Environmental impacts of shale-gas production

David Kramer, in the July 2011 issue of PHYSICS TODAY (page 23), presented a fairly thorough review of the status and issues associated with the extraction of shale gas in the US. Much is still unknown about the environmental effects of shale-gas production. Eight federal and state government agencies are currently working together to collect baseline data on a future shale-gas drill site in southwestern Pennsylvania, with the intent of monitoring environmental impacts through the drilling and fracturing process and for some time afterward.[1]

Several statements in Kramer's news story are misleading or incorrect. The piece mentions gas industry claims that no case of groundwater contamination caused by hydraulic fracturing (fracking) has ever been documented. In the next paragraph, Anthony Ingraffea of Cornell University is quoted as stating that "thousands of cases" of groundwater contamination due to oil and gas drilling have been documented. Despite requests, Ingraffea has not shared that documentation or published it in the peer-reviewed literature.

Although the two statements regarding groundwater sound contradictory, they are, in fact, two separate issues. In most instances, fracking takes place at such great depths that it is highly unlikely to affect shallow aquifers in any way. Detailed microseismic data in both the Marcellus and Barnett shales[2] showed that none of the induced fractures in the shales approached within several thousand vertical feet of the deepest freshwater aquifers overlying them. On the other hand, a surface spill of fracturing fluid, followed by ground infiltration and percolation down to an aquifer used for drinking water, is a much more likely contamination route. Indeed, that is how many common contaminants—from gasoline additives to agricultural fertilizers—have entered the groundwater.

The Kramer account also overstates that Marcellus shale fracking operators must find the means to dispose of up to 7 million gallons of wastewater generated per well. Drillers typically use 3 million to 5 million gallons of water to frac a multistage well, and only about a quarter to a third of that total volume of water is recovered. Because of higher disposal costs under new regulations, flowback is now essentially 100% recycled into the next well as a standard practice. After the final frac treatment, the recycled water is injected down a separate disposal well, as stated in the article.

The issue of methane in groundwater requires much more data and analysis before any conclusions can be drawn. Each case probably has unique circumstances and requires a forensic-type investigation to determine the source of the gas and the route by which it may have migrated into a domestic water well. The Duke University study[3] Kramer cites suffers from several flaws, including a lack of predrilling baseline data and no assessment of the local geology or hydrology. Alternative explanations, such as gas migration from shallow bedrock into aquifers, were not explored.

It is important for the scientific and regulatory communities to focus on protecting water resources, air quality, habitat, and ecosystems during shale-gas production. Objective data are needed to update state oil and gas regulations, identify environmental concerns, and define mitigation strategies for the production of this important resource. Misleading or inaccurate statements do little except shift focus away from the real problems and needlessly worry the public.

References

1. For a summary and details of the study, see D. J. Soeder, *Eos Trans. Am. Geophys. Union* **91**(32), 277 (2010).
2. K. Fisher, *American Oil and Gas Reporter* **53**(7), 30 (2010).
3. S. G. Osborn, A. Vengosh, N. R. Warner, R. B. Jackson, *Proc. Natl. Acad. Sci. USA* **108**, 8172 (2011).

Daniel J. Soeder
(daniel.soeder@netl.doe.gov)
US Department of Energy
Morgantown, West Virginia

David Kramer's news item was informative and enlightening regarding the environmental impact of shale-gas hydraulic fracturing (fracking). There is yet another environmental impact not mentioned: mining of the sand that is needed for fracking. In the past few years, energy companies have been leasing or purchasing land that holds the 500-million-year-old Jordan sandstone formation stretching across Minnesota and Wisconsin, beneath woodland, farmland, and bluffs. The silica sand from that formation is ideal for fracking. One company, Gulfport Energy, has access to 20 million tons of it.

At least three environmental problems attend the mining of sand from the Jordan formation. First, the topography of the land will be changed forever; the bluffs will be gone. Second, the dust from silica sand causes a variety of lung diseases, including cancer. Third, large trucks continually transporting the sand to wells in Texas and elsewhere will negatively affect the natural beauty and serenity of the area.

Sand mining is generally not well regulated at the state or federal level. Local citizens, cities, and counties have been questioning and opposing the massive mining operations, but city and county governments simply do not have the financial resources to contest the actions of large energy companies. Interested readers should see "Silica sand is the new gold" by Josephine Marcotty for the *Star Tribune*, online at http://www.startribune.com/local/123670439.html.

