Flowing Fluid Electrical Conductivity Logging at the Heletz Site for Detailed Hydraulic Information for CO_2 injection

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Abstract

A deep subsurface CO_2 storage test will be performed through two newly constructed well at Heletz (Isreal). Flowing Fluid Electrical Conductivity (FFEC) logging is planned to be performed before the CO_2 injection to understand the hydraulic conductivity structure of the target injection aquifers (three sandstone layers). In this study, we present the result of the deign study of the FFEC logging procedure to be applied at the newly constructed wells for detail hydraulic information. We have further studied the possibility of using FFEC logging in the monitoring well to determine the relative flow rates and their possible time variation during CO_2 injection.

Background

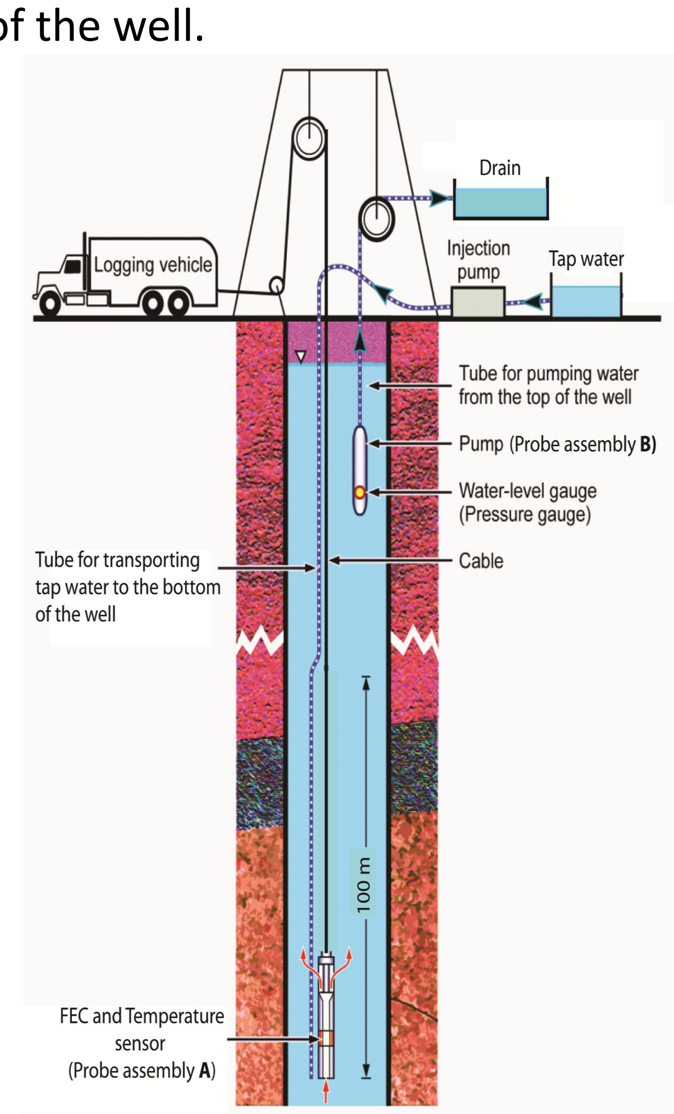
Heletz area is located in the southern part of the Mediterranean Coastal Plain of Israel, about 7 km from the coastal line (the city of Ashkelon). In the frame of the MUSTANG project, two new wells at the vicinity of Well Heletz 18 (H-18) are being drilled and will be used for the study of the effects of CO_2 injection for geological storage. The target storage formation comprises three sandstone layers, having a cumulative thickness of ~10 meters, at a depth of 1600 m approximately. The approximate wellbore diameter is 8.5" (21.6 cm) within a resolution of ~10%. A complete background information such as porosity, permeability, aquifer thickness, hydraulic head, geometry of cap-rocks, salinity are necessary for the successful planning of the field injection or for modeling the flow and transport of injected CO_2 in the target formation. Although some of the preliminary hydraulic information are available for Heletz test site from previous geophysical logging and pumping tests, detailed information of hydraulic conductivity structure as a function of depth of the target layer of newly constructed well is needed.

Objectives

This poster presents results of a continuing study on the application of a fast method (Flowing Fluid Electrical Conductivity, FFEC) for characterization of hydraulic structure of reservoir layers used for CO_2 storage. This results are specifically on **(1)** the detailed design of FFEC testing procedure applicable to the proposed CO_2 injection test site at Heletz and **(2)** the feasibility of using FFEC logging to monitor the flow rates and their possible variations through individual conductive layers at the monitoring well during CO_2 injection.

