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Report on the dataset of the Brine Injection at the CO_2 Storage Pilot Site Ketzin, Germany

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1 Introduction

The Ketzin pilot site has been the longest-operating European onshore CO_2 storage site. Between June 2008 and August 2013, a total amount of 67 kt of CO_2 has safely been injected into a saline aquifer. The reservoir consists of 630 m to 650 m deep sandstone units of the Stuttgart Formation of Upper Triassic age. These were deposited in a fluvial environment (Förster et al., 2010). A sequence of about 165 m of overlaying mudstones and anhydrites is sealing the storage complex and act as caprock (Martens et al., 2012).

The research and development programme at Ketzin is among the most extensive worldwide in the context of geological CO_2 storage (Giese et al., 2009). Research activities have produced a broad data base and knowledge concerning the storage complex at Ketzin itself but also CO_2 storage in general (Liebscher et al., 2013; Martens et al., 2011-2014; Würdemann et al., 2010; Schilling et al., 2009).

This publication compiles the operational data (flow rate, cumulative mass, density, injection temperature, electrical conductivity and in-well pressure data) recorded during a field experiment on brine injection at the Ketzin pilot site during October 2015 to January 2015. Anyone should feel free to make use of the published data for any ethical purpose (civil use) – for example for process modelling and engineering.

Recommended citation for this data report is:

Möller, F., Liebscher, A., Schmidt-Hattenberger, C. (2016): Report on the dataset of the Brine Injection at the CO_2 Storage Pilot Site Ketzin, Germany, (Scientific Technical Report STR; 16/05), Potsdam: GFZ German Research Centre for Geosciences.
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http://doi.org/10.5880/GFZ.6.3.2016.001

Coordinates: 12.868592 E, 52.491326 N

Keywords: CO_2, brine injection, remediation, residual saturation, Ketzin

2 Motivation and overview on the course of the test

Prior to the injection of CO_2, the sandstones in the reservoir were filled with brine with a salinity of about 240 g/l NaCl equivalent (dominantly NaCl and subordinate $CaCl_2$, Zimmer et al., 2011). This brine has been displaced partially by the injected CO_2.

With the brine injection, the area between the wellbores Ktzi 201 (injector and observation well) and Ktzi 200 (observation well) should be partially re-filled with brine. This process has been monitored with a geoelectrical system of vertically installed electrodes within these wells ("VERA" vertical electricity resistivity array, Schmidt-Hattenberger et al., 2014). With VERA, the electrical resistivity distribution in the observation area and its changes during the different operational phases and field tests have been determined and evaluated.

The test aimed at:

A) Quantification of the residual gas saturation:
After the injection of CO_2 into the saline aquifer, brine is re-injected into the same horizon. It will partially displace the gas and part of the CO_2 will remain within the pore space (residual gas saturation).
The brine injection simulates the natural back flow of brine into the formation in time lapse mode and has been monitored with VERA. Thus it is possible to compare the results from this monitoring tool before and during CO_2 injection (displacement of brine by CO_2) with those during and after the brine injection (displacement of CO_2 by brine).

B) Evaluating brine injection as a means for leakage remediation:
The test should also give insight on the feasibility of using brine injection as a means for leakage remediation: Upon completion of the test, pressure within the well will be further monitored. Thus it will be possible to determine the timespan until pressure rebuild within the well occurs. Injection of brine (or water) might be a cost-effective measure to kill (i.e. making it pressureless) and shield the well quickly for a certain timespan to allow for a work-over job.

Figure 1 gives an overview on the whole test. The test has been carried out between October, 12th 2015 and January 06th in 2016. The well has been killed with a plunger pump within ~ 20 minutes at about 250 l/min with a total mass of approximately 4.7 t of brine. Subsequently, a rotary pump was used to continuously inject brine.

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During the first 48 h of injection, a high injection rate (> 2.5 t/h) has been targeted to avoid possible backflow of the CO_2 in the vicinity of the well.

From October 14th the target injection rate has been ~1.4 t/h.

