Managing Air Quality Issues Associated With Hydraulic Fracturing

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Background

The use of hydraulic fracturing, also referred to as “fracking” or “fracing,” by the oil and natural gas industries to extract oil and natural gas has been expanding in recent years. The process involves injecting a mixture of sand, water, and various chemicals under extremely high pressure deep into shale deposits or other rock formations. This process facilitates the fracturing of these rock formations, which allows the release of oil or natural gas. Emissions of air toxics, some of which are classified as hazardous air pollutants (HAP), as well as volatile organic compounds (VOC) and methane, may occur as a result of this process.

Recent public hearings conducted by the U.S. Environmental Protection Agency (EPA) regarding their proposed emissions control regulations for the oil and gas industry provided a forum for concerned parties to express concerns regarding emissions of air pollutants from activities related to fracking. The proposed EPA regulations are scheduled for implementation by April 3, 2012, and are designed to reduce emissions of HAP, VOC, and methane, as well as other pollutants such as sulfur dioxide (SO₂) and nitrogen oxides (NOₓ). Some individual states are also in various stages of imposing regulatory requirements on fracking activities.

The Issues

There are several important air quality concerns that may be associated with fracking and related activities. These include:

• Possible increases in regional ozone formation due to the release of VOC and NOₓ.
• Near-field air quality impacts and potential health risks due to the release of air toxics and other pollutants.
• Local odor problems due to the release of hydrogen sulfide (H₂S).
• Long-term impacts on global warming due to the release of methane, a greenhouse gas.
Various air pollutants may be emitted from certain activities related to fracking, such as well completion, flaring, and the operation of compressors. During the process of well completion, a mixture of VOC and methane, as well as air toxics such as benzene, ethylbenzene, and n-hexane, can flow to the surface at high velocity and be released to the atmosphere. This phenomenon, known as flowback, can last from 3 to 10 days.

EPA has proposed new regulations designed to help control and manage the environmental impacts due to fracking performed by the oil and gas industry. Under the terms of a modified consent order, the final regulations are now scheduled to be implemented by April 3, 2012. The proposed regulations include New Source Performance Standards (NSPS) and National Emission Standards for Hazardous Air Pollutants (NESHAP) for various oil and natural gas operations.

The proposed NSPS regulations would extend current emission control requirements that apply to natural gas processing plants to a wider range of emission points. The proposed NSPS regulations would require reductions of VOC emissions from:

- New hydraulically fractured natural gas wells
- Re-completions of existing natural gas wells that are fractured or re-fractured
- Pneumatic controllers
- Compressors
- Condensate and crude storage tanks
- Natural gas processing plants.

The proposed rules would require a combination of green completion and flaring for most fractured wells. The proposed NSPS regulations would also require additional SO₂ emissions reductions at those natural gas processing plants with the highest H₂S content.

These proposed regulations are intended to reduce VOC emissions by about 25 percent from the oil and natural gas industry, including a nearly 95 percent reduction of VOC emissions from new and modified hydraulically fractured gas wells. EPA believes that these emissions reduction will be achieved largely through the implementation of existing technology to capture natural gas that is currently released to the atmosphere.

EPA conducted separate technology reviews and residual risk assessments to support the proposed NESHAP regulations that would apply to the following two categories: (1) oil and natural gas production and (2) natural gas transmission and storage. The proposed NESHAP changes will mostly affect benzene emission control requirements at certain glycol dehydrators and would impose air toxics control requirements on crude oil and condensate tanks at major HAP sources.

EPA’s risk assessments considered actual and potential emissions from major sources in these two industrial sectors. For oil and gas production, EPA concluded that although risks from actual emissions are acceptable, potential risks from currently allowable emissions were not acceptable. EPA proposed reductions in allowable air toxics emissions to lower the potential risks. For natural gas transmission and storage, EPA concluded that the risk from air toxics emissions was acceptable but proposed reductions in emissions to lower the associated risk.

