Wastewater disposal causes sharp rise in central US earthquakes

Nearly 90% of region's quakes now caused by water injected into underground wells.

Alexandra Witze

18 June 2015

Sue Ogrocki/AP

Oklahoma has recorded 70% of the earthquakes to hit the central United States over the past six years.

Two new studies provide the strongest evidence yet that oil and gas companies have caused a rash of earthquakes in the central United States by injecting wastewater into underground wells.

One study, in *Science*, finds that the extraordinary increase in quakes took place almost exclusively within 15 kilometres of such wells[1]. The second, in *Science Advances*, confirms that most seismic activity in one state, Oklahoma, is linked to wells that are used to dispose of huge volumes of saltwater[2].

Both findings are a significant step forward in explaining why earthquake rates have soared in the central United States. In the 1970s, there were no more than 30 magnitude-3 or greater earthquakes per year in the region. That rate accelerated sharply in 2009, reaching more than such 650 quakes last year.

Officials in the affected states, which include Oklahoma, Texas, Arkansas and Ohio, have been debating whether to strengthen regulation of these wells. In March, Kansas began requiring oil and gas operators in two counties that border Oklahoma to slash their injection rates.

The *Science* paper is the most definitive statistical analysis to link earthquakes and injection wells. Earlier research had analysed only single quakes or small groups of quakes. “People had been focused on the smaller picture and not looking at the big picture,” says team leader Matthew Weingarten, a graduate student at the University of Colorado at Boulder.

Aiming for that broader view, he and his colleagues assembled a database of more than 187,000 injection wells across the central and eastern United States, and compared that to data on 7,175 earthquakes that struck the region between 1973 and 2014. If an earthquake happened within 15 kilometres of an operating well, the researchers considered that quake and that well to be linked.

Before 2000, about one-fifth of all earthquakes were associated with injection wells. By 2014, that share rose to 87%. “It’s not just that more earthquakes are happening — more earthquakes are happening preferentially near injection wells,” Weingarten says. And the faster the wells injected fluid into the ground — especially more than 300,000 barrels a month — the more likely they were to be associated with an earthquake.

But the work also reveals places where injection wells are not linked with quakes, such as the Texas Gulf Coast and the Williston basin of North Dakota. Other factors are almost certainly involved, such as how the local geology dictates where fluid flows below ground.

The second paper looks at the seismic hotspot of the central United States — Oklahoma, home to 70% of all the region’s earthquakes in the past six years. “The scale of earthquake triggering in Oklahoma is an order of magnitude greater than these other cases around the country,” says Rall Walsh, a graduate student at Stanford University in California who led the *Science Advances* study.

Most of the quakes are too small to be felt, but others have been large enough to damage homes and businesses. A magnitude-5.6 earthquake in 2011 in Prague, Oklahoma, crumpled turrets on a university building, and seismologists have warned that larger and more damaging tremors are possible.

Walsh and his adviser, geophysicist Mark Zoback, studied three areas in the central and northern part of the state that have seen the biggest rise in quakes. The scientists compared the numbers and locations of earthquakes with injection well locations and disposal rates. All three regions saw earthquake rates rise dramatically as saltwater injections increased as much as tenfold. The work is “more definitive evidence” of the link, says William Ellsworth, a seismologist at the US Geological Survey in Menlo Park, California.

In Oklahoma, the water being put into the ground is mostly salty water that comes up during oil exploration and is then re-injected after the oil has been stripped out. It is not from the controversial practice of hydraulic fracturing, a common public misconception[3].

To retrieve oil and gas, Oklahoma operators use ‘dewatering’ techniques that involve huge amounts of wastewater, more so than many states. They inject fluid deep into a rock layer that sits above ancient basement rock. Walsh and Zoback argue that the injected water increases the pore pressure, which causes faults in the basement rock to slip.

The new work could help drillers to reduce the risk of earthquakes — if they pay attention to how much fluid has been injected in which parts of the state. “The real problem is the total amount of injection coming from all the wells,” Zoback says. “There’s no easy fix by just saying, don’t inject above some certain rate.”

Nature | doi:10.1038/nature.2015.17795

References

1. Weingarten, M., Ge, S., Godt, J. W., Bekins, B. A. & Rubinstein, J. L. *Science* **348**, 1336–1340 (2015).
2. Walsh, F. R. III & Zoback, M. D. *Sci. Adv.* e1500195 (2015).
3. Rubinstein, J. L. & Mahani, A. B. *Seismol. Res. Lett.* http://dx.doi.org/10.1785/0220150067 (2015).