The University of Pittsburgh Graduate School of Public Health
Special Issue: Health Effects of Shale Gas Extraction

PhQ

PUBLIC HEALTH QUARTERLY

health effects
OF SHALE GAS EXTRACTION

What is known and what can we predict?

A MESSAGE FROM THE DEAN
DONALD S. BURKE, MD

This special issue of Public Health Quarterly summarizes an important conference we recently here at Pitt titled, "Health Effects of Shale Gas Extraction: What is known and what can we predict?"

The public health impact of Marcellus Shale drilling is a contentious topic; passions are high and battle lines have been dug between the various pro-drilling and pro-environmental advocacy groups. All too often, opinions posing as facts are lobbed back and forth through the media. Seeing a need for objective analysis, we specifically designed this conference to shed light, not just more heat. We sought to create a forum where the best, most up to date science could be presented, discussed, and dispassionately assessed.

According to the U.S. Geological Survey, the Marcellus Shale is more than 350 million years old. It marks the ancient location of a shallow inland sea and river delta, where massive amounts of mud rich in organic material were deposited. This sediment was eventually buried under other geologic strata, and became compressed and heated over geologic time. Now, eons later, the organic material trapped in the sediment has been degraded into hydrocarbons, including natural gas, and the minerals in the sediment have formed the fine-grained rock known as shale. Salts from the inland sea concentrated and crystallized in the shale beds. Natural gas is extracted from the shale using a technique called hydraulic fracturing or "hydrofracking," in which water under high pressure forms fractures in the rock, which are propped open by sand or other materials to provide pathways for gas to move to the well. Effluents from the hydrofracking process reflect this ancient history and chemistry.

There are other important shale gas deposits elsewhere in the United States. The Marcellus Shale bed, which lies under us here in Western Pennsylvania, is named for town of Marcellus, in New York state, where an outcrop of the shale rock can be seen at earth's surface (the town of Marcellus, in turn, was named after Marcus Claudius Marcellus, a Roman general who conquered Syracuse in 211 BC.) For our conference we brought in scientists who are from regions around the country where shale gas drilling is already a much more mature industry than it is in the Marcellus region. We sought to learn from their experience what the key health issues are and what specific environmental research questions must be answered to ensure protection of the environment and the public's health.

The purpose of the conference was not to advocate for one position over another; advocacy groups on both sides make some good points. But I am satisfied that as academicians we did our jobs. We redirected the discussion toward thoughtful, scientific investigation and collaboration among academia, industry, government, and public advocates. Our responsibility as a public health research institution is to conduct solid research and share the results widely so that we can determine if people, the natural environment, and industry can co-exist in a mutually beneficial way. I view this as just a beginning of an important process.

The conference was generously supported by grants from The Heinz Endowments and the Richard King Mellon Foundation and capably organized by the faculty and staff of the GSPH Center for Healthy Environments and Communities.

Donald S. Burke

in this issue

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SPECIAL ISSUE: HEALTH EFFECTS OF SHALE GAS EXTRACTION

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health effects

OF SHALE GAS EXTRACTION

WHAT IS KNOWN AND WHAT CAN WE PREDICT?

In November, GSPH sponsored a day-long conference to explore the science and methodological approaches behind understanding environmental health impacts associated with increasing development of natural gas extraction from shale deposits found under wide geographical areas of the United States, especially the Marcellus Shale formation that underlies much of the Appalachian area that includes Pennsylvania.

Natural gas plays a key role in the nation's clean energy future and energy independence. Over the past few years, several key technical, economic, and energy policy developments have spurred increased gas extraction and especially the use of hydraulic fracturing to recover gas over a wider diversity of geographic regions and geologic formations. However, as with any technology that involves management of potentially toxic substances, there have been increasing concerns about the impact of increased hydraulic fracturing and other associated gas extraction procedures on drinking water resources, air quality, public health, and the environment in the vicinity of gas extraction facilities. The United States government has identified a lack of critical research on these impacts and gaps in basic research pertaining to the mobilization of toxic hazards, regional differences in hazards generated, pathways of human exposure, and amounts of exposures that hamper full assessment of health risks from the hazards released during current gas extraction methodologies.

The conference presented the scientific challenges and issues that are being explored by government and academic investigators, as well novel methodologies being employed to assess the health impacts and reduce the hazards produced by gas extraction, refining, and delivery operations. In his opening remarks, GSPH Dean Donald S. Burke, MD, said, "We all seek an integrated strategy for a sustainable energy sector of the economy. We must help industry learn best practices for protection of public health and the environment. Our purpose here today is to provide a more measured voice about the health consequences of the Marcellus shale."