EPA’s risk assessment analyses and the resulting conclusions are subject to uncertainties related to the accuracy of the emissions data that are used, the dispersion modeling techniques and assumptions, and the dose-response relationships that are incorporated. EPA used emissions data based on actual 2005 emissions from the National Emissions Inventory (NEI) that had been developed for the 2005 National-Scale Air Toxics Assessment (NATA). Although the NEI data were reviewed and supplemented with data from industry when available, EPA acknowledges in its draft risk assessment that the uncertainties in its emission inventory likely dominate the uncertainties in its exposure...
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modeling estimates. Some of the uncertainties regarding emissions include the use of assumed HAP-specific VOC ratios for approximately 75% of the facilities for which no HAP emissions were available in NEI. The short-term screening analyses to estimate maximum individual risk assumed a ratio of 10 between peak short-term and average annual emission rates. This assumption likely overstates the individual short-term risk for many facilities.

Public comments at the EPA hearings included concerns about potential health effects related to emissions of air pollutants from fracking. Some testimony claimed significant air quality impacts at nearby residences, schools, hospitals, and other sensitive areas due to emissions from the wells. Some individuals complained of severe odor problems due to emissions of H2S, while others expressed concerns related to air toxics emissions. Several citizens referenced health problems that they believe are due to emissions of air toxics from the wells, from flaring, and from the burning off of holding ponds. While some supported the proposed regulations as a way of allowing fracking to continue while managing its environmental impacts, others want fracking to be banned due to its potential associated health effects. Comments from industry representatives were mixed, with some supporting the proposed regulations but requesting additional time for implementation and compliance and others opposing the regulations due to associated costs and other concerns. Some industry testimony asserted that EPA’s emissions estimates for well completions were significantly overestimated, meaning that the validity of the cost benefits presented for green completions could be overstated.

These issues have important implications for the natural gas and oil industry beyond the costs that will be associated with complying with the proposed requirements. Even if the industry fully complies with the final regulations when implemented, there is a possibility of subsequent claims related to air pollutant emissions and possible health effects. The risk assessment methodology used by EPA may not accurately characterize the actual emissions and associated health risk for any individual facility or operation. Having a more complete understanding of air emissions associated with fracking and their potential air and health impacts in the area surrounding these operations would provide a framework for more accurately assessing potential risks and for addressing potential litigation.

The Technical Approach

Industry can quantify the air quality impacts of emissions related to fracking and help put them into some context using a variety of means. Approaches can include dispersion modeling, emissions estimates, monitoring studies or assessments, and health risk assessments.

Dispersion modeling studies can provide spatial and temporal estimates of pollutant concentrations over large areas, taking into account meteorology, land use, and topography. Dispersion modeling can also be used to assess the contributions of various emission sources to predicted ambient concentrations. In addition, these modeling tools can be used to test various operational and control technology scenarios and to assess the associated air quality impacts. Dispersion modeling can also predict impacts, which can then be incorporated in health risk assessments.

Atmospheric dispersion models can be used to predict impacts of gaseous and particulate emissions. Photochemical models can be used to assess the impact of fracking-induced emissions on regional ozone. The Community Multi-Scale Air Quality (CMAQ) modeling system and the CAMx model are both three-dimensional eulerian atmospheric chemistry and transport models that can simulate the dispersion of particulate and gaseous pollutants. Both models can simulate photochemical processes and the evolution of ozone in the atmosphere and can be applied at scales ranging from suburban to continental.

The CALPUFF dispersion model is a variable-trajectory puff model that is capable of simulating the transport, dispersion, transformation, and deposition of emissions from a complex array of sources, including volume and
area sources, point sources (i.e., stacks or vents), and emissions from flares. AERMOD\(^5\) is a simpler steady-state model that can be used to estimate near-field impacts for a wide variety of source types.

Computational fluid dynamics (CFD) modeling may also be useful to represent complex flow conditions due to high-temperature flares or around facility structures. In the near field, interaction of the wind field with buildings or structures can cause high concentrations of pollutants, which may result in a health risk, an odor problem, or a significant risk of explosion. Some released gases may be heavier than air and may settle and cause high concentrations in low-lying areas on or near a facility. CFD modeling can also be used to characterize the near-field behavior of complex emission sources, so they can be coupled to a longer range dispersion model such as CALPUFF or AERMOD.

A real-time air quality forecast system can also be developed to detect periods when meteorological conditions could lead to high ambient concentrations of air toxics or other pollutants emitted during the fracking operations. The key to the warning system is to use real-time, gridded meteorological forecast fields issued by the National Centers for Environmental Prediction (NCEP) as a driver for the CALPUFF dispersion modeling system. The CALPUFF system can then use these predicted meteorological fields to predict the concentration field around a site. Such forecasts can then be used to modify operations to minimize air quality impacts to the surrounding communities.

