Influences of Deep Well Injection of Waste Brine on the Environment in the Werra Potash Region, Germany

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The effects of waste brine disposal by deep well injection for more than 70 years in eastern Hessia and Western Thuringia have been observed by governmental institutions for a long time. The Geological Survey of the state of Hessia is concerned with the investigation of the geological and hydrogeological basis and the evaluation of the spreading of waste brine in the underground. The results are presented here.

1. Reasons for deep well injection

The potash industry (Kali und Salz GmbH) has got three potash mines in the state of Hessia, mining the horizontal bedded potash beds Hessia and Thuringia between the approximately 200 to 300 m thick Werra Salt (Zechstein 1). The depth of mining is 400 m to 1000 m.

Due to the composition of the potash beds (mainly hard salt, carnallite and kieserite, BEER (1996)), the special importance of the potash factories is the production of magnesium and potash-sulfates. Although a new production process by means of electrostatic separation (ESTA) has been established since the 1970's, there is still an amount of nearly 11 to 12 million m^3 magnesia-, potassium- and sulfate-rich waste brine to be disposed off. About 3 to 4 Mio. m^3 waste brine can be discharged directly into the river Werra. The amount of direct disacharge into the river depends on its total run off and the limits of 2500 mg/l chloride and 65° dH (german total hardness) at a measuring station downstream the potash factories.

Soon after the beginning of the potash mining it became clear that the total amount of waste brine couldn't be disposed off this way because of ecological reasons and the demands of water resources management.

Since 1925, the main portion of waste brines have therefore been injected into the Plattendolomit aquifer (Leine Carbonate, Zechstein 3). A sum of 675 Mio m^3 waste brine in Hessia (1928 until today) and 233 m^3 in Thuringia (1925 to 1968) has been injected. In 1980, the injection reached its maximum with 21,5 Mio m^3. Since then, the amounts have decreased because of the new ESTA-Process to 8-9 Mio m^3 per year.

2. Geology of the injection horizon

The Plattendolomit consits of highly permeable cavernous and fractured limestones and dolomites (MÖLLER, 1985). It contains natural saline groundwater which is isolated from the upper aquifer in the Bunter (used for the production of drinking water) and the horizontal bedded salt deposits of Zechstein 1 by very low permeable sequences of Zechstein 2-7. The overlying strata of the Werra salt are intensively block-faulted. Tertiary volcanism has caused numerous basaltic dikes (KÄDING 1962; KNIPPING, 1989), impoverishing the potash beds nearby and causing migration ways for groundwater in the overlying strata.

The Plattendolomit is lying in depths between 0 m at its outcrop in the Richelsdorf mountains and 1000 m under surface in the center of the Eiterfeld syncline (Figure 1). At the 3 injection wells in the injection area Eichhorst and the 9 wells of the injection area Hattorf the depth is between 450 and 500 m. The thickness of the Plattendolomit is 20 to 25 m. The potential area for injection is limited by the so called Salzhang, the inclined plain between beginning and total dissolution of the Zechstein Halite. Low permeability of the Plattendolomit in the outer region of the Salzhang (salt slope) leads to waste brine

spreading only in the area overlying the partly and completely undissolved Werra Halite. In the outer region of and outside the Salzhang, the overlying strata are strongly brecciated and cemented by the residue of insoluble contents of salt and therefore an aquifuge. Beginning solution at the inner region of the Salzhang, on the other hand, can cause high-transmissivity zones and the possibility of migration along faults into the Bunter. Long-termed measurements of piezometric groundwater surface have shown the pressure effects of injection, which cannot be recognized outside the Salzhang but only in its inner regions and above the undisturbed Werra salt.

The transmissivity of the Plattendolomit in the area of the inner „Salzhang" is about 1 to 10 Darcy. The cavity volume in these areas is estimated to be 10 to 15%, whereas it is about 10% and lower in undisturbed areas. The total cavity volume in the Plattendolomit in Hessia is estimated to be 1000 mio m^3, so that about 300 mio m^3 is still left, of which 100 m^3 are proved and 200 m^3 are prognostic.

