By Ruth McDermott-Levy, PhD, RN,
Nina Kaktins, MSN, RN, and
Barbara Sattler, DrPH, RN

Fracking, the Environment, and Health

New energy practices may threaten public health.

Melissa Owen became concerned when her 10-year-old son developed such severe nosebleeds that she used tampons to stop the bleeding. Soon after, a blistering rash appeared on his skin, and his sister began having similar nosebleeds. The Colorado family's physician attributed these symptoms to air pollution caused by the use of hydraulic fracturing—"fracking"—to extract natural gas in their community. He recommended they move.

In northeastern Pennsylvania, the Micelles family thought signing a lease to allow fracking operations on their farm would relieve some of their financial burden. But within the first week of drilling, Elizabeth Micelles noticed a sweet odor and a metallic taste in her mouth; by the second week, she and her husband and three children were experiencing fatigue, dizziness, vomiting, headaches, and nosebleeds. A visit to their NP and laboratory tests revealed that each had measurable levels of benzene, a known human carcinogen, in their blood.

These acute health problems are common among people living in communities in which "unconventional" oil and natural gas extraction, such as fracking, occurs. (These examples are composites based on the experiences of families affected by fracking as compiled by the Damascus Citizens for Sustainability.[1]) Common symptoms or complications among people living near fracking sites include[2-4]

- fatigue.
- burning eyes.
- dermatologic irritation.
- headache.
- upper respiratory (difficulty breathing), gastrointestinal (severe abdominal pain), musculoskeletal (backache), neurologic (confusion, delirium), immunologic, sensory (smell and hearing), vascular, bone marrow (nosebleeds), endocrine, and urologic problems.
- the risk of endocrine disruption.
- changes in quality of life and sense of well-being.

Longitudinal reports from long-term exposure to contaminated air and water from gas extraction don't exist, but anecdotal reports make clear that the removal of fossil fuels from the earth directly affects human health. It's well known, for instance, that the combustion of fossil fuels emits greenhouse gases that contribute to climate change,[5] and increased rates of asthma, cardiovascular disease, and lung cancer are all associated with our reliance on and use of fossil fuel energy, including coal, oil, and natural gas.[2, 6-8]

Children are at higher risk than adults for developing asthma and suffering complications from asthma owing to poor air quality, which can be caused by the burning of fossil fuels.[9, 10] As the population ages, older adults become more vulnerable to climate-related extremes in temperature and ambient air pollution from fossil fuels because of comorbidities and age-related changes, such as decreased respiratory reserve and the slowing of cardiac compensatory mechanisms.[11-14] Moreover, there are numerous occupational hazards for the fossil fuel extraction workforce, ranging from noise concerns[15, 16] to major injuries[17] and respiratory irritants that result in chronic disease.[18]

Despite these health concerns and efforts to institute a moratorium on fracking until its environmental and health effects are better understood, the United States continues to rely heavily on fossil fuel energy. Currently, 36% of annual U.S. energy consumption is derived from petroleum, 26% from natural gas, 20% from coal, and 8% from nuclear sources, with only 9% supplied by renewable energy, such as wind and solar power.[19] President Obama's administration has repeatedly emphasized its plan to continue development of all energy sources—including a significant expansion of drilling and fracking operations for natural gas and oil. Although the extraction of these nonrenewable sources of energy help the United States to meet its current energy demands and security needs, it's critical that the human and ecologic health threats associated with fracking be better understood and addressed.

FRACKING

Extracting natural resources trapped within the pore spaces of low-permeable rock, such as shale, typically requires drilling deep—up to 8,000 feet.[20] Using a process called high-volume hydraulic fracturing, or fracking, areas of weakness and small fractures

When Jodie Simons and Jason Lamphere put a lighter to their faucet, the high methane content of the water sets it on fire. Since gas drilling started in their Pennsylvania neighborhood, they've been without clean drinking or bathing water. High levels of methane in drinking water can create a risk of explosions and asphyxiation hazards for households. Photo by Nina Berman / NOOR / Redux.

