

Fracking's Enhanced Oil and Gas Recovery Means More Earthquakes

Earthquakes, traffic deaths, worker deaths and injuries, low birth weights, increased overall mortality, benzene, methane emissions, drinking water contamination, prostitution, organized crime, and let's not forget gonorrhea; this list reads like the scene sequences of a B horror movie. Yet all these, and more, have been linked, albeit sometimes far from conclusively, to fracking.

Even if there remains some residual uncertainty as to whether fracking narrowly defined causes earthquakes, enhanced methods of oil and gas production most certainly do. Ground zero, so to speak, is Oklahoma. The numbers are startling.

Before 2000, earthquakes greater than magnitude 3.0 on the Richter Scale occurred at a baseline rate of 1.6 per year in the state. By contrast, in 2015, seismologists project over 900. This 500-fold increase in hazard is perhaps unprecedented, leaving in the dust even the increased lung cancer risk from tobacco smoking of 25-fold. By contrast, the increased hazard from common environmental pollutants such as dioxin is typically less than 2-fold.

Here establishing cause and effect is easy, even acknowledging the inevitable uncertainties in the data and their analysis. The increased number of earthquakes is so huge that nit picking the data and their analysis will not change the bottom line. So what if the actual hazard is "only" 100-fold? Worse for the skeptic, he or she here has the burden to answer the additional rather obvious question: If not enhanced oil and gas production, then what?

Oil production in the United States has increased dramatically over the last decade or so. These enhanced production methods involve injecting into wells immense quantities of water

under pressure. This in turn generates considerable underground forces, triggering and causing earthquakes.

Many of the wells causing earthquakes are injection wells, through which massive amounts of water get injected into depleted fields, for the specific purpose of increasing oil and gas recovery. This is like blowing on a straw in a glass of water — pressure applied on one well causes nearby wells to bubble up oil and water.

The remaining wells causing earthquakes dispose of contaminated water from production wells, some of which produce more than five times as much contaminated water as oil, and at least some of which are fracked wells. That contaminated water would be a huge environmental problem, were it to remain on the surface.

Weingarten's and colleagues' *Science* article from earlier this year provides even more detail, as to exactly which wells cause earthquakes. They study two maps of the central and eastern United States. The first shows locations of wells, and their characteristics (e.g., water injection rate, well depth, and geologic characteristics). The second map shows spatial location of earthquakes. Weingarten then asks what kinds of wells are found near earthquakes. He finds that wells injecting more than 300,000 barrels a month are most strongly correlated with earthquakes.

This is a correlation. Typically scientists are unwilling to infer causation from a correlation. So why is this situation different? A half century ago, in studying causes of disease, Bradford Hill laid out some broadly useful criteria for drawing conclusions about cause (here enhanced oil production methods) and effect (here earthquakes).

Going through the Hill criteria, we find close to a clean sweep in favor of



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causation. For starters, the "Strength" of the association is certainly large, what with the 500-fold effect size. "Temporality" is present in that the increased earthquakes follow by just a few years the increased use of enhanced oil and gas production methods. There is a "Dose-Response," since the correlation is strongest for precisely the wells with the highest injection rates. And there is "Plausibility," since the basic laws of physics and geology make it easy to see how injecting massive amounts of water under pressure could lead to forces that might trigger or cause earthquakes. It all fits. And if that is not enough, there are no viable alternative hypotheses.

This is not just a story about earthquakes. It is also about water, massive amounts of contaminated water. The numbers are almost inconceivable. 300,000 barrels of water is 70,000 tons, or over 400 train cars. And that is just what goes down a single injection well under pressure in a month. Weingarten finds over 400 injection wells this size, out of a total of 187,000 studied. And this has been going on for many years.

Humans cause earthquakes when we move massive amounts of water around, and pressurize that water, to extract fossil fuels. We then burn these fossil fuels and change the Earth's climate. This cannot continue. Either humans will proactively change our own civilization, or the Earth's geology and climate will change our civilization for us. •

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