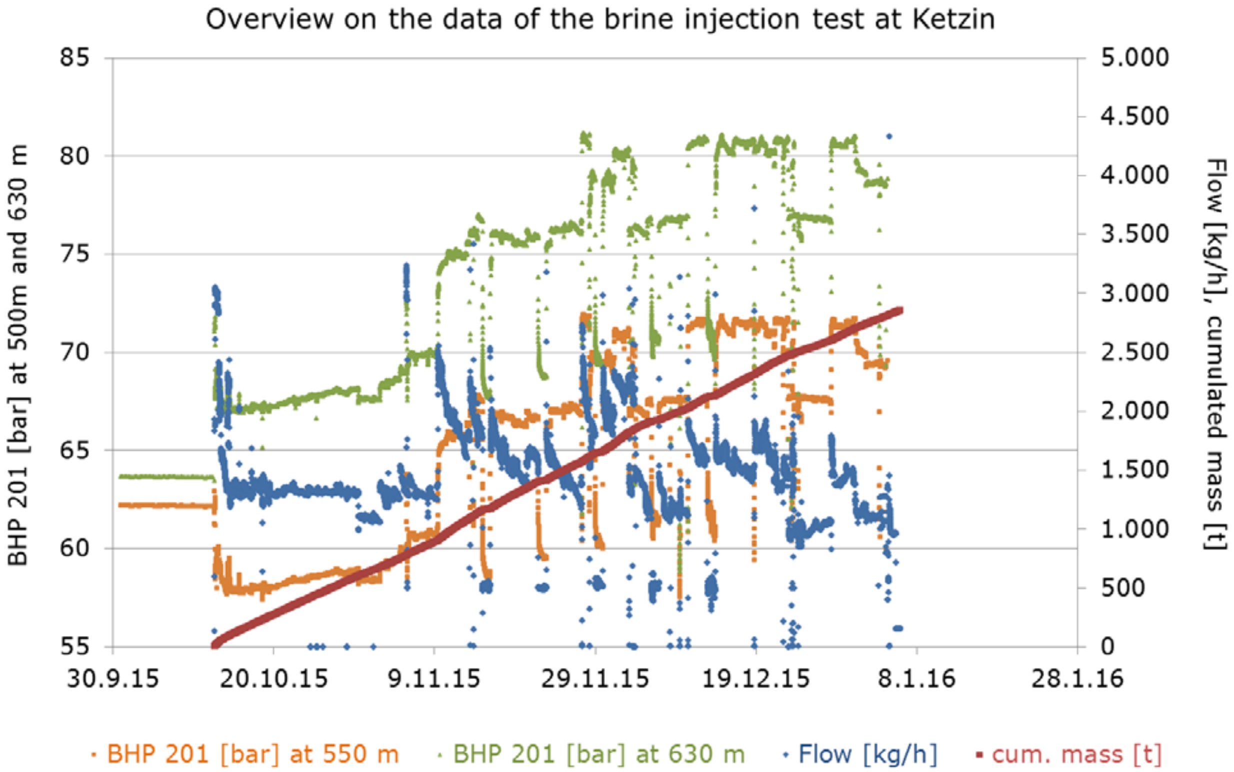

Figure 1: Operational data of the brine injection test. The bottom-hole pressure has been measured at 550 m (orange squares) and has been extrapolated to match the reservoir level at 630 m (green triangles); both shown at the primary y-axis. Flow (blue diamonds) and cumulated mass (orange squares) are shown on the secondary y-axis.

The electrical monitoring indicated only slight changes within the reservoir during the first weeks. Thus it has been tried to increase the injection rate from November 9th on. Also a repeated pressure pulse has been added. This has been achieved through lowering the injection rate on Sundays to 0.5 t/h for about 24 h until December 13th.

The pressure in the formation gradually increased during the experiment. Maximum al-lowed reservoir pressure for the Ketzin site was 85 bar. To leave a safety margin, it has been decided to switch the injection regime to be pressure driven: From December 12th on, the operations crew adjusted the injection rate continuously so that the formation pressure was stabilised at around 81 bar.

Continuous injection ceased on January 06th and a rest of about 1.8 t of brine left in the surface tanks and in the hoses was pumped discontinuously into the well in the following days during the dismounting of the surface facilities.

3 Infrastructure

3.1 Wellbores

At the Ketzin pilot site, a total of five wellbores has been drilled and completed. One of them (Ktzi 202) has been abandoned in 2015. Three wells reach down to the storage formation and one shallower well (P300) ends above the cap rock. The respective coordinates of the deep wellbores are depicted in Figure 2. An overview on the technical data of the wellbore relevant for this publication (Ktzi 201) is given in Table 1. Further information on the wellbores can be found in Prevedel et al. (2009) and Möller et al. (2012).

Data published in this contribution refer to the wellbore as follows:

- CO2 Ktzi 201/2007 – abbreviated as: Ktzi 201 (production & monitoring)

Table 1: Technical Overview on the wellbore Ktzi 201

	Ktzi 201
Diameter (innermost casing)	5 ½'' with 3 ½'' production string
True Vertical Depth	755 m
Connection to reservoir	Filter screens at: 632-636 m; 637-642 m; 645-649 m; 650-654 m
End of injection string packer (transition to 5 ½'')	560 m
Pressure/temperature gauge at	550 m

3.2 Test layout

Professional equipment and personnel has been hired from a service company to conduct the test. The piping and instrumentation flowchart is shown in Figure 3.