that already exist in the rock are further opened. Depending on the characteristics and depth of the rock, fracking a single well requires the high-pressure injection of anywhere from 2 to 10 million gallons of water mixed with sand[21] and 80 to 300 tons of hazardous and nonhazardous chemicals.[22]

Colborn and colleagues compiled a list of chemicals known to be used during natural gas extraction.[3] Of the more than 350 that were investigated further, 75% were found to potentially affect the respiratory and gastrointestinal systems, the liver, and various sensory organs. Moreover, more than half of these chemicals could affect the brain and nervous system.[3] It's estimated that 15% to 80% of the fluid containing these chemicals flows back through the well to the surface,[20] where it's usually stored at the well site in tanks or open, lined pits, awaiting transport to treatment facilities or to deep-well injection sites for permanent disposal.

Fracking operations have grown exponentially since the mid-1990s, when technologic advances and increases in the price of natural gas made this technique economically viable. Fracking is currently taking place in Arkansas, California, Colorado, Louisiana, North Dakota, Oklahoma, Pennsylvania, Texas, Virginia, West Virginia, and Wyoming. Other states, such as Alabama, Indiana, Maryland, Michigan, Mississippi, New Jersey, New York, and Ohio, are either considering or preparing for drilling using this method. Vermont has permanently banned fracking, and New York and North Carolina have instituted temporary bans. New Jersey currently has a bill before its legislature to extend a 2012 moratorium on fracking that recently expired, whereas Maryland has decided not to approve fracking permits until a state panel studying its safety has completed its final report, which is expected in mid-2014. Although a fracking moratorium was recently lifted in the United Kingdom, the government is proceeding cautiously because of concerns about earthquakes and the environmental impact of drilling. Fracking is currently banned in France and Bulgaria.

HEALTH RISKS

It's believed that the potential health consequences of fracking begin at the onset of drilling and may last long after the operation has concluded. Researchers have described an array of environmental factors and health risks associated with fracking and other extraction processes.[6, 23, 24] These include water and air contamination; increased intensity in diesel-truck traffic volume; constant, elevated noise levels; occupational hazards; and stress within rural communities from a swelling population made up of drilling crews