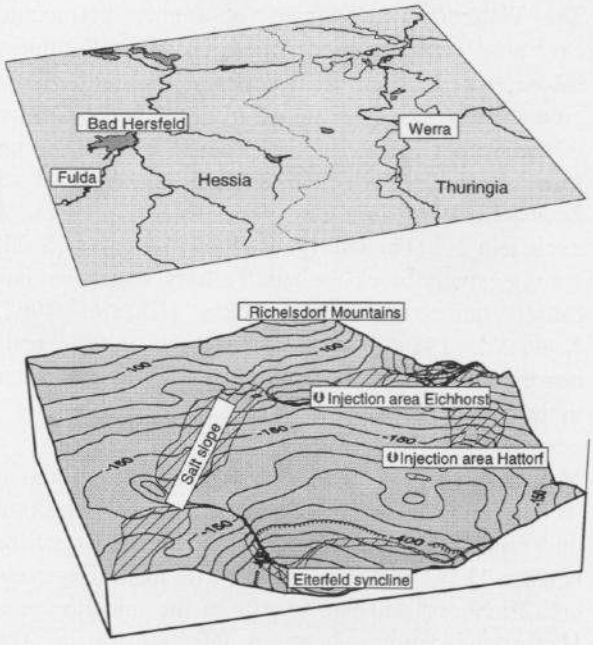

Figure 1. Altitude of the top of the Plattendolomit (m above sea level)

3. Principles of deep well disposal of waste brine

The waste brines have densities between 1,15 and 1,30 g/cm^3 so that they mainly underflow the formation water of the Plattendolomit with densities about 1,01 g/cm^3 and displace them to higher regions of the Plattendolomit and along faults into overlying strata of the Bunter (FINKENWIRTH & FRITSCHE, 1993). They also mix with the formation water and so the spreading of the waste brine can be recognized as a „zone of mixing and displacement" with the help of hydrochemical analysis of the water of 22 ground-water measuring points in the Plattendolomit. The principle is shown in Figure 2. About 200 other measuring points are used to control the groundwater in the overlying strata.

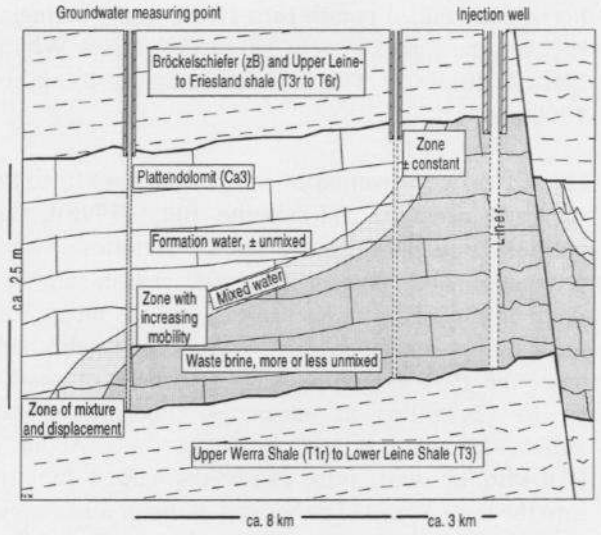

Figure 2. Principle of the movement of waste brines

The currently affected area of about 480 km^2 in the Plattendolomit contains natural formation water with relatively low to middle salt concentrations, highly concentrated waste brines and a mixture of both. A great amount of waste brine moves - more or less unmixed - into depressions of the Plattendolomit. Totally unmixed waste brine can only be found near the injection wells, whereas the maximum salt

concentrations in the nearest groundwater measuring points only reach 70% of the concentration of the waste brine (figure 3).

4. Spreading of waste brine

The varying composition of waste brines, especially during the last 20 years, has been used to investigate the origin, the direction and velocity of waste brine flow. In the observation wells, similar increase of the ion concentrations can be found, but they are dependent on the distance between observation wells

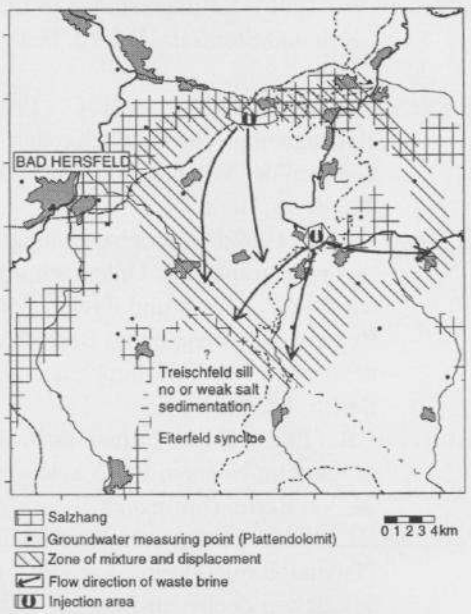

Figure 3. Map of moving directions an influences of deep well disposal in the Plattendolomit