Many thanks to Charles Christen, DrPH, MEd; Kyle Ferrar, MPH; Shannon Kearney, MPH, CPH; Matt Kelso; Samantha Malone, MPH, CPH; and Drew Michanowicz, MPH, CPH.

The full summaries, videos of some presentations, and the conference program with bios of all the speakers can be accessed at www.fractracker.org/2010/11/recap-of-gsphs-shale-gas-conference.html.

The following summaries of the presentations—which have been edited for length here—were compiled by staff in the Center for Healthy Environments and Communities, the conference's organizing body.

Health and Safety Considerations in the Extraction of Fossil Fuels

Bernard Goldstein, MD, is a professor in GSPH's Department of Environmental and Occupational Health, as well as the school's past dean. Goldstein started off the conference with a discussion about the need for public health, government, and industry to use proper risk communication techniques when discussing risk of natural gas drilling with the public. For example, if the industry had openly discussed the ingredients of the fluid used to hydraulically fracture the shale and the purposes of those ingredients when hydraulic fracturing was first used, it would have prevented a significant amount of unnecessary fear regarding the fact that the exact composition of each company's well stimulation mixture is proprietary.

Additionally, Goldstein called for public health to conduct prospective research on the potential public health impacts of shale gas drilling, because it is difficult to make connections retrospectively.

Inorganic Geochemistry of Marcellus Shale Hydrofracturing Waters

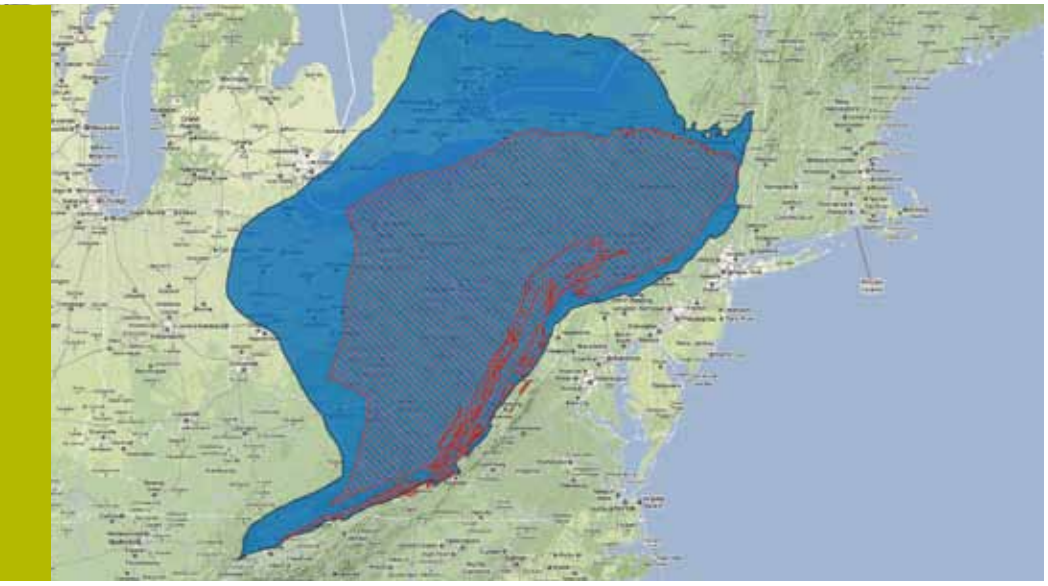
Carl S. Kirby, PhD, began his presentation by defining the terms "slick water" and "frack-water." Slick water consists of water, proppant, and slicking agents that are pumped down into the drilled well. Frack water identifies the liquids returning up to the surface after hydrofracturing has been completed. This liquid includes the slick water, as well as a concentration of brine water from within the well. The concentration of brine is largely irregular, and depends upon the geochemistry of the drilled strata, and the amount of time the slick water remained in the well bore before returning as frack water. The extent of dissolution of salts/brines in the frack water is a major concern, since the current treatments of frack water do not provide an assurance that these chemicals can be removed. Therefore, the options for frack water are storage, recycling and reusing, transporting the frack water to be treated at specialized facilities, or reinjection. Much of the frack water goes to Ohio where it is injected into deep wells, a method the industry calls a "closed loop."