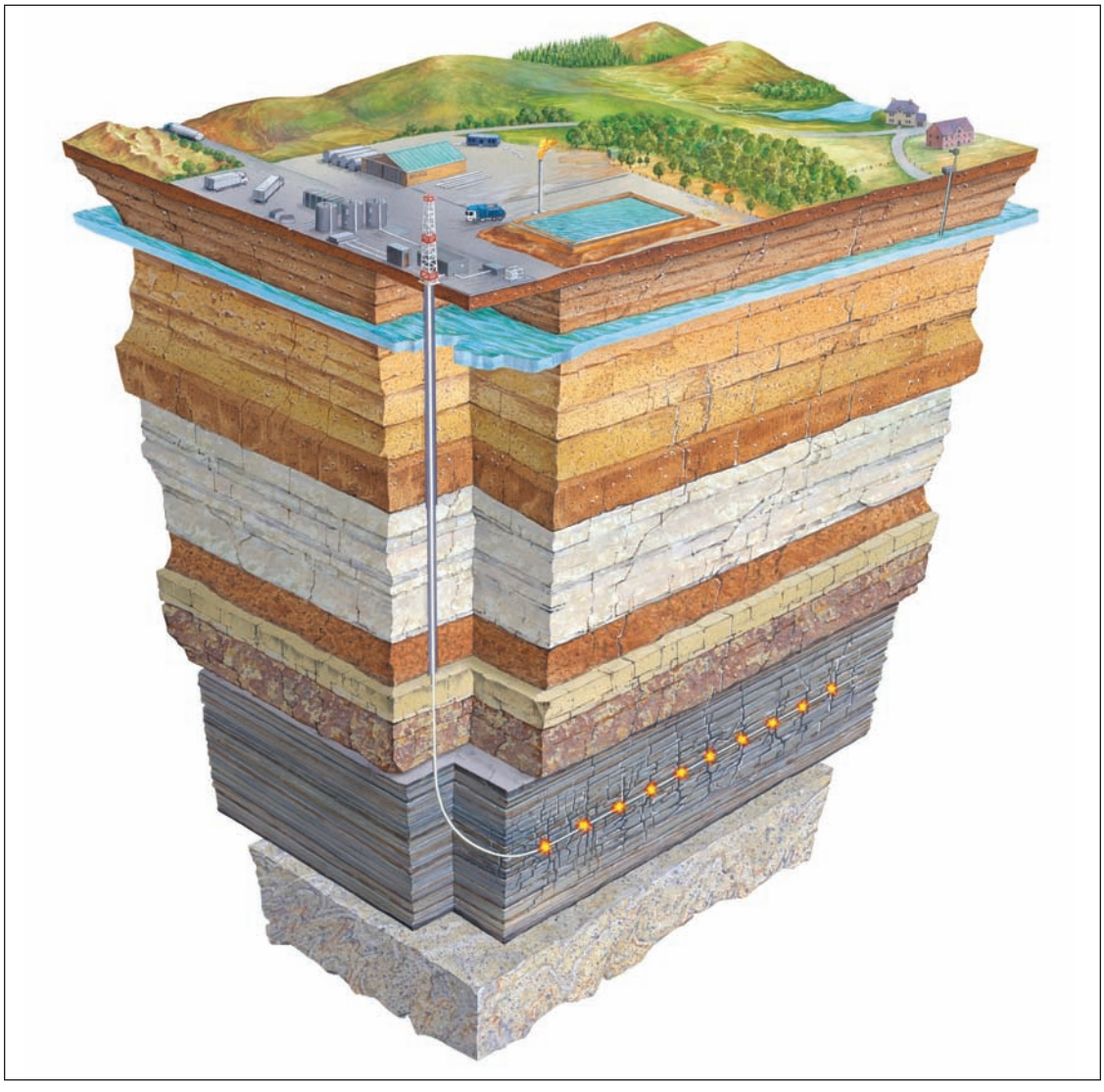

Figure 1. In hydraulic fracturing, or fracking—the method used to extract gas from shale deposits—rock layers are fractured by fluids (a mixture of sand, chemicals, and water) pumped under high pressure from the surface (upper left) down through horizontal wells (lower right) to form fissures in the shale. The sand keeps the fissures open, allowing the gas to flow into the well and be taken to the surface. Image by Gary Hincks / Science Source Images.

and related businesses, and the subsequent increased demands on the social and health care infrastructures.[23]

There are also potential economic and ecologic issues, including decreased property values owing to drilling site proximity, drilling malfunctions, and violations of regulations designed to protect the environment, which could lead to long-term environmental and health damages to the surrounding community. Furthermore, compared with conventional gas extraction methods, the fracking process leads to what's believed to be a 30% greater amount of methane "escape."[25] Methane can also leak from the well and during natural gas processing, transport, storage, and distribution.[25]

Water contamination. People obtain drinking water from either surface water, which includes rivers and reservoirs, or groundwater aquifers, accessed by public or private wells. There are already a host of documented instances in which nearby groundwater

has been contaminated by fracking activities, requiring residents with private wells to obtain outside sources of water for drinking and everyday use.[26, 27]

A primary health hazard is methane migration from active drilling sites to aquifers. In Pennsylvania, Osborn and colleagues found that the average methane level was 17 times higher in private drinking-water wells within one kilometer, or about 3,280 feet, of active drilling sites, compared with those in nondrilling areas.[26] High levels of methane in drinking-water supplies create a risk of explosions and asphyxiation hazards for households. In one case, the buildup of methane caused a private drinking-water well to explode.[27] Currently, the U.S. Environmental Protection Agency (EPA) doesn't regulate methane in drinking water, and there is a lack of research on the health effects of chronic exposure to methane in drinking water.[28]

Methane is only one of many chemicals of concern. In Pavillion, Wyoming, the EPA detected high concentrations of benzene, xylenes, purgeable hydrocarbons, and gasoline and diesel by-products in shallow groundwater near fracking-wastewater holding pits.[29] Collectively, these chemicals present risks of neurotoxicity, reproductive problems, and cancer.[30-32] The EPA determined that the most likely cause of the groundwater contamination was leaky pits used to store fracking fluid waste.[29] Groundwater contamination from toxic drilling wastewater poses a health risk to humans, as well as to pets and farm animals that drink or bathe in the contaminated water.