Brine has been transported to the test site via road tankers and then stored in brine tanks on site.

The left hand flow path from the tanks in Figure 3 was only used to initially kill the well. Afterwards, the brine went only through the smaller transfer pump (right hand side in Figure 3). Candle filters were used to filter out dirt particles to prevent possible plugging of the injection well filter screens.

Before entering the wellhead, flow rate, cumulated mass, density, temperature and electrical conductivity of the brine were measured.

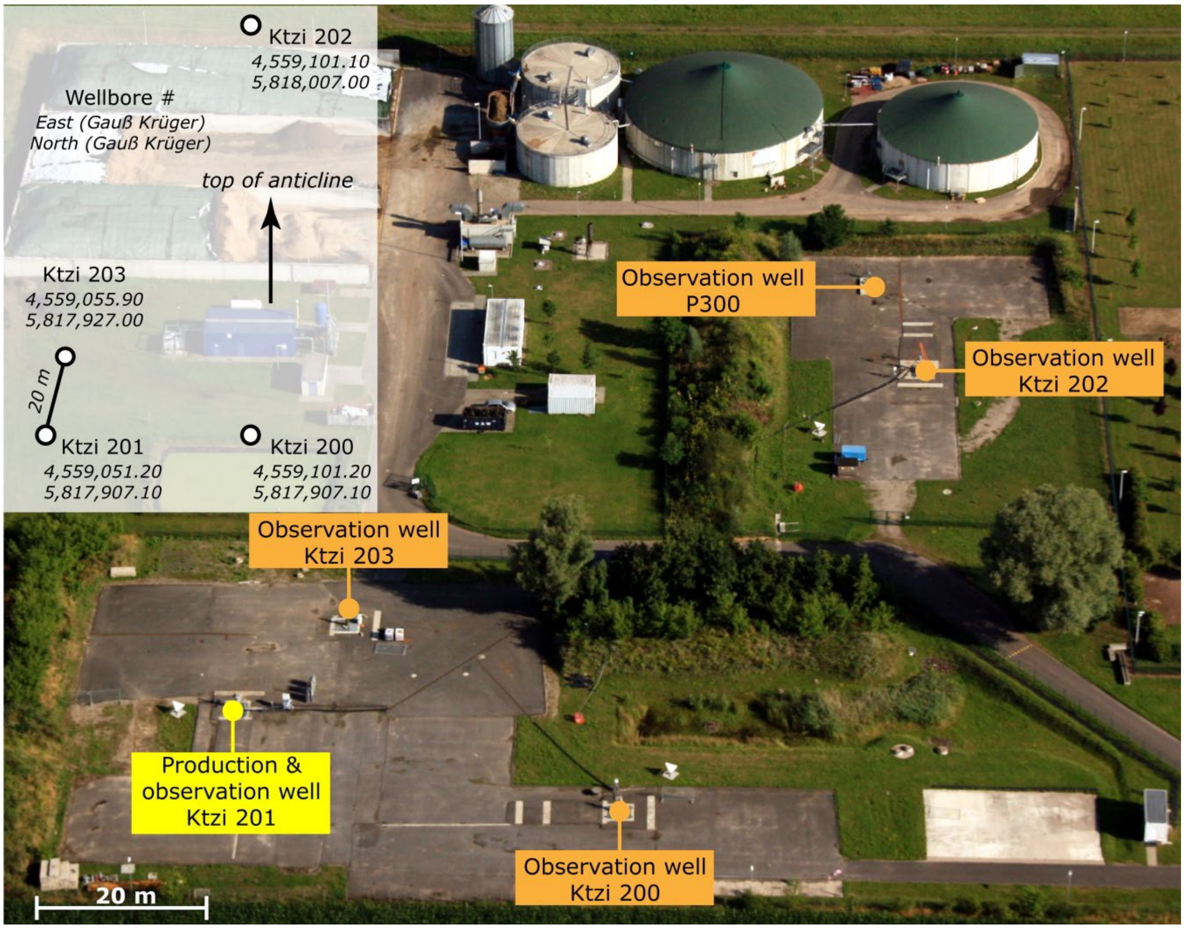

Figure 2: Aerial view on the Ketzin pilot site with focus on the wellbores. Note that Ktzi 202 has been abandoned in 2015.