Trace Metal Chemistry of the Marcellus Shale

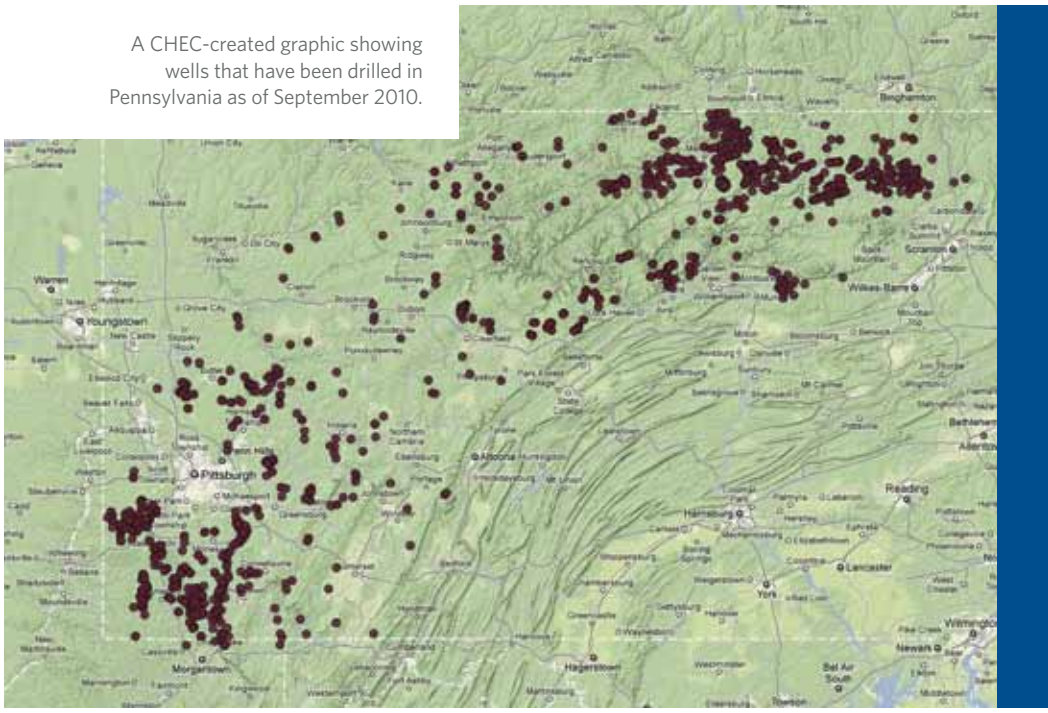
Tracy Bank, PhD, discussed the chemistry of the Marcellus Shale, beginning with the geology of the formation. Shale is a sedimentary rock consisting of a fine-grained composition of a mixture of minerals, mostly clay minerals. The Marcellus Shale is a black shale that was formed in relatively deep waters, devoid of oxygen. Trapped decaying matter in and around these areas nearly 400 million years became natural gas, oil, and coal.

Conditions that conserve organic matter also favor the conservation of redox (changing of a molecule's oxidation number, commonly in the form of a gain or loss of electrons) sensitive metals such as iron, zinc, molybdenum, and uranium. Bank's research focused on the solubility of uranium, and she explained that the solubility of uranium is dependent upon redox conditions. Concentrations of uranium are higher where there are higher levels of total organic carbon, and higher levels of natural gas is certainly what industry is seeking.

Bank explained that the shale layer and rock formations thousands of feet underground are lacking oxygen, and thus are in a reducing redox state. When large amounts of pressure and water are introduced into these underground formations by fracking, the oxidation states and reducing conditions can be altered leading to the mobilization of uranium, iron, and zinc. This can and does happen naturally to rock layers exposed to weathering, as it does in the Marcellus Shale outcrops.



This map shows the geographic extent of the Marcellus Shale area (red hash marks) and the Utica Shale area, which lies thousands of feet below the Marcellus Shale and extends beyond it.



A CHEC-created graphic showing wells that have been drilled in Pennsylvania as of September 2010.

Unconventional Gas Extraction in Legacy Energy Production Landscapes: Uncertainties in History, Contamination, and Interactions

Dan Bain, PhD, addressed the correlation of Southwestern Pennsylvania's legacy landscapes and natural gas extraction. An important public health concern is the potential for the interaction of varying water compositions used in the Marcellus Shale production process and mobilization (or movement) of metals through legacy surface sediment, i.e. sediment resultant from the effects of coal mining on the region. According to Bain, sediment drives most chemical interactions at the water-sediment interface. Therefore, it is critical to continue to monitor ground and surface water for increases in metal content. The mobilization of sodium is of particular concern to riparian ecosystems.

As coal mining left its imprint on the region, gas extraction from Marcellus Shale will undoubtedly leave another set of legacy sediment types.

Bain proposes that continued research regarding comprehension of flood plains and near surface bed rock is necessary to appropriately model possible outcomes from movement of industry specific waters through legacy sediment.