Despite the evidence of health risks related to fracking, communities and health care providers have had limited access to information about the chemicals used in the hydraulic fracturing process, as well as limits placed on their ability to inform and share information about chemical exposures. For example, Pennsylvania's Act 13 of 2012 states that drilling companies are not required to share information about the components or concentration of chemicals if these are deemed proprietary trade secrets.[33] This act also requires that health professionals submit a written request for information on proprietary solutions used in fracking and sign a "confidentiality agreement" identifying that the information is needed to diagnose or treat an individual.

Although exceptions are made for emergency situations, these policies delay nurses' and other health care providers' ability to quickly assess and treat the public or extraction workforce for potentially hazardous exposures. Furthermore, the Pennsylvania law states that health care professionals are not permitted to share exposure information. This hinders the development of effective, evidence-based assessment and treatment practices related to the health effects of these chemicals on exposed patients.[33]

Air pollution. The air is significantly impacted by fracking operations, including by the release of methane, which is especially likely during the initial period following hydraulic fracturing injection and during transport of the fuel to customers.[25] Public health threats related to climate change, which is partly a function of the continued release of greenhouse gases like methane, are forecast to be one of the greatest global health concerns of this century.[5] Moreover, high levels of known carcinogens in the air, such as benzene, have been attributed to natural gas drilling operations.[6]

The large fleets of diesel trucks (typically 1,000 to 2,000 per well) that are required to support the fracking process significantly increase ground level ozone and particulate matter[15, 34] as well as the risk of traffic accidents.[35] Ground level ozone is a potent pulmonary irritant responsible for reduced pulmonary function and the exacerbation of asthma and emphysema.[36, 37] Elevations in particulate matter are responsible for an increased incidence of asthma,[38] cardiovascular disease,[39] chronic obstructive pulmonary disease, and cancer.[40]

Occupational hazards. Statistics collected by the Department of Labor and analyzed by the Centers for Disease Control and Prevention show a correlation between drilling activity and the number of occupational injuries related to drilling and motor vehicle accidents, explosions, falls, and fires.[17] Extraction workers are also at risk for developing pulmonary diseases, including lung cancer and silicosis (the latter because of exposure to silica dust generated from rock drilling and the handling of sand).[41] At the well sites, workers can be exposed to dangerously high levels of silica—as many as 79% of hydraulic fracturing sites exceed the National Institute for Occupational Safety and Health standards for silica dust.[18]

Additionally, the extraction workforce is at increased risk for radiation exposure. Fracking activities often require drilling into rock that contains naturally occurring radioactive material (NORM), such as radon, thorium, and uranium.[42-44] Rock cuttings containing NORM may be buried at the drilling site or taken to a landfill. However, NORM is also brought to the surface intermingled with fracking fluids and subsequently deposited in open lined pits or holding tanks as waste.[21] While awaiting permanent disposal, the radioactive materials become concentrated, producing "technologically enhanced NORM" (TENORM).[21, 44] Workers may be exposed to TENORM at the drilling site or through the spilling of waste material during transport; and while many TENORM contains low levels of radiation, extraction

workers and people living near drill sites can potentially be exposed to elevated levels of radiation.[44]

THE ANA'S STANCE

The "precautionary principle" or approach was developed in recent decades in response to the perceived risk to health and the environment posed by certain activities. This concept places the burden of proving that an activity is safe for human health or the environment, in the absence of scientific consensus, on the entity initiating the activity. This principle has been embraced by the American Nurses Association (ANA), which in 2003 adopted a policy that states that when there's an environmental threat to human health, nurses must advocate for public policies that reduce risk to people and the natural environment.[45]

Evidence-Based Resources on Fracking and Its Health Impacts

Alliance of Nurses for Healthy Environments
A Web forum on fracking and public health.
http://bit.ly/ZYFBaU

