Hydraulic Fracturing 2.0

The Sept. 18 tour will take us in and around Midland-Odessa and presumes a basic understanding of hydraulic fracturing. This primer includes citations to both scientific studies and journalistic work. Even if you have reported on the topic before, you will find that if you become familiar with the topics in this primer you will be better prepared for the day.

Overview

This 47-minute video introduces HF and its chemicals, including some data and analyses. It was partially funded by the EPA and produced by The Endocrine Disruption Exchange.

http://www.endocrinedisruption.com/chemicals.video.php

The American Petroleum Institute also has an introductory video on their HF resource page.

http://www.api.org/Policy-and-Issues/HF.aspx
http://www.api.org/oil-and-natural-gas-overview/exploration-and-production/hydraulic-fracturing/hydraulic-fracturing-safe-oil-natural-gas-extraction.aspx

Chemical Usage

Some disclosure is occurring on www.fracfocus.org, as required by Texas state law and other states.

Bloomberg reported on the limits of reporting on fracfocus.
http://www.bloomberg.com/news/2012-08-14/fracking-hazards-obscured-in-failure-to-disclose-wells.html

The Endocrine Disruption Exchange cross-referenced chemicals found in drilling pits with health effects (in other words, an in-depth look in one limited area)
http://www.endocrinedisruption.com/chemicals.pits.php

Health effects

There has been some study of health impacts of unconventional gas mining published recently. Abstracts included with citations -- if you want more, often your local library can help you secure the full article without cost.

Colborn, T.; Kwiatkowski, C.; Schultz, K., and Bachran, M. *Natural gas operations from a public health perspective.* Human & Ecological Risk Assessment. 2011; 17(5):1039-1056.
Abstract
The technology to recover natural gas depends on undisclosed types and amounts of toxic chemicals. A list of 944 products containing 632 chemicals used during natural gas operations was compiled. Literature searches were conducted to determine potential health effects of the 353 chemicals identified by Chemical Abstract Service (CAS) numbers. More than 75% of the chemicals could affect the skin, eyes, and other sensory organs, and the respiratory and gastrointestinal systems. Approximately 40-50% could affect the brain/nervous system, immune and cardiovascular systems, and the kidneys; 37% could affect the endocrine system; and 25% could cause cancer and mutations. These results indicate that many chemicals used

during the fracturing and drilling stages of gas operations may have long-term health effects that are not immediately expressed. In addition, an example was provided of waste evaporation pit residuals that contained numerous chemicals on the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and Emergency Planning and Community Right to Know Act (EPCRA) lists of hazardous substances. The discussion highlights the difficulty of developing effective water quality monitoring programs. To protect public health we recommend full disclosure of the contents of all products, extensive air and water monitoring, coordinated environmental/human health studies, and regulation of fracturing under the U.S. Safe Drinking Water Act.

McKenzie, Witter, Newman, Adgate. *Human health risk assessment of air emissions from development of unconventional natural gas resources*, in Science of the Total Environment, May 2012, Vol. 424, p. 79-87
Abstract: Background: Technological advances (e.g. directional drilling, hydraulic fracturing), have led to increases in unconventional natural gas development (NGD), raising questions about health impacts. Objectives: We estimated health risks for exposures to air emissions from a NGD project in Garfield County, Colorado with the objective of supporting risk prevention recommendations in a health impact assessment (HIA). Methods: We used EPA guidance to estimate chronic and subchronic non-cancer hazard indices and cancer risks from exposure to hydrocarbons for two populations: (1) residents living >½mile from wells and (2) residents living ≤½mile from wells. Results: Residents living ≤½mile from wells are at greater risk for health effects from NGD than are residents living >½mile from wells.Subchronic exposures to air pollutants during well completion activities present the greatest potential for health effects. The subchronic non-cancer hazard index (HI) of 5 for residents ≤½mile from wells was driven primarily by exposure to trimethylbenzenes, xylenes, and aliphatic hydrocarbons. Chronic HIs were 1 and 0.4. for residents ≤½mile from wells and >½mile from wells, respectively. Cumulative cancer risks were 10 in a million and 6 in a million for residents living ≤½mile and >½mile from wells, respectively, with benzene as the major contributor to the risk. Conclusions: Risk assessment can be used in HIAs to direct health risk prevention strategies. Risk management approaches should focus on reducing exposures to emissions during well completions. These preliminary results indicate thathealth effects resulting from air emissions during unconventional NGD warrant further study. Prospective studies should focus on health effects associated with air pollution. [Copyright: Elsevier]

Also, the Colorado School of Public Health was commissioned to perform a health impact assessment for Garfield County. Here is the second draft of that controversial document:

http://www.garfield-county.com/public-health/documents/19_HIA_2nd_draft_appendix-d.pdf