Water Management Challenges in Marcellus Shale Gas Production

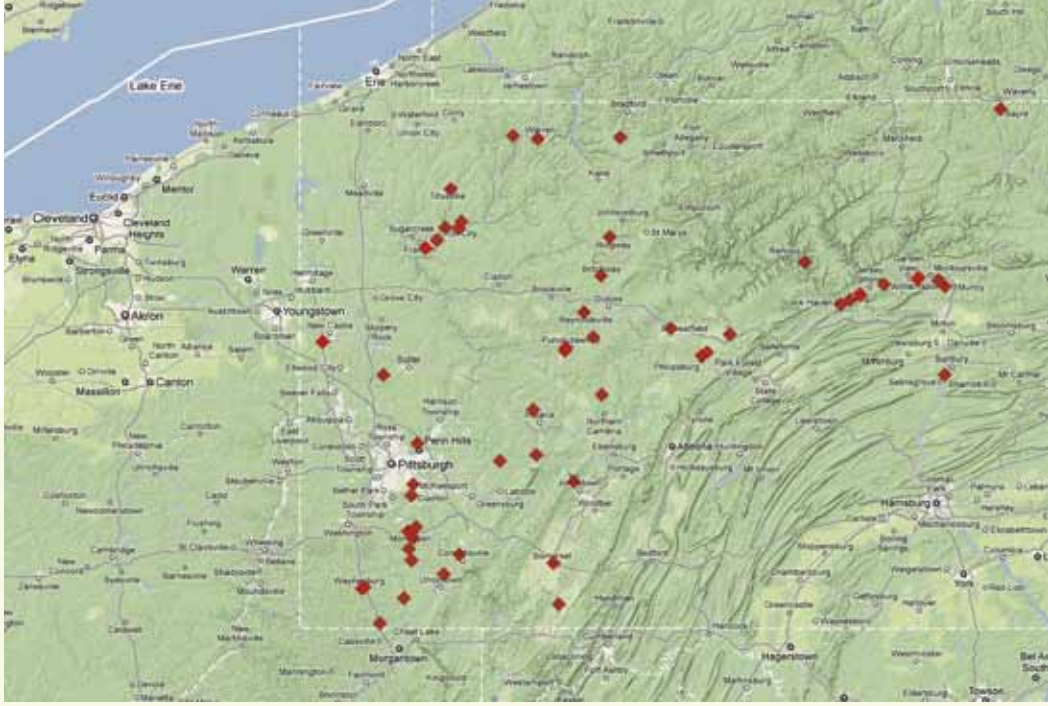
John Veil presented information based on his work funded by the U.S. Department of Energy concerning water issues.

During site preparation, storm water runoff should be considered from all land areas disturbed during construction, which includes following proper sediment control practices and stabilizing exposed surfaces (generally prepared with gravel). Different operators follow different degrees of storm water management.

Water is also necessary for the drilling fluids and can range from 1 million gallons in the Haynesville Shale to 60,000 gallons in the Fayetteville Shale. The amount of water depends on the types of drilling fluids used and the depth and horizontal extent of the wells. The Marcellus Shale drilling volume falls near the lower end of this range at 800,000 gallons per well. Drilling waste is then sent to lined pits.

Hydraulic fracturing is another major water issue. The water needed for a single well in the Marcellus region may require 1 million to 5 million gallons. Individual well volumes of water are generally not a critical issue, but collectively can be important within a region. Sources of water can be a stream, river or lake, ground water well, impoundment created by the producer, and a public water supply. Pipelines or tanker trucks (more often) can deliver water to the site. Water is then deposited in impoundments or tanks.

Veil discussed how much water would be needed in a high production year. He stated that it is hard to predict the maximum number of wells, but that the report by the United States Geological Survey goes back to the year 2005 and does accurate measurements. The totals for Pennsylvania, West Virginia, and New York are about 25 million gallons per day. The total water withdrawal is 7,457 million gallons per day, which means that less than 1 percent of the total water supply is used. That means there is ample water in the Marcellus region for well drilling, but water needs and considerations will differ according to geographic location and the season.



A CHEC-created graphic showing facilities that are approved to receive oil and gas wastewater.

Long-Term and Cumulative Assessment of the Impact of Marcellus Shale Drilling

Michel Boufadel, PhD, PE, spoke about factors leading to the movement and retention of flowback water. He indicated that this can happen from the bottom of the well up during injection and fracturing, as well as from the ground down in the case of pit leaks.