American Public Health Association
Policy Statement: The Environmental and Occupational Health Impacts of High-Volume Hydraulic Fracturing of Unconventional Gas Reserves.
http://bit.ly/TYv13W

Natural Resources Defense Council
Information on the health impacts of natural gas extraction and climate change.
www.nrdc.org/energy/gasdrilling

Physicians, Scientists, and Engineers for Healthy Energy
Learning models and continuing education about the health effects of shale gas extraction.
www.psehealthyenergy.org

Southwest Pennsylvania Environmental Health Project
Information and assessment tools for health care providers working in gas extraction communities.
www.environmentalhealthproject.org

U.S. Environmental Protection Agency
"Questions and answers about EPA's hydraulic fracturing study."
http://1.usa.gov/Zvvl5x

The ANA's policy says: "the Precautionary Principle implies that there is an ethical imperative to prevent rather than merely treat disease, even in the face of scientific uncertainty."

In June 2012, the ANA passed a resolution drafted by the Pennsylvania State Nurses Association entitled "Nurses' Role in Recognizing, Educating and Advocating for Healthy Energy Choices."[45-47] It calls for a national moratorium on new drilling permits for unconventional natural gas and oil extraction based on mounting evidence that fracking leads to human health threats, disruption in communities, and ecologic degradation. It emphasizes the need for nurses to be well versed in the health risks associated with fossil fuel energy and supports their engagement in patient and community education as well as in policy and advocacy work. The resolution asserts that it's critical for nurses to know that safer energy options—such as wind, hydroelectric, solar, and geothermal power—exist, and that state and national policies can help or hinder whether the use of these alternative energy sources is explored.

NURSING IMPLICATIONS

Addressing our national energy needs while assuring the health of communities and the extraction workforce is a complex and multifaceted issue. Nurses can best promote the health of their patients, the community, and the public by embracing the precautionary approach and supporting energy policies that make human health a priority. The ANA's resolution calling for a moratorium on drilling permits provides a framework for nurses looking to influence energy policy, and calls for self-education and active support of legislation that would require better monitoring and regulation of the fossil fuel industry, particularly in regard to its effect on health.

Nursing and other health professional groups, such as the Alliance of Nurses for Healthy Environments, in addition to federal agencies, have published resources on fracking (see *Evidence-Based Resources on Fracking and Its Health Impacts*). Using these, nurses can gain a better understanding of the issues surrounding fracking and help to educate their colleagues, patients, and other members of their communities while also taking the lead in promoting better monitoring and prevention of the potential health effects associated with fracking.[48] Two of us (RM-L and NK), for example, have previously suggested that community health nurses in Pennsylvania, where there is extensive fracking operations on the Marcellus shale, incorporate evaluation of exposure risk (to air or water that may have been contaminated by drilling operations) into their patient assessments.[48]

Public and individual health concerns are rarely raised when energy policies are discussed on the state or federal level, and health professionals are typically excluded from these decision-making discussions. As Goldstein and colleagues noted last year, none of the advisory committees formed to investigate drilling activities on the Marcellus shale included representatives of state or federal public health agencies or individuals with expertise in the effects of environmental hazards on human health.[49]

Nurses are being joined in their efforts by a wide range of stakeholders, ranging from the health professionals in the American Public Health Association and Physicians for Social Responsibility, to national organizations such as Breast Cancer Action and Food and Water Watch, to grassroots organizations such as Catskill Mountainkeeper and Frack Free Stark County. Many of the well-known national environmentalist organizations are actively engaged as well, such as the Sierra Club, the Nature Conservancy, and the Natural Resources Defense Council. National Nurses United and the ANA have both called for banning new fracking permits. These two nursing organizations have constituents throughout the country who are engaged in legislative and other policy initiatives regarding fracking.

Both the Maryland Nurses Association and the Pennsylvania State Nurses Association have been actively engaged in efforts to address fracking. The national Alliance of Nurses for Healthy Environments has received several grants to help coordinate nurses' educational and policy efforts on fracking, to keep current on scientific studies, and to develop nursing spokespeople and leadership around this critical issue.

