Carbon: captured!

Anthropogenic emission of carbon dioxide is a key influence on the global climate change that has been observed over the last century. While government agencies set long-term goals to cut carbon emissions, pioneering research is exploring ways of dealing with today's problem today. Carbon capture and storage (CCS) represents one promising fix to this challenge: we're familiar with extracting oil, gas and water from deep subsurface reservoirs, so why not inject our waste emissions back underground and make use of some spare space? Dr Monika Ivandic, a post-doctoral researcher in geophysics at Uppsala University in Sweden, is using seismic imaging methods to monitor CCS operations as part of the CO_2SINK and CO_2MAN projects, making sure that captured carbon stays well-and-truly captured.

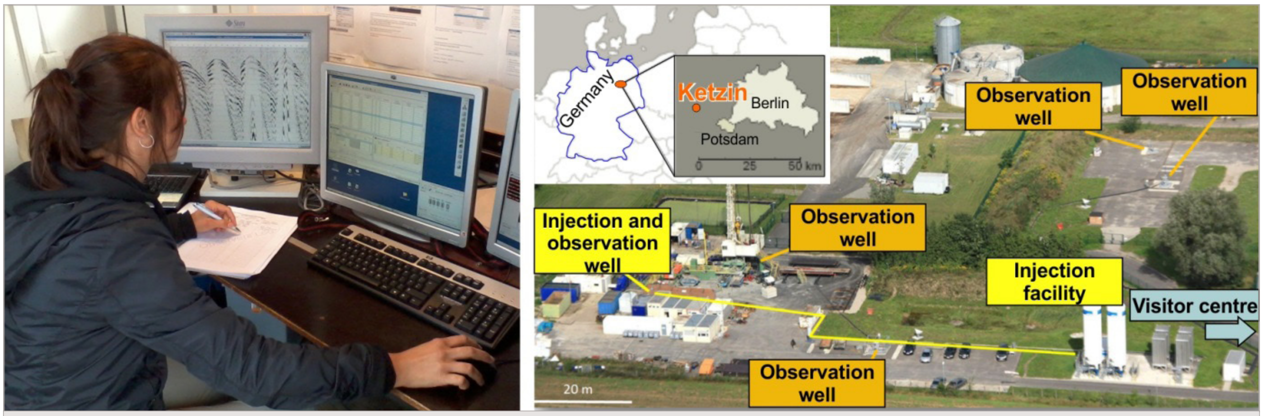
"Our projects examine whether geological storage is an option for reducing CO_2 emissions," Ivandic says. "A critical component of long-term CCS is our ability to adequately monitor the movement of CO_2 in the subsurface." So how is this done? In essence, Ivandic conducts time-lapse photography of the subsurface CO_2 plume, only at the seismic scale. By repeating a seismic survey at the same site, she builds up a series of images from which the growing subsurface volume of CO_2 can be monitored. "Time-lapse seismic surveys have been widely adopted for measuring subsurface fluid flow," she tells me. The general trick is that gas injection changes the physical properties of the subsurface reservoir – for example, reducing its bulk density – which in turn changes the reservoir's seismic response. Careful seismic data acquisition and processing can then map where those changes are taking place.

The gas injection in question takes place west of Berlin at the Ketzin CCS study site, Europe's first and longest-lived on-shore CO_2 storage facility (Martens et al., 2011). Since 2008, Ketzin has been pumping CO_2 into saline sandstone aquifers, sealed beneath impermeable mudstones some 640 m below the ground. In 2005, prior to the start of CCS operations, researchers performed a baseline seismic survey and then repeated it for comparison in 2009 and 2012, in which time over 65,000 tonnes of CO_2 had been injected.

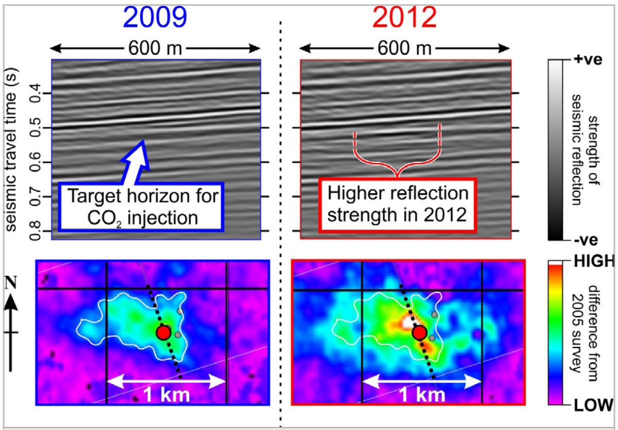
With some pride, Ivandic states that "the monitoring methods used at Ketzin are among the most comprehensive in the field of CO_2 storage." Injection will cease this year, marking the first time that a CCS reservoir has been monitored throughout and beyond its operational cycle.

Ivandic's seismic images (next page) show clear changes in the subsurface – both in cross-sectional (upper) and plan (lower) views – which are directly attributable to the growing gas plume. Of course, there's a real need for such comprehensive study: the problem with injecting thousands of tonnes of free-spirited gas into the ground is that it doesn't always stay where you need it to. In fact, Ketzin itself proves that you should always expect the unexpected. Theoretically, the CO_2 was expected to migrate north into the highest part of the reservoir. "That's not what we're observing at the moment," says Ivandic, who tells me that lithological variations in the reservoir are causing the gas to head west. "In spite of very detailed data, fine-scale reservoir structure can be difficult to discover and can seriously affect the CO_2 migration. That's why time-lapse seismic imaging of the CO_2 plume evolution during and after injection is crucial." The next seismic survey is scheduled for 2015, and Ivandic is "really curious to see how the reservoir and plume will behave once the site is closed. An exciting period is ahead of us!"