Although the typical Marcellus Shale well is 7,000 feet deep, the earth is highly fractured, and when the flowback water is injected or hydraulically fractured at pressures up to 10,000 psi, it is possible for this water to migrate up thousands of feet, depending on the connectivity of the faults and joints.

The other method for flowback water migration is the possibility of pit spills. Boufadel emphasized that most current models are inadequate, because they do not account for the high density of the brine. Because of this, the flowback water tends to seep deeper in the ground than fresh water would, and remain in the aquifers longer. In addition, shallow sensors may not be able to detect the contamination for years.

Air Quality Monitoring Strategies

Robert Field, PhD, spoke about factors leading to the creation of wintertime ozone in Sublette County, Wyoming. The sudden appearance of the phenomenon was surprising to residents, since ozone is usually an urban problem during the summertime. Field examined the link between the ozone production and the natural gas industry in the state.

The conditions to create ozone are known, and include the presence of ozone precursors, sunlight, and other atmospheric conditions. Rural Wyoming made for a convenient laboratory to determine the scope of the contribution of the gas industry, because unlike Pennsylvania, it was not already present in the air from other industrial activities. Field indicated that the Wyoming Department of Environmental Quality has already been using the information to predict days favorable to the creation of ozone, and has even worked to prevent it by asking operators to limit their polluting activities on those days.

Responding to questions from the audience, Field indicated that environmental conditions in Pennsylvania are less favorable for wintertime ozone in particular, although ozone in the summer remains a concern.

Addressing Combined Effects of Air Pollution and Social Stressors Exposures on Health in Communities Affected by Natural Gas Fracturing

Jane Clougherty, MSc, ScD, presented on her previous work concerning air monitoring in New York City and the culmination of indirect impacts to various users. Clougherty's work focused on air pollution monitoring schemes, needs and assumptions of air monitoring for multiple-source emissions.

Passive ambient air monitoring can produce powerful data if strong variability is present, as well as numerous monitoring locations. The focus of her talk was not to demonstrate how monitoring could be implemented in or around gas extraction sites, but was to provide a case study to encompass impacts across communities and regions and how stress can relate to these various levels. Indirect or non-primary effects, social stressors, and potentially synergistic social-environmental effects, can certainly apply to the Marcellus Shale boom. Health research has indicated that chronic stress can affect the immune, endocrine, and respiratory systems, and even susceptibility to the common cold.

Short-Term Air Quality Impacts from Marcellus Shale Operations in Southwest PA

Chief of the Pennsylvania Department of Environmental Protection's (PADEP) Air Quality Monitoring Division, Nick Lazor, addressed the department's efforts to conduct short-term air quality sampling near Marcellus Shale drilling operations. The PADEP sampled five counties in Southwestern Pennsylvania using an array of gas chromatography and mass and infrared spectroscopy instruments to assess concentrations of ambient air target pollutants.

Preliminary data indicates methane, propane, ethane, and benzene were present at Marcellus Shale compressor sites. Additionally, methyl-mercaptan was detected above odor threshold, while carbon monoxide, carbon dioxide, and ozone were not detected above national ambient air quality standards. The PADEP recognizes the importance of this initiative and plans to evaluate further monitoring efforts after a comparative analysis between all five sites has been concluded.

Use of Health Impact Assessment to Help Inform Decision Making Regarding Natural Gas Drilling Permits in Colorado

Roxana Witter, MD, MSPH; John Adgate, PhD; and Jim Rada presented about a health impact assessment (HIA) that was conducted in Battlement Mesa, Garfield County, Colo., an area that experienced a "boom and bust" of natural gas drilling. In 2005, Rada began conducting ambient air monitoring for particulates and other contaminants. At this time, Rada educated citizens and also encouraged dialogues between the industry and citizens. The formal health assessment began in 2009. In addition to their own epidemiological investigations, the researchers held stakeholder meetings with citizens, state agencies, and industry to gather their input and perspectives. The researchers were able to release a draft of the HIA in September 2010 which showed that quality of health was not significantly affected, but the community felt some impacts, such as an increase in violent crimes, a doubling of Chlamydia cases, and an increase in school enrollment.