Joseph Kapusta
(kapusta@umn.edu)
University of Minnesota
Minneapolis

Fluid dynamics and Pollock's paint applicators

Authors Andrzej Herczyński, Claude Cernuschi, and L. Mahadevan ("Painting with drops, jets, and sheets," PHYSICS TODAY, June 2011, page 31) describe Jackson Pollock's painting technique and purport to explain the physics underlying the flow of paint by scaling relations, given in their equations 1, 2, and 3. Their scaling relations, however, are for a Newtonian viscous fluid, for which the shear rate is proportional to the shear stress. But paint is a complex non-Newtonian fluid that does not satisfy this linearity requirement.[1] Experiments with a cylindrical wooden rod initially dipped into a container of ordinary wall paint can readily show that the scaling relations do not conform with observations.

For a video showing the formation and shape of Pollock's paint jet, see http://www.youtube.com/watch?v=ajZCjlxv7GI. Observe that the shape of an actual jet does not conform with the theoretical shape shown in figure 4b of the article, because the authors drew the figure without taking into account that paint also is an incompressible fluid. This property implies that the initial radius of the jet is smaller than the radius of the rod, as observed in the video, instead of larger, as shown in figure 4b.

Reference

1. V. N. Constantinescu, *Laminar Viscous Flow*, Springer, New York (1995), p. 26.

Michael Nauenberg
(michael@physics.ucsc.edu)
University of California, Santa Cruz

My compliments to authors Andrzej Herczyński, Claude Cernuschi, and L. Mahadevan on their quantitative analysis of Jackson Pollock's painting technique. The article offers welcome insights into his creative process and artistic achievements. I was especially pleased that the authors explained why the term "drip painting," commonly used to characterize his preferred method of deploying viscous material, is both incorrect and misleading.

I was somewhat puzzled, however, by the authors' choice of the word "trowel" to describe Pollock's favorite paint applicator and by their use of it interchangeably with "rod" and "stick." He did mention using a trowel, but he generally applied fluid paint with hardened brushes—he said he used them "more as sticks rather than brushes." Surely a trowel (from the Latin *trulla*, meaning "ladle") would hold much more paint than a rod or stick. The authors failed to note that Pollock also painted with flexible, soft-bristle brushes, from which the material flowed very differently than it would from a stiff stick or hardened brush. Even more curious, they never mentioned his well-known use of basting syringes, which dispense a lot more paint than do either sticks or brushes and therefore give a much longer line; they also produce squirts that have their own kind of trajectories and velocities.

Examples of Pollock's paint applicators are preserved and displayed at the Pollock-Krasner House and Study Center (http://www.pkhouse.org) in East Hampton, New York. The artist's former home and studio, it now belongs to Stony Brook University. The collection also includes many still photographs and three motion pictures that show Pollock using the tools and materials in question. I think the authors would have benefited from examining those resources at the museum, where the paint-covered floor of Pollock's studio vividly testifies to the variety and dynamic character of his technical innovations.

Helen A. Harrison
(helen.harrison@stonybrook.edu)
Pollock-Krasner House and Study Center
East Hampton, New York

Herczyński, Cernuschi, and Mahadevan reply: Since our primary aim was to invite readers to consider very simply the physics of pouring paint, we modeled paint as a Newtonian liquid. That model, as Michael Nauenberg writes, assumes a linear relation between the stress and the strain rate. Paint, a suspension of pigments and polymers in a solvent, may indeed exhibit nonlinear rheological characteristics. Taking that into account would lead to slightly different relationships than those we propose, but many of the qualitative features—for example, the coiling patterns on the substrate—would remain the same. However, effects due to elastic stresses, surface-tension gradients during drying, and so forth are not included in our description. We should have clearly noted the caveats of our minimal approach but are glad to have the opportunity to do so now.

Nauenberg also claims that our qualitative sketch of a thinning paint stream is inconsistent with observations. In fact, the shape of a draw-down jet is controlled by the competition between viscous and gravitational forces via the dimensionless parameter $\mu^2/\rho^2 g R^3$, where R is the radius of the jet at its origin, μ is the viscosity, ρ is the density, and g is the acceleration due to gravity. For highly viscous paints, the parameter is large, and thinning would be relatively gradual as a result.

Helen Harrison is correct to point to Jackson Pollock's wide range of implements, such as brushes of different bristle types and basting syringes. The artist kept experimenting and exploited many other techniques, even occasionally imprinting the canvas with his