Flowing FEC Method

Flowing Fluid Electric Conductivity (FEC) is fast way to determine the distribution of hydraulic connections over depth and internal heterogeneity of the well.



(From Doughty et al. 2005)

- Formation water of the well first replaced with deionized water by pumping from the bottom of the well.
- Well water then pumped at constant flow rate from the top and EC probe moved up & down into the well.
- As formation water enters the well, FFEC profile as a function of depth obtained until steady state concentration reached.
- The BORE II code solves the one-dimensional advection-diffusion equation for flow and transport along the well using the finite-difference method to estimate the hydraulic conductivity structure over well depth.

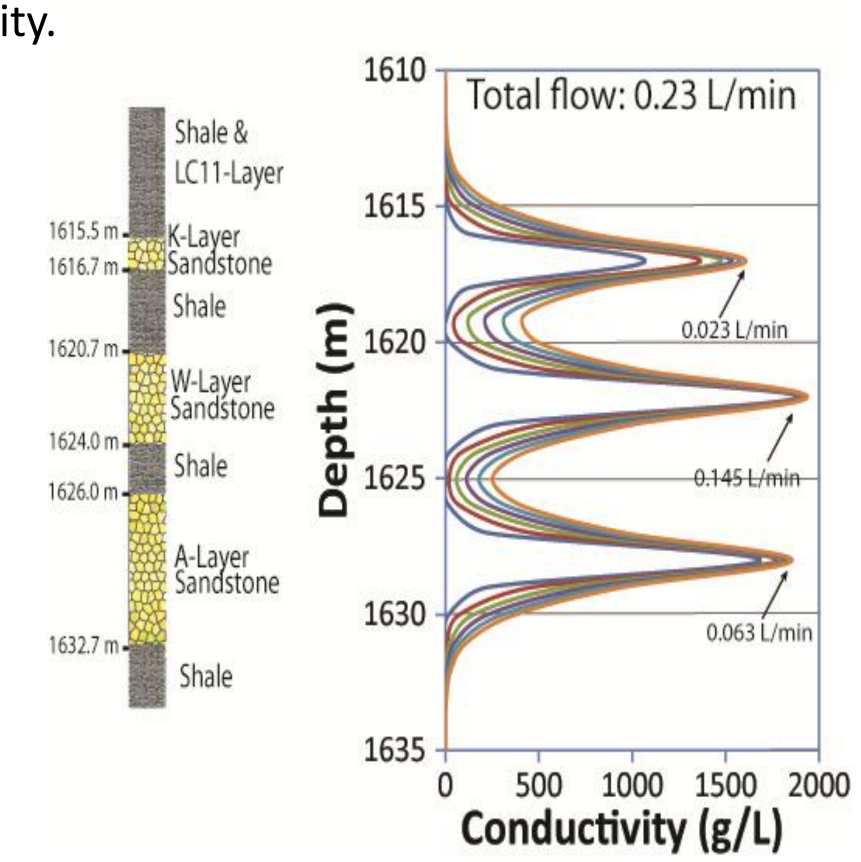
FFEC Logging Procedure

After considering well details, we arrive at the following design of field logging schedule at Heletz test site:

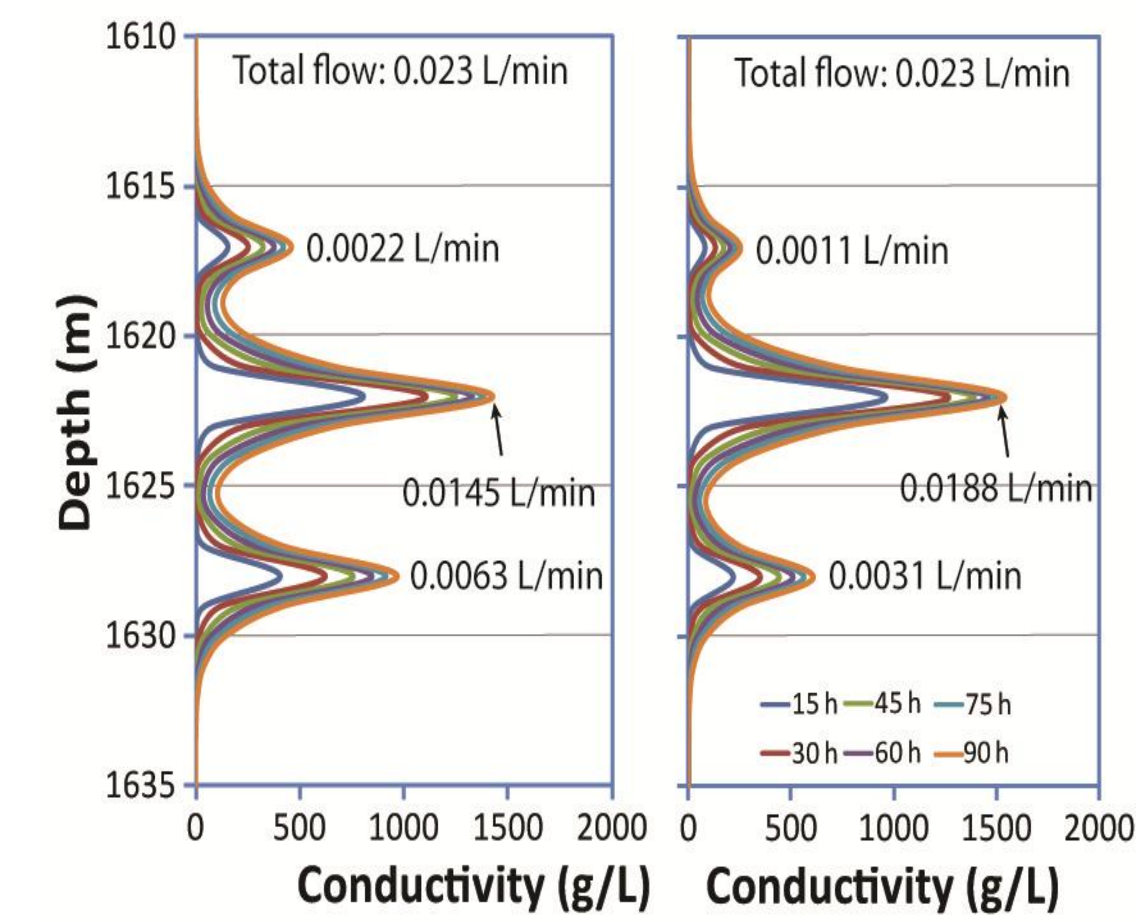
Activity Time		Measurement Time		Day	Description
Start	End	Start	End		
				Day 1	
8:00	8:30				Site preparation
8:30	11:00				Installing of EC logging tools and tubing [Probe assembly A] for tap water injection (tubing bottom at 1670 m for injection)
11:00	11:50				Installing of pump and tubing [Probe assembly B] for extraction, and water level sensor (at 250 m, below anticipated lower water table level)
					Continuous measurement of water level
12:00	14:30				Replacement of well bore water with tap water, using bottom tubing for injecting tap water and upper tubing for extracting bore water at same rate (Q_{bore} = 30 L/min), Practice run
14:30					Stop injection and pumping
14:40		14:40	15:00		EC measurement (UP, for 200 m, speed = 10 m/min, Q = 0) [For practice run]
	15:30	15:10	15:30		EC measurement (DOWN, for 200 m, speed = 10 m/min, Q = 0) [For practice run]
15:40	16:20				Start Pumping at Q_1 = 10 L/min [For practice run]
15:40		15:40	16:00		EC measurement (UP, speed = 10 m/min, 1st Scan) [For practice run]
	16:20	16:00	16:20		EC measurement (DOWN, speed = 10 m/min, 1st Scan) [For practice run]
16:30	7:55 (Day 2)				Replacement of well bore water with tap water, using bottom tubing for injecting tap water and upper tubing for extracting bore water (Q_{bore} = 30 L/min) (circulation 1)
				Day 2	
8:00		8:00	8:40		EC measurement (UP and DOWN, for 200 m, speed = 10 m/min, Q = 0)
		8:40	9:00		Break in logging
	10:00	8:40	10:00		EC measurement (Repeat above 2 steps for 2 more times)
					Break in logging
10:20	15:00				Pumping at Q_1 = 10 L/min
10:20		10:20	10:40		EC measurement (Q_1=10 L/min, 1st Scan, UP) (speed = 10 m/min) for 200 m
	11:00	10:40	11:00		EC measurement (Q_1=10 L/min, 1st Scan DOWN) (speed = 5 m/min)
					Break in logging
11:20		11:20	11:40		EC measurement (Q_1=10 L/min, 2nd Scan, UP) (speed = 10 m/min)
	12:00	11:40	12:00		EC measurement (Q_1=10 L/min, 2nd Scan, DOWN) (speed = 10 m/min)
					Break in logging
12:20	15:00	12:20	15:00		Repeat 3 more times
16:30	7:55				Replacement of well bore water with tap water, using bottom tubing for injecting tap water and upper tubing for extracting bore water (Q_{bore} = 30 L/min) (circulation 2)