Monitoring studies can be source oriented, with the aim of characterizing the nature and magnitude of air pollutant releases. Monitoring studies can also be oriented toward estimating or measuring existing ambient levels of pollutants and can involve the measurement of pollutant levels or the review of existing monitoring data.

Emissions estimates may be based on measurements, mass balance considerations, emission factors, or scientific or engineering calculations. Improved emissions estimates for fracking operations can lead to more accurate estimates of source impacts and associated risks.

Risk assessments can be used to evaluate exposure to hazardous air pollutants due to fracking operations. The scope of the risk assessment can be limited to single risk estimates, typically for a highly exposed individual within a population (deterministic risk assessment), or can be expanded to risk estimates across the full distribution of the exposed population (i.e., probabilistic risk assessment).

[CFD model vertical cross-section view of CO\(_2\) concentration due to emissions from flare pits]
Exponent’s Expertise

The Atmospheric Sciences staff at Exponent provides consulting services in air quality and atmospheric sciences. Our staff specializes in air quality and meteorological modeling, permitting, and licensing. They investigate routine or accidental releases of chemicals to the atmosphere, simulate transport and fate of chemical substances, and develop measures of prevention and control, such as emergency preparedness and response. Areas of air quality modeling include industrial plumes, dense gases, photochemical reactions, mobile sources, forest fires, explosions, radioactive releases, and odors.

Clients benefit from our multidisciplinary approach, which includes the support of staff across multiple practice areas. Our atmospheric scientists work closely with chemical engineers, combustion specialists, and thermal and process engineers to predict and evaluate the release and dispersion of air emissions.

Exponent scientists have participated in the original development of or contributed to five of the seven U.S. EPA models recommended in the Guideline on Air Quality Models. Most notable of these is the CALPUFF model, an advanced non-steady-state meteorological and air quality modeling system recommended by the EPA as the preferred model for assessing long-range transport of pollutants or for near-field applications involving complex meteorological conditions. Other EPA-recommended models that bear the imprint of the Atmospheric Sciences staff include the Buoyant Line and Point (BLP) source model commonly used for aluminum reduction facilities, the Offshore and Coastal Dispersion (OCD) model for emission sources in offshore or shoreline locations, and the Complex Terrain Dispersion Model (CTDM). Our staff also developed the PRIME building downwash model that is incorporated into the CALPUFF and AERMOD models. Additionally, they have designed and implemented several real-time air quality forecast systems to help manage air quality impacts due to industrial or mining operations.

The Atmospheric Sciences staff has worked extensively with the OpenFOAM®, and ANSYS FLUENT® CFD models to characterize source terms and simulate complex flows over building structures or other obstacles. Our staff also works closely with Exponent’s Thermal Sciences staff to address emissions and dispersion of pollutants from flaring using the STAR-CCM+® CFD model from CD-Adapco.

Exponent scientists and engineers have expertise in both emissions and ambient air monitoring and can assist clients with planning, implementing, and managing monitoring studies. Exponent is familiar with the latest measurement techniques to quantify gaseous and particulate air pollutants, both on the ground and at the source. We are frequently called upon to investigate unusual atmospheric releases of chemicals, assess air pollution risks, simulate transport and fate of chemical substances, or develop measures of prevention and control, such as emergency preparedness and response. We have conducted air quality analyses in locations throughout the U.S. and internationally, including desert, tropical, temperate, and arctic environments, and have communicated our analytical results effectively to the general public, regulatory bodies, and in courts of law.

Exponent scientists and engineers are highly knowledgeable in risk assessment methodologies and related analyses that are critical components of many environmental regulatory decisions and are frequently used in litigation.
References


About Exponent Health Sciences

Exponent is a leading engineering and scientific consulting firm dedicated to providing solutions to complex problems. Exponent has one of the foremost health sciences consulting practices in the United States. Our scientists, physicians, and regulatory specialists evaluate a full range of environmental and public health issues, including potential health effects associated with environmental agents, chemicals, consumer products, food safety and nutrition, and pharmaceutical products. Our clients rely on us for incisive and objective assessments that address physical, chemical, and biological phenomena in order to arrive at solutions that can be relied upon to make important decisions. In addition, Exponent performs research and analysis in more than 90 science-and engineering-related technical disciplines.

More information about our Health practice, as well as our other capabilities, can be found at www.exponent.com.

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