Increasingly, we are seeing nurses on boards, commissions, and advisory councils for environmental health. The national Children's Environmental Health Network has a nurse on its board of directors, and the EPA's Children's Health Protection Advisory Committee has several nurses. Maryland's Commission on Environmental Justice and Sustainable Communities also includes several nurses. Ensuring that nurses are involved with these councils and commissions requires that we be proactive, contacting the chairpersons and staff of such bodies, finding out when a seat will become available, having a state or national nurses association make a nomination or support a nomination, and, or course, finding nurses willing to take on these roles.

Evidence of the negative human and ecologic health effects of fracking are emerging, and it should be noted that sufficient evidence has been presented to the ANA, the American Public Health Association, and the American Medical Association's Resident and Fellow Section to result in a call for a moratorium on the issuance of new fracking permits nationally. Nurses' voices in our communities, in state legislatures, in Congress, and with the EPA can help to keep health issues front and center as we address national energy needs and policies. ▼

Ruth McDermott-Levy is an assistant professor at the Villanova University College of Nursing, Villanova, PA; Nina Kaktins is an adjunct nursing professor at the Chatham University College for Continuing and Professional Studies, Pittsburgh, PA; and Barbara Sattler is a professor at the University of San Francisco School of Nursing and Health Professions. Contact author: Ruth McDermott-Levy, ruth.mcdermott.levy@villanova.edu. *The authors have disclosed no potential conflicts of interest, financial or otherwise.*

REFERENCES

1. Damascus (PA) Citizens for Sustainability. *List of the harmed*. 2012. http://www.damascuscitizensforsustainability.org/2012/05/list-of-the-harmed.
2. Bamberger M, Oswald RE. Impacts of gas drilling on human and animal health. *New Solut* 2012;22(1):51-77.
3. Colborn T, et al. Natural gas operations from a public health perspective. *Hum Ecol Risk Assess* 2011;17(5):1039-56.
4. Perry SL. Using ethnography to monitor the community health implications of onshore unconventional oil and gas developments: examples from Pennsylvania's Marcellus Shale. *New Solut* 2013;23(1):33-53.
5. Costello A, et al. Managing the health effects of climate change: Lancet and University College London Institute for Global Health Commission. *Lancet* 2009;373(9676):1693-733.
6. McKenzie LM, et al. Human health risk assessment of air emissions from development of unconventional natural gas resources. *Sci Total Environ* 2012;424:79-87.
7. Peng RD, et al. Emergency admissions for cardiovascular and respiratory diseases and the chemical composition of fine particle air pollution. *Environ Health Perspect* 2009;117(6):957-63.
8. Penney S, et al. *Estimating the health impacts of coal-fired power plants receiving international financing*. Washington, DC: Environmental Defense Fund; 2009. http://www.edf.org/sites/default/files/9553_coal-plants-health-impacts.pdf.
9. Suwanwaiphatthana W, et al. Outdoor air pollution and children's health. *Pediatr Nurs* 2010;36(1):25-32.
10. Tzivian L. Outdoor air pollution and asthma in children. *J Asthma* 2011;48(5):470-81.
11. Hajat S, et al. Heat-related and cold-related deaths in England and Wales: who is at risk? *Occup Environ Med* 2007;64(2):93-100.
12. Medina-Ramon M, Schwartz J. Who is more vulnerable to die from ozone air pollution? *Epidemiology* 2008;19(5):672-9.
13. Miller CA. In: *Nursing for wellness in older adults*. 5th ed. Philadelphia: Wolters Kluwer Health/Lippincott Williams and Wilkins; 2009. p. 442-5.
14. Villeneuve PJ, et al. Short-term effects of ambient air pollution on stroke: who is most vulnerable? *Sci Total Environ* 2012;430:193-201.
15. Garfield County, Colorado. *Environmental health: Battlement Mesa HIA/EHMS:Battlement Mesa health impact assessment (second draft)*. Glenwood Springs, CO; 2011. http://www.garfield-county.com/environmental-health/battlement-mesa-health-impact-assessment-draft2.aspx.
16. Martinez LF. Can you hear me now? Occupational hearing loss, 2004-2010. *Mon Labor Rev* 2012;135(7):48-55.