and injection wells. As shown by the examples of three different groundwater measuring points for the ions chloride and magnesium, the development of the chemical water composition in the Plattendolomit can allow conclusions on the flow velocity. The influences of the typical water composition after introducing the ESTA fabrication process (rising of magnesium, potassium and sulfate ions, stagnation of chloride and sodium ions) can for example be recognized after ca. 7 years in the distance of 6 km at well Friedewald 2. The velocity of the waste brine in this inner area of the „Salzhang" accordingly is 2,3 m/day. Between the wells Friedewald 2 and Weisenborn 2 the waste brine moves 2,7 km in ca. 6 years (1,2 m/day). It can also be shown that the concentrations of the waste brine cannot be reached in the observation wells, proving that a part of formation water is still there, overlying the waste brine or mixed with it.

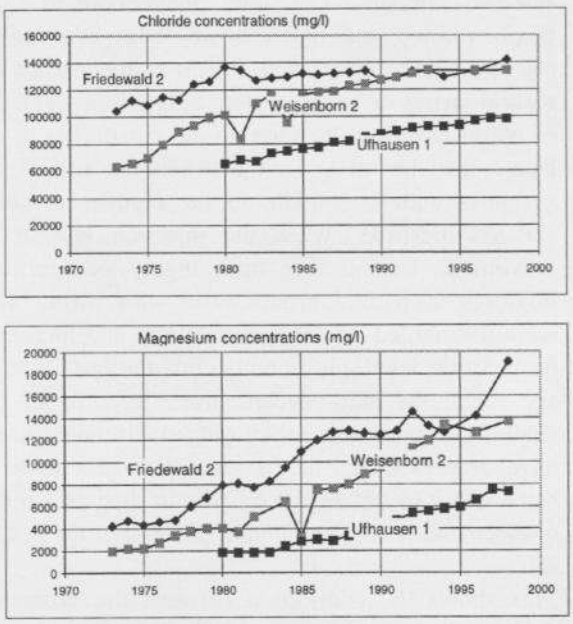

Figure 4. Development of chloride and magnesium concentrations in the Plattendolomit groundwater depending on the distance to the injection wells

5. Hydrochemical influences on the injection aquifer, on overlying strata and on the surface

To estimate the share of waste brine in the groundwater, an index of chemical parameters has

been designed, based on the calculation of mixtures between waste brine and natural formation water in the Plattendolomit before injection activties. The groundwater in both Plattendolomit and higher strata is classified into several types such as intensively influenced and distinctly influenced by waste brine, influenced only by formation water or influenced by discharge of water from the big salt heaps of the potassium works (SKOWRONEK et.al., 1999).

The migration of groundwater between Plattendolomit, Bunter and the quarternary unconsolidated rocks takes place along faults, especially in the Salzhang area and along basaltic dikes. Areas with deeply carved river valleys and a shallow height of the Plattendolomit are predetermined and have shown these connections already before deep well injection took place by natural rising of saline water. Substantial influence of waste brine on the sweet water ressources in the Bunter can be recognized between the end of the seventies and the middle of the eighties at some isolated locations, when the injection was at its maximum. During this time highly concentrated mixtures of natural groundwater with waste brine were discharged into the river Werra and increased its chloride load substantially. For the last three to six years, the salt concentrations in most of the shallow groundwater monitoring wells and springs have decreased and at the same time the share of brine water in this region has diminished as a result of electrostatic (dry) treatment (ESTA) of the potash salt.
This shows the connection between the decreased deep well injection quantity and the quality of groundwater and surface water in the affected regions.
Nevertheless, mainly in the valley of the river Werra mixed brines containing waste brines still move into the overlying aquifers and to the surface along faults. The result is a discrete, continuous discharge of saline groundwater into the river Werra. This discharge enlarges the concentration especially for chloride and increases the chloride load in the range of 10-20% of the total chloride load of river Werra.

In this way, about 5-15% of the entire disposed waste brine volumina have been lost via surface discharge. Nowadays, the duration of the transport parts of disposed waste brines from the injection wells to the area of surface discharge can be said to take more than 15 years.
Additional movements of saltwater into the overlying aquifer of the Buntsandstein (Bunter) possibly connected to deep well disposal occur at some isolated locations, but all over the highly permeable inner region of the Salzhang in the surface catchment areas of the rivers Werra and Fulda.

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