Water usage and disposal

Usage. Congress ordered the EPA to re-visit hydraulic fracturing and bring its findings back. The draft is due out later this year. The agency has opted to study effects on water through the entire production cycle.
http://www.epa.gov/hfstudy/

A New York Times investigation into drilling wastewater found it is sometimes hauled to sewage plants not designed to treat it and then discharged into rivers that supply drinking water, contains radioactivity at levels higher than previously known, and far higher than the level that

federal regulators say is safe for these treatment plants to handle.
http://www.nytimes.com/2011/02/27/us/27gas.html?ref=drillingdown&_r=0

Injection. Produced water is sometimes injected to enhance recovery, so its important to make the distinction between "disposal" and injection when talking to industry and regulators before you report.
The Columbus Dispatch has a nice graphic on how it works.
http://www.dispatch.com/content/topic/news/2011/How-an-injection-well-works.html

Environmental Protection Agency regulates underground injection, or delegates it to the states. This page explains the process and its regulation.
http://water.epa.gov/type/groundwater/uic/index.cfm

A new story in ProPublica shows injection wells used to dispose of the nation's most toxic waste are showing increasing signs of stress as regulatory oversight falls short and scientific assumptions prove flawed.
http://www.propublica.org/article/trillion-gallon-loophole-lax-rules-for-drillers-that-inject-pollutants

Researchers are investigating scores of technologies that could help with water conservation in hydraulic fracturing. Keep up with the latest at this website: http://barnettshalewater.org/reports.html

Earthquakes

The U.S. Geological Survey has been examining the connection between deep waste water injection wells, used to dispose of the waste water from shale gas drilling and production, and earthquakes.

Here is the citation for a major study that came out with conference proceedings earlier this summer. The study is not yet published.

Ellsworth, W. L., US Geological Survey, Menlo Park, CA; Hickman, S. H., US Geological Survey, Menlo Park, CA; Lleons, A. L., US Geological Survey, Menlo Park, CA; McGarr, A., US Geological Survey, Menlo Park, CA; Michael, A. J., US Geological Survey, Menlo Park, CA; Rubinstein, J. L., US Geological Survey, Menlo Park, CA. *Are seismicity rate changes in the midcontinent natural or manmade?*
Abstract A remarkable increase in the rate of M 3 and greater earthquakes is currently in progress in the US midcontinent. The average number of M >= 3 earthquakes/year increased starting in 2001, culminating in a six-fold increase over 20th century levels in 2011. Is this increase natural or manmade? To address this question, we take a regional approach to explore changes in the rate of earthquake occurrence in the midcontinent (defined here as 85° to 108° West, 25° to 50° North) using the USGS Preliminary Determination of Epicenters and National Seismic Hazard Map catalogs. These catalogs appear to be complete for M >= 3 since 1970. From 1970 through 2000, the rate of M >= 3 events averaged 21 +- 7.6/year in the entire region. This rate increased to 29 +- 3.5 from 2001 through 2008. In 2009, 2010 and 2011, 50, 87 and 134 events occurred, respectively. The modest increase that began in 2001 is due to increased seismicity in the coal bed methane field of the Raton Basin along the Colorado-New Mexico border west of Trinidad, CO. The acceleration in activity that began in 2009 appears to involve a combination of source regions of oil and gas production, including the Guy, Arkansas region, and in central and southern Oklahoma. Horton, et al. (2012) provided strong evidence linking

the Guy, AR activity to deep waste water injection wells. In Oklahoma, the rate of M >= 3 events abruptly increased in 2009 from 1.2/year in the previous half-century to over 25/year. This rate increase is exclusive of the November 2011 M 5.6 earthquake and its aftershocks. A naturally-occurring rate change of this magnitude is unprecedented outside of volcanic settings or in the absence of a main shock, of which there were neither in this region. While the seismicity rate changes described here are almost certainly manmade, it remains to be determined how they are related to either changes in extraction methodologies or the rate of oil and gas production.

An earlier USGS paper, available through open file, also made a connection between HF and earthquakes.
http://www.ogs.ou.edu/pubsscanned/openfile/OF1_2011.pdf