17. Mode Na, et al. Fatalities among oil and gas extraction workers—United States, 2003-2006. *MMWR Morb Mortal Wkly Rep* 2008;57(16):429-31.
18. Esswein E, et al. Worker exposure to crystalline silica during hydraulic fracturing. Atlanta: Centers for Disease Control and Prevention; 2012.
19. U.S. Energy Information Administration. *Annual energy review 2011*. Washington, DC: Office of Energy Statistics, U.S. Department of Energy; 2012 Sep 27. DOE/EIA-0384(2011). http://www.eia.gov/totalenergy/data/annual/pdf/aer.pdf.
20. U.S. Environmental Protection Agency, Office of Research and Development. *Hydraulic fracturing research study*. Washington, DC; 2010 Jun. EPA/600/F-10/002. Science in action; www.epa.gov/safewater/uic/pdfs/hfresearchstudyfs.pdf.
21. Kargbo DM, et al. Natural gas plays in the Marcellus Shale: challenges and potential opportunities. *Environ Sci Technol* 2010;44(15):5679-84.
22. New York City Department of Environmental Protection, Hazen and Sawyer, and Leggette, Brashears and Graham. *Final impact assessment report: impact assessment of natural gas production in the New York City water supply watershed*. New York: New York City Department of Environmental Protection; 2009 Dec 22. http://www.nyc.gov/html/dep/pdf/natural_gas_drilling/12_23_2009_final_assessment_report.pdf.
23. Witter RZ. *Use of health impact assessment to help inform decision making regarding natural gas drilling permits in Colorado*. Glenwood Springs, CO: Garfield County (CO) Board of County Commissioners; 2010 Oct 4. http://www.garfield-county.com/public-health/documents/BOCC_Draft_HIA_Presentation_10_4_10%5B1%5D.pdf.
24. Witter RZ, et al. *Use of health impact assessment (HIA) to help inform decision making regarding natural gas drilling permits in Colorado [podcast]*. Pittsburgh, PA: Center for Instructional Development and Distance Education, University of Pittsburgh; 2010.
25. Howarth RW, et al. Methane and the greenhouse-gas footprint of natural gas from shale formations. *Clim Change* 2011;106(4):679-90.
26. Osborn SG, et al. Methane contamination of drinking water accompanying gas-well drilling and hydraulic fracturing. *Proc Natl Acad Sci U S A* 2011;108(20):8172-6.
27. Roberts JS. Testimony of J.Scott Roberts, Deputy Secretary for Mineral Resources Management, Department of Environmental Protection (Pennsylvania) May 20, 2010. http://www.pagoppolicy.com/Display/SiteFiles/112/Hearings/5_20_10/5_20_10_Roberts_Testimony.pdf.
28. Jackson RB, et al. *Research and policy recommendations for hydraulic fracturing and shale-gas extraction*. Durham, NC: Duke University, Center on Global Change; 2011. http://www.nicholas.duke.edu/cgc/HydraulicFracturingWhitepaper2011.pdf.
29. DiGiulio DC, et al. *Investigation of ground water contamination near Pavillion, Wyoming [draft]*. Ada, OK: Environmental Protection Agency, Office of Research and Development, National Risk Management Research Laboratory; 2011 Dec. EPA 600/R-00/000. http://www.epa.gov/region8/superfund/wy/pavillion/EPA_ReportOnPavillion_Dec-8-2011.pdf.
30. Agency for Toxic Substances and Disease Registry. *Toxicological profile for total petroleum hydrocarbons (TPH)*. Atlanta: U.S. Department of Health and Human Services, Public Health Service; 1999 Sep. http://www.atsdr.cdc.gov/toxprofiles/tp123-p.pdf.
31. Agency for Toxic Substances and Disease Registry. *Toxicological profile for benzene*. Atlanta: U.S. Department of Health and Human Services, Public Health Service; 2007 Aug. http://www.atsdr.cdc.gov/toxprofiles/tp3.pdf.
32. Agency for Toxic Substances and Disease Registry. *Toxicological profile for xylene*. Atlanta: U.S. Department of Health and Human Services, Public Health Service; 2007 Aug. http://www.atsdr.cdc.gov/toxprofiles/tp71.pdf.