The researchers also conducted a HIA to identify potential problems. They looked at eight major areas of concern based on the stakeholder meetings: air quality, water quality, traffic, noise, economic conditions, social conditions, health infrastructure, and accidents/malfunction. Of those, the researchers identified four key areas of concern based on available data (shown in descending order below) that pose the highest risk of producing negative health impacts:

Air quality, Traffic, Water quality and Community wellness (defined by looking at crime rates, mental health, substance abuse and suicide, occurrence of sexually transmitted infection, and enrollment in K-12 education)

Spatial Data Infrastructure for Evaluating the Health Impact of Gas Well Drilling in North Texas

David Sterling, PhD, CIH, has studied the development of the Barnett Shale in Texas. Over-development has resulted in close proximity of drilling and wells to homes, elementary schools, and other populated locations. Drilling in the Barnett Shale has occurred since the 1970s, and in densely populated areas, including Denton, Tarrant, and Johnson counties since 1999. There are more than 16,000 wells in these counties, 26,000 wells in the Barnett shale and other shales, and 20,000 permitted wells. Current issues involve encroaching proximity.

> High benzene levels have been measured in Dish, Texas, and other locations such as on an organic goat farm.

The Texas Commission on Environmental Quality (TCEQ) maintains a monitoring Web site for air emissions but more information and the development of a spatial data infrastructure is necessary for air and water models. The data collection also needs to be reported, made visual, and have transparency. One of the many research goals should be to connect this data with health outcomes. Data challenges in the Barnett region include gathering good population estimates, information on how many wells are contaminated, and getting hold of malleable data. And finally, Sterling emphasized the need for this information to be available for decision makers.

Research Methods and Results of the Baseline Socioeconomic Study of the Impact of Marcellus in Pennsylvania

Teri Ooms recently undertook a project to assess the current social and economic conditions relating to gas well development in the Marcellus Shale formation in Pennsylvania, with the goal of obtaining baseline data for future longitudinal assessment of subsequent community changes that occur in Appalachian counties. The study consisted of a survey of Marcellus residents and interviews with key informants (elected and appointed leaders, representatives of human service and educational agencies, and civic organizations) in five Pennsylvania counties (Lackawanna, Luzerne, Westmoreland, Greene, and Susquehanna) and five counties in other shale-rich states (Texas and Arkansas). This study was conducted to gather and assess the perceptions of current and future economic, social, and environmental impacts associated with large scale natural gas development.

Of the many study results that Ooms discussed, people living in the Marcellus region generally knew very little about the nature and development of the industry. Few people actually sought out objective information from authoritative sources. Many felt that as a result of the industry coming into Pennsylvania, the quality of their natural environment and drinking water would worsen, while employment options and training would improve. Ooms noted there was tension within communities because of varying lease and royalty rates and tension when there is a separation between land ownership and mineral rights (called a split estate). Most participants supported a severance tax in Pennsylvania, and almost all of them agreed that if a severance tax is enacted, some of the money should be allocated for local government expenses.

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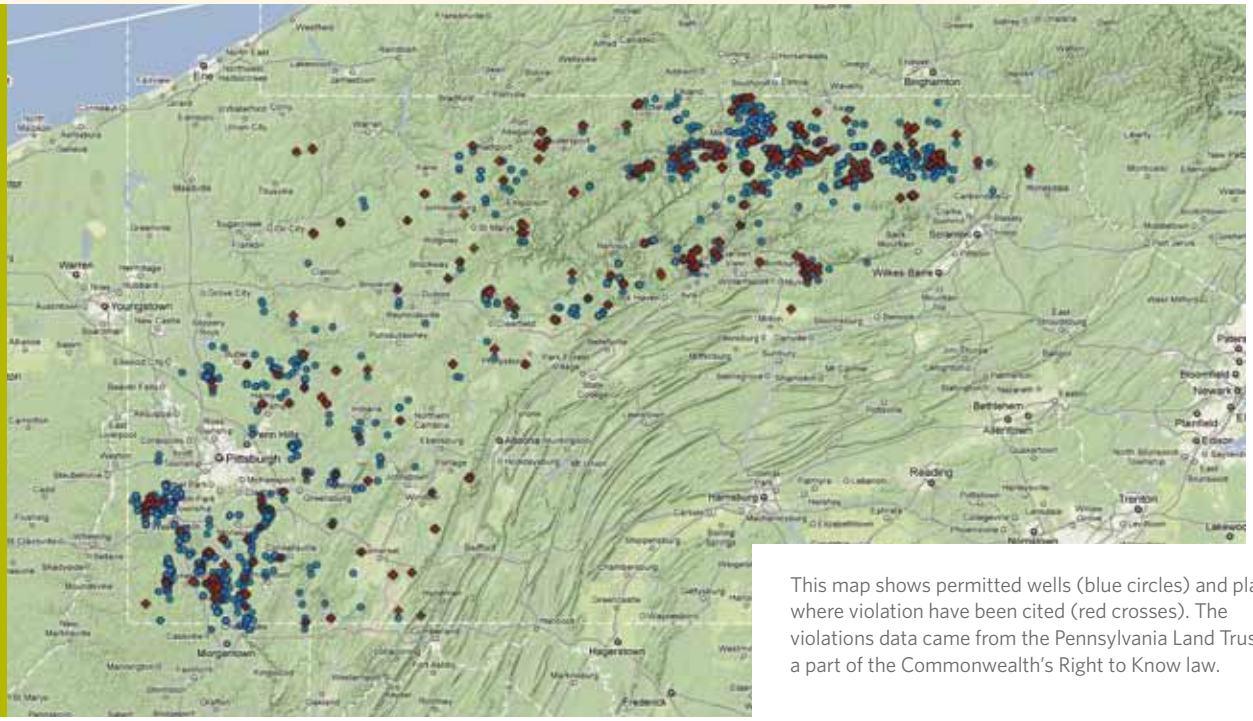