Air quality

Eduardo P. Olaguer, *The potential near-source ozone impacts of upstream oil and gas industry emissions.* Journal of the Air & Waste Management Association, Vol. 62, Issue 8, 2012, p. 966-977 http://www.tandfonline.com/doi/abs/10.1080/10962247.2012.688923 Abstract Increased drilling in urban areas overlying shale formations and its potential impact on human health through decreased air quality make it important to estimate the contribution of oil and gas activities to photochemical smog. Flares and compressor engines used in natural gas operations, for example, are large sources not only of NOx but also of formaldehyde, a hazardous air pollutant and powerful ozone precursor. We used a neighborhood scale (200 m horizontal resolution) three-dimensional (3D) air dispersion model with an appropriate chemical mechanism to simulate ozone formation in the vicinity of a hypothetical natural gas processing facility, based on accepted estimates of both regular and nonroutine emissions. The model predicts that, under average midday conditions in June, regular emissions mostly associated with compressor engines may increase ambient ozone in the Barnett Shale by more than 3 ppb beginning at about 2 km downwind of the facility, assuming there are no other major sources of ozone precursors. Flare volumes of 100,000 cubic meters per hour of natural gas over a period of 2 hr can also add over 3 ppb to peak 1-hr ozone somewhat further (>8 km) downwind, once dilution overcomes ozone titration and inhibition by large flare emissions of NOx. The additional peak ozone from the hypothetical flare can briefly exceed 10 ppb about 16 km downwind. The enhancements of ambient ozone predicted by the model are significant, given that ozone control strategy widths are of the order of a few parts per billion. Degrading the horizontal resolution of the model to 1 km spuriously enhances the simulated ozone increases by reducing the effectiveness of ozone inhibition and titration due to artificial plume dilution. Implications: Major metropolitan areas in or near shale formations will be hard pressed to demonstrate future attainment of the federal ozone standard, unless significant controls are placed on emissions from increased oil and gas exploration and production. The results presented here show the importance of improving the temporal and spatial resolution of both emission inventories and air quality models used in ozone attainment demonstrations for areas with significant oil and gas activities.

Petron, et al, *Hydrocarbon emissions characterization in the Colorado Front Range: A pilot study,* Journal of Geophysical Research, Vol. 117, D04304, 19 pp., 2012
Abstract The multispecies analysis of daily air samples collected at the NOAA Boulder Atmospheric Observatory (BAO) in Weld County in northeastern Colorado since 2007 shows highly correlated alkane enhancements caused by a regionally distributed mix of sources in the Denver-Julesburg Basin. To further characterize the emissions of methane and non-methane hydrocarbons (propane, n-butane, i-pentane, n-pentane and benzene) around BAO, a pilot

study involving automobile-based surveys was carried out during the summer of 2008. A mix of venting emissions (leaks) of raw natural gas and flashing emissions from condensate storage tanks can explain the alkane ratios we observe in air masses impacted by oil and gas operations in northeastern Colorado. Using the WRAP Phase III inventory of total volatile organic compound (VOC) emissions from oil and gas exploration, production and processing, together with flashing and venting emission speciation profiles provided by State agencies or the oil and gas industry, we derive a range of bottom-up speciated emissions for Weld County in 2008. We use the observed ambient molar ratios and flashing and venting emissions data to calculate top-down scenarios for the amount of natural gas leaked to the atmosphere and the associated methane and non-methane emissions. Our analysis suggests that the emissions of the species we measured are most likely underestimated in current inventories and that the uncertainties attached to these estimates can be as high as a factor of two.

Armendariz, Al. *Emissions from natural gas production in the Barnett Shale area and opportunities for cost-effective improvement*.
http://www.edf.org/sites/default/files/9235_Barnett_Shale_Report.pdf

Howarth, Santoro, Ingraffea. *Methane and the greenhouse gas footprint of natural gas from shale formations*. Climatic Change Lett. 2011, 106 (4), 679-690
Abstract We evaluate the greenhouse gas footprint of natural gas obtained by high- volume hydraulic fracturing from shale formations, focusing on methane emissions. Natural gas is composed largely of methane, and 3.6% to 7.9% of the methane from shale-gas production escapes to the atmosphere in venting and leaks over the life- time of a well. These methane emissions are at least 30% more than and perhaps more than twice as great as those from conventional gas. The higher emissions from shale gas occur at the time wells are hydraulically fractured—as methane escapes from flow-back return fluids—and during drill out following the fracturing. Methane is a powerful greenhouse gas, with a global warming potential that is far greater than that of carbon dioxide, particularly over the time horizon of the first few decades following emission. Methane contributes substantially to the greenhouse gas footprint of shale gas on shorter time scales, dominating it on a 20-year time horizon. The footprint for shale gas is greater than that for conventional gas or oil when viewed on any time horizon, but particularly so over 20 years. Compared to coal, the footprint of shale gas is at least 20% greater and perhaps more than twice as great on the 20-year horizon and is comparable when compared over 100 years.

