Hydrogeology

Author: Michael Kühn

Head of Hydrogeology, GFZ German Research Centre for Geosciences

Published: December 18, 2013

Groundwater - raw material and resource

Groundwater is an important part of the water cycle that is controlled and affected by numerous processes. The underground groundwater circulation systems are of a complexity that is difficult to understand due to the fact that they cannot be accessed directly. This is why it is a particular challenge for scientists to record and describe groundwater systems and reproduce models of them. This includes the scientific characterization of factors and processes that have an effect on the quality and quantity of the groundwater and their development in space and time.

Groundwater is the most widespread and most used raw material in the world and provides the only access to water for people in many areas. The most important use of groundwater as a resource for human beings is as drinking water and raw water. Presently, more and more challenges for research keep arising that involve the use of georesources in deep groundwater systems (e.g. CO_2 storage, geothermal energy, unconventional gas reservoirs or energy storage) and the resulting effects on the valuable resource drinking water in the shallow groundwater systems that needs protection and preservation. This is why scientists focus on understanding the dynamic interactions between shallow and deep groundwater systems and their quantitative description through computer-based process simulations.

The term groundwater does not distinguish between fresh and saltwater. The latter is of little or no use, because it is not suitable for drinking or raw water supply. Groundwater generally comprises all water located beneath the earth's surface irrespective of its quality. The composition of groundwater, particularly its salt content, varies from one location to the other, and significantly alters with depth.

UNESCO surveys predict that as early as 2050 half the drinking water resources of the earth will be no longer usable due to salinization or anthropogenic pollutants. This shows the importance of preventive and restorative groundwater protection. The sustainable and responsible management of groundwater as a resource must be a top priority, not least to avoid crises and conflicts centred on water. Especially the use of georesources in deep groundwater systems is of great importance here, since it always has — or can have — an influence on shallow groundwater systems as well. The hydraulic connection of these two groundwater systems (shallow and deep) and existing paths of migration (fault zones and discontinuities) are not observed or researched either at all or to the extent necessary to date.

In December 2000, the European Water Framework Directive (EWFD) established a uniform framework for measures in the field of water policy among EU member states. The central goal of the directive is to establish good water conditions both in terms of quantity and quality and to maintain that condition in the future. One criterion for identifying the good quality of groundwater according to EWFD is the elimination of pollutants (also, for example, in the form of saline water intrusion).

In Germany, 70 % of drinking water and raw water come from groundwater sources. Shortages caused by excessive groundwater extraction are only an issue in a few areas of Germany. However, there is a negative influence on the quality in local and regional areas, in particular in Northern Germany. The use of groundwater in Northern Germany is complicated, in some areas even rendered impossible due to geogenic and anthropogenic contamination. One factor that poses a risk to our water supply is, for example, groundwater salinity.

A new area of research is the evaluation of the influence of the use of georesources in deep groundwater systems (e.g. the storage of CO_2 in saline aquifers or the production of unconventional hydrocarbon from shales) when looking at the threat to freshwater resources in shallow areas. In the future, this will be of vital importance for a sustainable groundwater management.

Interdependencies between deep and shallow groundwater aquifer systems caused by fracking

Fracking can create or reactivate hydraulic connections between the deep aquifer systems in the reservoir area and the shallow aquifers that are used for drinking water production. The risks that may be caused by this fact need to be examined individually for each site at which the hydraulic fracturing technology is to be used. If possible, the chance that frack fluids or reservoir fluids migrate into near-surface aquifers must be excluded.

Every evaluation of risks is specific to the location. This means that each selected site must be examined thoroughly to be able to make a statement regarding possible risks to near-surface groundwater systems. One key factor is that the sites are examined taking into account the barrier-function of the overburden.

In the North German Basin, one of the potential target areas for the production of shale gas, the underground is composed generally of characteristic sequence of hydrogeological layers. The usable freshwater resources are located in the shallow groundwater near the surface. Depending on the geology of an area, layers containing saltwater are located in a vertical distance of several tens of metres to a few hundred metres. Freshwater and saltwater are usually divided by low-permeability clay layers of large regional extend. These generally prevent the migration of freshwater from the upper into the lower layers and vice versa the upward migration of saltwater. As far as the production of unconventional natural gas through the technique of hydraulic fracturing is concerned, these layers form additional barriers that prevent the vertical migration of frack fluids. This is in addition to the multi-barrier-systems of caprocks directly above every potential reservoir, which are still necessary and must continue to be a requirement.

The risks are assessed by means of computer-based process simulations, with a reflection of the geological conditions of the underground that is as accurate as possible. This setup is then used to test a large spectrum of production scenarios. With this method, the flow of fluids and mass transport processes are quantified in connection with fracturing measures. As a rule, simulations are carried out using the so-called "conservative approach" taking into account the site-specific cumulative effect of individual adverse factors in order to determine the potential risks.

One of the questions that need to be taken into account is the development of cracks that may cause or reactivate hydraulic conductivities between shallow and deep groundwater aquifer systems if conditions are unfavourable. As a general rule, hydraulic fracturing aims to avoid generating cracks that extend outside the target formation. A theoretical estimate of the maximum length of cracks is possible based on practical reservoir engineering experience. According to these estimates the generation of cracks in aquifers that provide drinking water is not to be expected if the chosen target horizon is located deep enough.

Conservative simulation scenarios of related underground processes (taking into account mechanics, flow, transport and chemical reactions) overestimate possible transport distances in the simulation results due to the selected parameters and boundary conditions. In this way simulations are applied to minimize risks for specific situations in the field. Physically, however, the migration of reservoir fluids or frack fluids from the reservoir into adjacent groundwater systems cannot be excluded.

Nevertheless, I believe that the quality of the groundwater in the layers containing drinking water will not be affected as long as the geological barriers are fundamentally intact, the target reservoir for gas extraction is deep enough, hydraulic fracturing is done properly and all available safety measures are taken. The essential prerequisite for each potential site is the comprehensive exploration of the local geological and hydrogeological conditions regarding the potential conductivities for frack fluids. Only based on a comprehensive site investigation that always includes the drilling of one or more exploratory wells can a reliable risk evaluation be carried out.