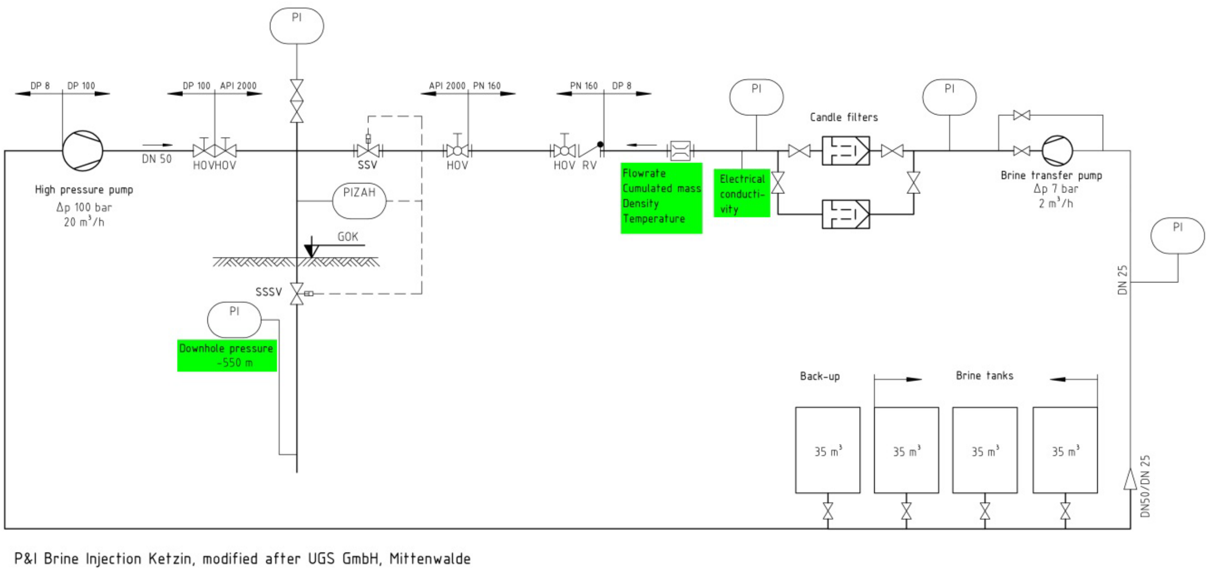

Figure 3: Piping and instrumentation flowchart for the CO_2 brine injection test

4 Data acquisition and correction

All data published in this contribution have been acquired via a data logger as mean values over intervals of 5 minutes.

4.1 Definition

Data point in this publication means the evaluated signal from a sensor (e.g. “BHP at 550 m” with a certain value - e.g. “69.40 bar”)

4.2 Description of the data points

The following data points are published (reference to Figure 3, green box underlay):

4.2.1 Flow [kg/h]

Flow rate of the injected brine. Measured with a coriolis type flow meter (Krohne Optimass 7000; accuracy mass flow +- 0.1% of measured value)

4.2.2 Cum. mass [t]

Cumulative mass of the injected brine. Based on measured flow with the coriolis type flow meter specified under 4.2.1.

4.2.3 Density [kg/dm^3]

Density of the injected brine. Measured with the coriolis type flow meter (Krohne Optimass 7000; accuracy density +- 2 kg/m^3).

4.2.4 Temperature [°C]

Temperature of the injected brine. Measured with the coriolis type flow meter (Krohne Optimass 7000; accuracy temperature +-1 °C).

4.2.5 El. Conductivity [mS/cm]

Electrical conductivity of the injected brine, measured with Endress + Hauser Indumax CLS50 [accuracy +-(5 µS/cm + 0.5 % of measured value)].

4.2.6 BHP 201 [bar] at 550 m

Bottom-hole pressure of the wellbore Ktzi 201 at 550 m depth (~ 80 m above reservoir depth), acquired via fibre-optical sensor based on Bragg grating technique (Weatherford “Optical Pressure-Temperature Gauge”, 0…690 barg; calibrated with 14.7 PSI as atmospheric pressure).

4.2.7 BHP 201 [bar] at 630 m

Calculated pressure at top-reservoir within the well Ktzi 201. Pressure has been calculated from the measured pressure at 550 m adding the weight-column of 80 m to reservoir level with the measured density of the brine.

4.3 Data correction

The coriolis type flow meter failed at certain time intervals, possibly due to low brine temperature. Values for “Flow” and “cum. mass” had to be approximated during these times by measuring the level of the brine storage tanks and calculating the resulting flow rates accordingly. Those values are set in red font color in the attached data sheet (Möller et al., 2016).

During the last two days of the experiment, the downhole pressure sensor failed and no data correction or alternative source is available. Values marked as error value (#NV).

5 Acknowledgments

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