This map shows permitted wells (blue circles) and places where violation have been cited (red crosses). The violations data came from the Pennsylvania Land Trust as a part of the Commonwealth's Right to Know law.

Marcellus shale drill cuttings

How Should We Think About the Economic Consequences of Shale Gas Drilling?

Susan Christopherson, PhD, is an economic geographer whose research and teaching focus on economic development, urban labor markets, and location patterns in service industries, particularly the media industries. Christopherson stated in her presentation that the southern tier of New York state is already experiencing the impact of the Marcellus Shale boom. Truck traffic has increased and land values are rising, even though drilling is located in Pennsylvania and still excluded from New York. Money is coming into these areas and those surrounding areas with active drilling, but certain questions need to be answered, including: "What is the cost? For what period? What jobs will be created? What are the long-term outcomes?"

In order to appropriately address these questions, the factors that influence the pace and scale of drilling must be determined. These can include transportation costs, industry competition, regulatory capacity and requirements, taxes, and shortages. Current policy is projecting a boom and bust cycle from the shale gas drilling industry. The drilling cycle is front loaded, to drill as quickly as possible while Pennsylvania does not have a severance tax. Fifty percent of the total gas produced by a well is extracted within the first year, and production beyond five years is uncertain. The repetitive short-term process of drilling multiple wells must be considered, which means the majority of jobs are only temporary. Also, Christopherson advised analyzing the spending patterns for landowners who have received lease money. Large sums, rather than multiple disbursements, have the potential to be splurged.

The total cost to the communities has not been fully realized. Funding for schools and roads are currently the only area where there is any leverage from established policy. The boom and bust cycle will strain local economic systems. After the bust, communities are left with too many schools, police, teachers, and services without a population and funds to support them. Responsible economic development comes from population growth, income growth, and economic diversity. In gas-producing counties, incomes actually grow more slowly. Evidence from western states shows less economic diversity and decreased ability for alternative investments in counties with drilling.

FUTURE DIRECTIONS

A common theme among the day's speakers was that more information is needed and that baselines should be established in order to determine any potential cause-and-effect relationship attributable to Marcellus shale drilling.

"We're just beginning to scratch the surface in terms of what we know and what we understand," said moderator **Radisav Vidic of Pitt's Department of Civil and Environmental Engineering.**

"Clearly there are lots of questions being raised and I think the exchange of information and sharing of information among stakeholders would be one crucial set. What's clear to me is that we don't have baseline data."

Without information on the initial conditions before Marcellus shale drilling began, potential impacts attributable to the drilling cannot be determined. "It's much better to do proactive studies to find out what the situation is right now so you have a baseline for comparison. The retroactive studies are very expensive and very inconclusive in the most part," Vidic said. "I think the challenge to the community—both the research community, the industry and the community that lives in this region—is to perhaps engage in some kind of a dialogue to collect sufficient information that would provide baseline studies in the region where perhaps drilling hasn't occurred, and then use that information to assess potential impacts from industrial activity. The critical issue really is to start exchanging the information in an unbiased and scientifically valid way to address the issues and ensure that everybody's questions are answered appropriately. I think both industry and the public have to play an important role in that."