Despite its unexpected migration, the good news at Ketzin is that the CO_2 looks to be locked away. But such operations are clearly not without risk, and Ivandic's group has navigated a fine line between scientific discovery, environmental legislation and societal impact. "The safety of the sequestration process is the most crucial aspect, for both man and nature, and thus for other CCS projects." Some commercial injection operations have encountered strong opposition from local German stakeholders, but Ketzin has been well-accepted by local politicians and public alike. While this is partly down to its non-commercial scale, it is also related to the fact that Ivandic's group has actively engaged with the local community, for example by holding weekly outreach and education events at a visitor centre.



Left: Dr Monika Ivandic oversees seismic acquisitions at the experimental site in Germany. Right: Aerial view over the Ketzin CCS facility, close to Berlin, Germany (Adapted from http://www.co2ketzin.de/en/pilot-site-ketzin/summary.html)



Time-lapse seismic data from the Ketzin CCS site, from 2009 and 2012 acquisitions (from Ivandic et al., in preparation). In cross-section (upper images), stronger seismic reflections are observed in the target aquifer but the rest of the data remains identical. This shows that the CO_2 volume in the aquifer has increased, but that it is contained. Map-view images (lower) reveal the size of the 2009 and 2012 CO_2 plumes compared to the 2005 baseline survey and suggested that it has migrated west from its injection site (red circle). The black dashed line shows the intersection with the cross-sections above.

Worldwide, interest in CCS is growing – something Ivandic has experienced first-hand. Many countries, including her homeland of Croatia, have no CCS operations but have estimated their potential storage capacity from data archives or from regional distributions of suitable reservoirs. Such estimates keep increasing, but The Worldwatch Institute suggests that today's seven active and planned CCS operations could only store 0.5% (35 million tonnes) of the CO_2 emitted in 2010 – hence CCS does not yet provide the answer to the global emissions challenge. Nonetheless, CCS expertise is in demand and, this year, Ivandic has completed a marathon schedule of workshop and conference attendance presenting CO$_2$MAN's latest observations (including at April's EGU General Assembly). Indeed, she was surprised to find that "the work and results attracted the attention of scientists not even involved in CCS projects!" Clearly, the world is becoming fascinated by grounded gas.

Adam Booth

Post-doc at Imperial College London, UK

More information

Monika Ivandic obtained her PhD from IFM-GEOMAR (Kiel, Germany) in 2008, then worked back in her native Croatia on a variety of geophysical projects for geotechnical and civil engineering applications, and started her post-doc at Uppsala in 2011. For those embarking on a post-doctoral career, Monika has the following advice. "Be ready for short-term contracts. More than a third of academics are on temporary contracts, a situation which results in frequent changes of job and city." However, such diversity also brings rewards. "It brings a lot of excitement and dynamics to your life! And as for the science, that's always a new page in your career."

References

Ivandic M. et al.: Geophysics monitoring of CO_2 at the Ketzin storage site – the results of the second 3D repeat seismic survey, 75th EAGE Conference & Exhibition, 2013 (conference abstract)

Martens S. et al.: Europe's longest-operating on-shore CO_2 storage site at Ketzin, Germany: a progress report after three years of injection, Enviro. Earth Sci., 67(2), 323–334, 2013

The real Silicon Valley

On the pathways of silicon on its way to the sea

Everybody knows Silicon Valley, but how many people can tell you about the importance of silicon in nature? One who surely can is Dr Wim Clymans. He is a young post-doctoral scientist at the Geology Department of Lund University in Sweden who dedicates his research to silicon and its biological role. "Silicon is highly underappreciated!" he starts. "People know oxygen, carbon, maybe nitrogen and phosphorus, but hardly anybody has heard of silicon as an important nutrient. Yet, it is vital for plankton in the oceans and other small forms of life in rivers. Silicon forms one of the base components for a well-balanced food system and is, therefore, very relevant," he explains. "Silicon travels from the land to the ocean via rivers and over-land flow in the valleys but, on its way, it can be fixed by vegetation. In our research, we delve deeper into the pathways of silicon on its road to the sea. This is important because, due to human interventions and climatic changes, the supply of silicon from the land to the sea may become distorted and the precious food system in rivers and seas may be altered."

Clymans and his colleagues have monitored several river catchments. In the old Meerdaal Forest in Belgium, for example, they took measurements for three years, equipping the area with devices to monitor the rainfall, the flow in the main stream and the presence of silicon in water samples. They examined this element in more than 800 samples of soil and river water that were collected in the course of this three-year period, which included some storm episodes.

Clymans detected notable differences in the amount of silicon in the stream in winter/spring and in summer/autumn. In a recent paper published in Biogeochemistry, he elucidated the reasons for this variation: "In contrast to larger and less densely forested areas, water stays only a few hours in the stream before it leaves our catchment and the stream is largely shaded. Biological activity in the river is thus low, and so is the uptake of silicon within the river. This led us to conclude that the seasonal variation must be related to processes that occur on the land, and to the connection between the land and the river." Moving the focus to the land, Clymans explains the varying link between the water in the soil around the stream and the stream itself: "In winter and spring, the soil water is in close contact with the stream because the soil is wet. Thus, rain easily drains via the soil to the river. In summer and autumn, the soil is drier and the connection between the soil water and the stream