized by the lack of oxygen and presence of ammonium, iron and manganese.



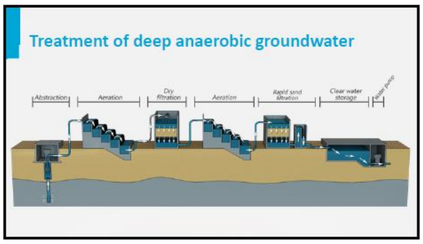
In general, the treatment of slightly anaerobic groundwater consists of aeration followed by submerged granular media filtration. You may remember that aeration is needed for the addition of oxygen and the removal of carbon dioxide. The oxygen is used for the oxidation of ferrous iron or Fe^{2+} to ferric iron, or Fe^{3+}, but it is also needed for the oxidation of ammonium and manganese.



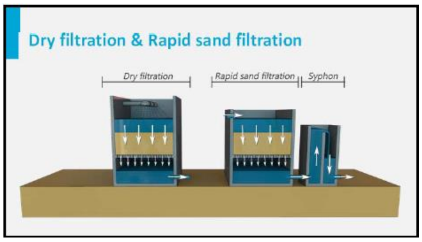
Aeration is followed by sand filtration, where the oxidized ferric iron hydrolyses to iron hydroxide flocs, which are removed by filtration in the sand bed. Manganese undergoes a partial chemical and biological transformation, while ammonium is biologically degraded by bacteria to nitrate. The growth of these bacteria, in combination with the iron and manganese flocs, result in an increase of the filter resistance and backwashing is needed to prevent clogging.



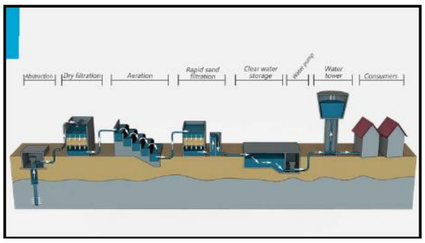
The last treatment scheme in today's lecture, is for deep anaerobic groundwater. Both oxygen and nitrate are absent in this groundwater, and organic material is broken down with sulfate as an oxidant. In deep anaerobic groundwater, iron, manganese and especially ammonium are present in high concentrations, in addition to hydrogen sulfide and methane.



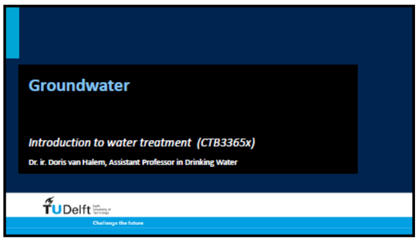
For the removal of ammonium a lot of oxygen is required, even more oxygen than can be dissolved in the water during aeration, in other words, more than the saturation concentration.
To prevent anaerobic conditions in the sand filter, double submerged filtration or dry filtration can be applied, followed by regular submerged filtration in cases of high ammonium concentrations. A dry filter differs from a wet filter.



In a dry filter, air passes along the sand grains together with the water, allowing oxygen in the air to replenish the oxygen in the water during filtration. Dry filtration is followed by submerged filtration because, in a dry filter, the breakthrough of particles may occur.



Now you know the basics of groundwater §abstraction and treatment, so why not also learn more about each individual treatment step? I can highly recommend the upcoming lectures on aeration, filtration and softening.



For now I thank you for watching and please use the discussion board if you have any questions.