33. Commonwealth of Pennsylvania General Assembly. An act amending Title 58 (Oil and Gas) of the Pennsylvania Consolidated Statutes Harrisburg, PA 2012.
34. Riedl M, Diaz-Sanchez D. Biology of diesel exhaust effects on respiratory function. *J Allergy Clin Immunol* 2005;115(2):221-8.
35. Law A, Hays J. Insights on unconventional natural gas development from shale: an interview with Anthony R. Ingraffea. *New Solut* 2013;23(1):203-8.
36. Chang YK, et al. The short-term effects of air pollution on adolescent lung function in Taiwan. *Chemosphere* 2012;87(1):26-30.
37. Office of Air Quality Planning and Standards, Outreach and Information Division. *Air quality index: a guide to air quality and your health*. Research Triangle Park, NC: U.S. Environmental Protection Agency 2009 Aug. EPA-456/F-09-002. http://www.epa.gov/airnow/aqi_brochure_08-09.pdf.
38. Manney S, et al. Association between exhaled breath condensate nitrate + nitrite levels with ambient coarse particle exposure in subjects with airways disease. *Occup Environ Med* 2012;69(9):663-9.
39. Haberzettl P, et al. Exposure to ambient air fine particulate matter prevents VEGF-induced mobilization of endothelial progenitor cells from the bone marrow. *Environ Health Perspect* 2012;120(6):848-56.
40. Turner MC, et al. Long-term ambient fine particulate matter air pollution and lung cancer in a large cohort of never-smokers. *Am J Respir Crit Care Med* 2011;184(12):1374-81.
41. McDonald JC, et al. Mortality from lung and kidney disease in a cohort of North American industrial sand workers: an update. *Ann Occup Hyg* 2005;49(5):367-73.
42. Office of Radiation and Indoor Air, Radiation Protection Division. *Technical report on technologically enhanced naturally occurring radioactive materials from uranium mining—volume 1: mining and reclamation background*. Washington, DC: U.S. Environmental Protection Agency; 2008 Apr. EPA 402-R-08-005.
43. Office of Radiation and Indoor Air, Radiation Protection Division. *Technical report on technologically enhanced naturally occurring radioactive materials from uranium mining—volume 2: investigation of potential health, geographic, and environmental issues of abandoned uranium mines*. Washington, DC: U.S. Environmental Protection Agency; 2008 Apr. EPA-402-R-08-005. http://www.epa.gov/rpdweb00/docs/tenorm/402-r-08-005-volii/402-r-08-005-v2.pdf.
44. U.S. Environmental Protection Agency. *About TENORM*. n.d. http://www.epa.gov/radiation/tenorm/about.html.
45. American Nurses Association. *ANA's principles of environmental health for nursing practice with implementation strategies*. Silver Spring, MD; 2007. http://www.nursingworld.org/MainMenuCategories/WorkplaceSafety/Healthy-NurseANAsPrinciplesofEnvironmentalHealthforNursingPractice.pd.
46. American Nurses Association, House of Delegates. *Resolution: nurses' role in recognizing, educating and advocating for healthy energy choices*. Silver Spring, MD; 2012. http://www.nursingworld.org/MainMenuCategories/WorkplaceSafety/Healthy-Work-Environment/Environmental-Health/PolicyIssues.
47. Pennsylvania State Nurses Association. *Nurses promote healthier energy choices*. 2012. http://psna.org/2012/07/nurses-promote-healthier-energy-choices.
48. McDermott-Levy R, Kaktins N. Preserving health in the Marcellus region. *Pa Nurse* 2012;67(3):4-10.
49. Goldstein BD, et al. Missing from the table: role of the environmental public health community in governmental advisory commissions related to Marcellus Shale drilling. *Environ Health Perspect* 2012;120(4):483-6.