Feasibility study of using FFEC logging to monitor flow rates during CO_2 Injection

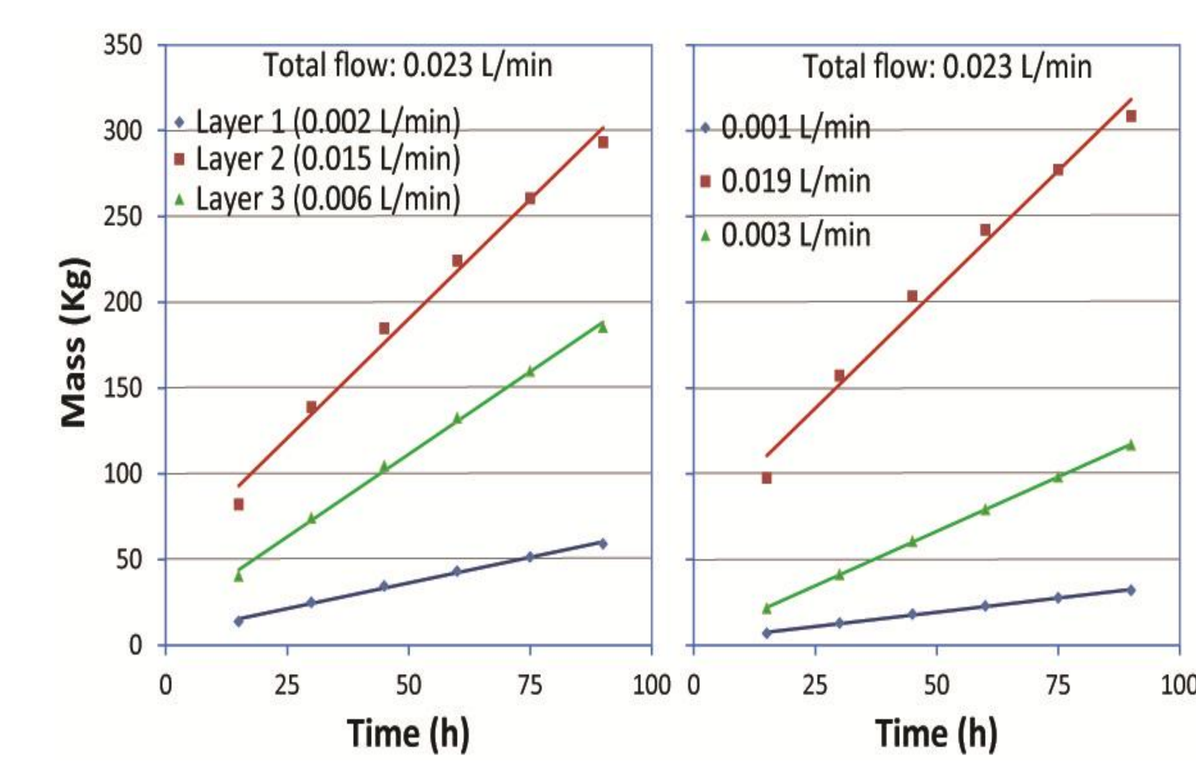
We suggest that it may be possible to monitor the flow rates in the individual conductive layers of the storage aquifers at the monitoring well using FFEC logging method. The figure (below) shows the salinity change due to flow in formation water through the monitoring well at their corresponding conductive layers, due to CO_2 injection (3.5 tones/h) at the target well located at 50 m away from the monitoring well. The salinity is higher in the middle layers as it has the highest permeability.



FFEC method can also be applicable to monitor the accelerated flow behavior via the most conductive aquifer as a function of time. The figure (below) shows an example of FFEC profile with enhanced salinity with time (i.e., flow rate through that layer) due to CO_2 injection.



The total salt concentration entered through formation water to the monitoring well (after complete replacement with deionized water during FFEC logging) increased linearly with time, however the rate of salt mass over time could be different for different conductive layer and they may also alter due to injected supercritical CO_2 with time (as shown in figure below).



Summary

- A complete design for conducting FFEC logging for detail hydraulic conductivity information have been presented for newly constructed well at Heletz site for CO_2 injection.
- It is suggested that FFEC logging method may be useful for monitoring the flow rates and their possible variations through the different layers in the CO_2 storage aquifers during CO_2 injection.
- The flow rates of the liquid phase through conductive layers can increase with time as more and more supercritical CO_2 (with lower density and viscosity) enters into these layers during injection.

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References

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