Soil quality

Drilling solids are often spread on farmland, a bio-remediation technique called “landfarming” More information from the EPA here: http://www.epa.gov/oust/pubs/tum_ch5.pdf

Adams, Mary Beth *Land application of hydrofracking fluids damages a deciduous forest stand in West Virgina*. Journal of Environmental Quality 40:1340-1344 (2011)
Abstract In June 2008, 303,000 L of hydrofracturing fluid from a natural gas well were applied to a 0.20-ha area of mixed hardwood forest on the Fernow Experimental Forest, West Virginia. During application, severe damage and mortality of ground vegetation was observed, followed about 10 d later by premature leaf drop by the overstory trees. Two years after fluid application, 56% of the trees within the fluid application area were dead. *Fagus grandifolia*Ehrh. was the tree species with the highest mortality, and *Acer rubrum* L. was the least affected, although all tree species present on the site showed damage symptoms and mortality. Surface soils (0–10 cm) were sampled in July and October 2008, June and October 2009, and May 2010 on the fluid application area and an adjacent reference area to evaluate the effects of the hydrofracturing fluid on soil chemistry and to attempt to identify the main

chemical constituents of the hydrofracturing fluid. Surface soil concentrations of sodium and chloride increased 50-fold as a result of the land application of hydrofracturing fluids and declined over time. Soil acidity in the fluid application area declined with time, perhaps from altered organic matter cycling. This case study identifies the need for further research to help understand the nature and the environmental impacts of hydrofracturing fluids to devise optimal, safe disposal strategies.

E.T. Slonecker, L.E. Milheim, C.M. Roig-Silva, A.R. Malizia, D.A. Marr, and G.B. Fisher, *Landscape Consequences of Natural Gas Extraction in Bradford and Washington Counties, Pennsylvania, 2004–2010 (This is a USGS open file. Download it here: http://pubs.usgs.gov/of/2012/1154/)*

Abstract Increased demands for cleaner burning energy, coupled with the relatively recent technological advances in accessing unconventional hydrocarbon-rich geologic formations, led to an intense effort to find and extract natural gas from various underground sources around the country. One of these sources, the Marcellus Shale, located in the Allegheny Plateau, is undergoing extensive drilling and production. The technology used to extract gas in the Marcellus Shale is known as hydraulic fracturing and has garnered much attention because of its use of large amounts of fresh water, its use of proprietary fluids for the hydraulic-fracturing process, its potential to release contaminants into the environment, and its potential effect on water resources. Nonetheless, development of natural gas extraction wells in the Marcellus Shale is only part of the overall natural gas story in the area of Pennsylvania. Coalbed methane, which is sometimes extracted using the same technique, is often located in the same general area as the Marcellus Shale and is frequently developed in clusters across the landscape. The combined effects of these two natural gas extraction methods create potentially serious patterns of disturbance on the landscape. This document quantifies the landscape changes and consequences of natural gas extraction for Bradford County and Washington County, Pennsylvania, between 2004 and 2010. Patterns of landscape disturbance related to natural gas extraction activities were collected and digitized using National Agriculture Imagery Program (NAIP) imagery for 2004, 2005/2006, 2008, and 2010. The disturbance patterns were then used to measure changes in land cover and land use using the National Land Cover Database (NLCD) of 2001. A series of landscape metrics is used to quantify these changes and are included in this publication.

Pipelines

American Petroleum Institute's video on the pipeline control room operations
http://www.api.org/oil-and-natural-gas-overview/transporting-oil-and-natural-gas/pipeline/pipeline-video.aspx

Battle lines series, Philadelphia Inquirer.
The Marcellus shale drilling boom has tapped a bounty of natural gas worth billions, but Inquirer reporters Joseph Tanfani and Craig R. McCoy found that thousands of miles of high-pressure pipelines carrying the gas to market are being installed with no government safety checks – no construction standards, no inspections, and no monitoring. In fact, state and federal regulators don't even know where many lines are located
http://www.philly.com/philly/news/special_packages/inquirer/marcellus-shale/134705168.html

Neighborhood and landowner impacts

Oil and Gas At Your Door. A guidebook prepared by the Oil and Gas Accountability project for property owners. Download a free pdf version here: http://www.earthworksaction.org/files/publications/LOguide2005book.pdf

The *Fort Worth League of Neighborhood Associations* received a $48,000 technical assistance grant from the U.S. Dept. of Transportation, Pipeline and Hazardous Materials Safety Administration to examine the number of pipelines in Fort Worth neighborhoods. Find the background here, http://www.fwlna.org/pipelines.html, and then download the 36-page report.

The *Fort Worth League of Neighborhood Associations* also funded a small study on local air quality impacts and made a recommendation for setbacks. Background information and link to the report are here: http://www.fwlna.org/air-quality.html

Citizens of the Shale, Denton Record-Chronicle. The series that launched a thousand ships. http://www.dentonrc.com/local-news/special-projects/gas-well-drilling-headlines/20120706-citizens-of-the-shale.ece

Pipeline, from the Pittsburgh Post-Gazette. Ongoing coverage in the Marcellus Shale. http://pipeline.post-gazette.com