DEVELOPMENT

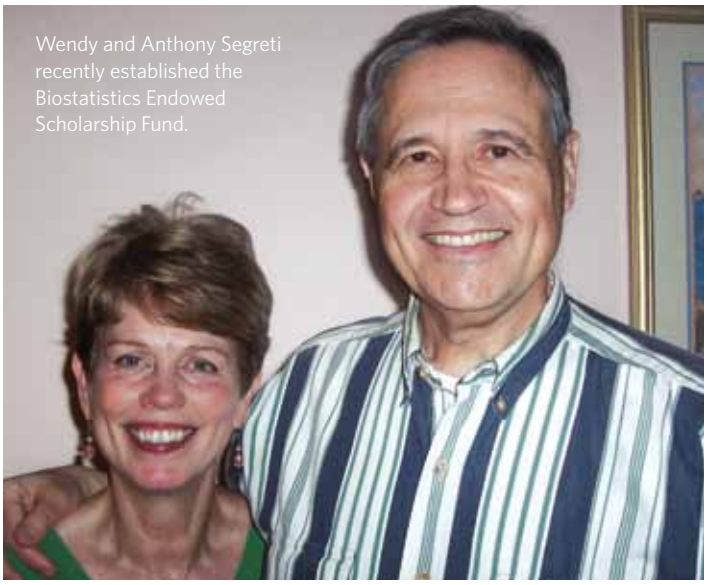
Dear friends,

As reflected in this issue, the Marcellus Shale symposium held November 19, 2010, is an excellent example of GSPH's continuing commitment to supporting a healthy environment for people in Southwestern Pennsylvania. Our scientific approach positions us to be the source of reliable, unbiased information for the media and, more importantly, policy makers. Engaging the public in collecting baseline data about our air and water quality in advance of significant Marcellus Shale drilling underscores the importance of GSPH with concerned citizens and the natural gas industry.

This is yet another example of community outreach by GSPH which has done so much since our founding in 1948 to improve public health. This work is funded primarily by the generosity of Pittsburgh foundations and people like you. We thank all of you who have supported our efforts to improve the health of older adults, children and the public at large in Southwestern Pennsylvania, across the country, and around the world.

Your support is also central to our attracting top students to GSPH. It is application and selection season for the next class of GSPH students. It is an intricate process of selecting the most promising students among the applicants, and encouraging those selected to matriculate here. Your gifts to provide scholarship support to these students are critical in attracting the best and brightest to GSPH.

Anthony Segreti, PhD, who earned an MS in biostatistics from GSPH in 1975, and his wife, Wendy, are among a growing number of alumni who have established a scholarship fund at GSPH. Segreti is a very successful biostatistician and is now a senior director at Targacept Inc., a highly respected biopharmaceutical company. The Segretis established the



Wendy and Anthony Segreti recently established the Biostatistics Endowed Scholarship Fund.

Biostatistics Endowed Scholarship Fund out of a sense of gratitude for the education Segreti received at GSPH, and to provide scholarship support to encourage highly competitive applicants to the Department of Biostatics to attend our program. Next month, a very promising applicant will be notified that he or she will be attending GSPH as a Segreti scholar. The honor and practical value of this will no doubt enhance the student's view of GSPH.

"Having being given so much by the Graduate School of Public Health and the Department of Biostatistics, it's a distinct pleasure for us to help support the next generation of biostatisticians," Segreti said.

Endowed funds at GSPH can be established with a minimum gift of $10,000, and this sum can be pledged over a three year period. For more information about how you can create your legacy at GSPH, please contact Apryl Eshelman, director of development at 412-624-5639 or eshelman@pitt.edu. Please consider joining Tony and Wendy Segreti, among others, in providing this much-needed scholarship support.

Thank you for your gifts to GSPH. Your generosity helps the school maintain our position as a leading, vibrantpublic health institution.

Apryl Eshelman
Director of Development
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PHOTO OF THE QUARTER

Creativity takes the cake at annual GSPH holiday party.

A cake in the shape of Parran Hall was the centerpiece of the annual GSPH holiday party, where faculty, students, alumni, and staff celebrated another great year at GSPH and looked forward new developments in 2011. Watch future issues of Public Health Quarterly for exciting announcements.

University of Pittsburgh

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Coming in the next issue of Public Health Quarterly

As GSPH welcomes Françoise Barré-Sinoussi, PhD, Nobel Laureate and co-discoverer of the human immunodeficiency virus, to accept the Porter Prize, PHQ will highlight the school's research in HIV/AIDS.

Plan on joining us for the Porter Prize events on Friday, May 20, 2011:

At 10:30 a.m. Barré-Sinoussi will give a scientific lecture in Ballroom A of the University Club, 123 University Place, Pittsburgh, PA 15261. The lecture is titled, "The Enigma of Diverse Host Responses to HIV/SIV Infection."

At 2 p.m. in Ballroom B of the University Club, Barré-Sinoussi will receive the Porter Prize and deliver a lecture titled, "HIV: A Discovery Highlighting the Global Benefit of Multidisciplinary Science."

To RSVP and for more information, please contact Jill Ruempler at ruempler@pitt.edu or 412-383-8849.