among Americans overall.[7] Past reforms—notably the ACA—fail to receive the credit they deserve, especially for enhancing children's use of preventive dental care services.[2] As a society, we need to fulfill the promise of health care for all, and develop integrated and humane models of care that include the mouth in the rest of the body for adults, too. AJPH

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All Columbia University, New York University, and University at Buffalo institutional review board and Health Insurance Portability and Accountability Act safeguards were followed.

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The Rush to Drill for Natural Gas: A Five-Year Update

Follow-up on: Finkel ML, Law A. The rush to drill for natural gas: a public health cautionary tale. Am J Public Health. *2011;101(5):785–85.*

Five years ago, *AJPH* published our article[1] discussing the potential harm to the environment and human health from horizontal drilling and high-volume hydraulic fracturing of shale (e.g., fracking; hereafter referred to as unconventional gas development or UGD). At that time, the United States was importing oil and gas to meet its energy needs, gasoline prices at the pump were at record high levels, and UGD was proceeding at a rapid pace. There was a paucity of empirical data to confirm or refute the potential for harm from the process of drilling, extracting, and transporting natural gas and oil trapped in formations of low permeability (e.g., shale). We concluded that much remained unknown about the potential for harm from UGD and advocated that preventive, cautionary action should be taken in the face of uncertainty. Given the lax regulatory climate at the time, we felt that the burden of proof should be shifted to the industry to minimize degradation and damage to the public's health and the environment.

Since 2011, there has been not only a surge in drilling for natural gas and oil in the United States (e.g., California, Colorado, Louisiana, North Dakota, Pennsylvania, Texas) and in other countries (e.g., Australia), but also a huge increase in the number of published studies focused on environmental and public health impacts associated with UGD. Nearly 700 peer-reviewed publications, most published since 2013, provide empirical evidence of the various environmental, health, and societal effects of UGD. Potentially serious consequences associated with UGD have become more clearly defined.

Environmental and health impacts are evident at every stage of UGD, including construction of well pads, drilling the wells, extracting the gas, storing the byproducts of the extraction (e.g., flowback fluids), transporting the natural gas by diesel trucks, construction of compressor stations, and building pipelines. Well blowouts, spills, and release of methane into the atmosphere occur to the detriment of the environment. Of particular concern is the use of chemicals, many known to be carcinogens, in the extraction phase. Industry is legally protected from disclosing the composition of chemical mixtures, making it very difficult to determine the consequences of exposure in the short and long term.

Management (storage, treatment and disposal) of flowback wastewater containing thousands of gallons of toxic chemicals is often lax, creating a situation of potential danger to those living in areas where UGD is active as well as to those living out of the region. Proper disposal of flowback fluids is critically important to the protection of both surface and ground water. Flowback wastewater can be stored in containment pits or tanks on site, but there are problems with this option. The failure of a tank, pit liner, or the line carrying fluid ("flowline") can result in a release of contaminated materials directly into surface water, shallow ground water, and soil. Streams and aquifers have been polluted from flowback wastewater.

Although some drill operators recycle flowback wastewater to be used again in the extraction phase, another option is to transport the wastewater to water

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treatment facilities authorized to treat and discharge flowback wastewater. However, the majority of these facilities are not equipped to treat the total dissolved solids in flowback fluids, which can reach extremely high levels of both concentration and variability. Flowback wastewater also has been sprayed on local roads, which, while perhaps expedient, is not the most prudent way to dispose of the fluid.

There is now ample empirical evidence to link shale gas development to surface and groundwater contamination.[2,3] Furthermore, there is strong evidence of an association between the injection of flowback fluids into underground injection wells and an increase in the frequency of earthquakes.

Air pollutants, such as hydrogen sulfide, nitrogen oxides, volatile organic compounds (e.g., benzene and formaldehyde), particulate matter, sulfur dioxide, and ground level ozone, are emitted or produced and released during all of the drilling and extracting phases.[4] Especially worrisome is the release of airborne pollutants during well venting, flaring, and burning gas on release. Truck traffic and diesel truck exhaust also contribute to airborne emissions of fugitive dust, fine particulate matter, and high benzene concentrations. Fugitive methane (emissions that are not captured for use) has considerable climate implications, as does the contamination of well water. Unconventional gas is predominantly methane, which is estimated to have a global warming potential 25 times greater than carbon dioxide over a 100-year period.[5]

Alarmed by "increasingly harmful environmental trends," the Rockefeller Foundation–Lancet Commission on planetary health was formed to address changes to the environment, including climate change, ocean acidification, land degradation, and water scarcity, on human health.[6]

A less well-known harm to the environment is the despoliation of farmland as a result of silica sand mining (frac sand), which is a necessary ingredient in the hydraulic fracturing process. Illinois, Wisconsin, and Minnesota have some of the richest agricultural land areas in the United States, areas that sit atop huge deposits of fine silica sand (St. Peter sandstone). Silica is used to keep the fissures in the rock open (a proppant) so that the locked-in oil and gas can escape. Silica sand mining has led to the destruction of large areas of Midwestern farmland. From a public health perspective, inhaling crystalline silica can lead to serious, sometimes fatal illnesses, including silicosis, lung cancer, tuberculosis (in those with silicosis), and chronic obstructive pulmonary disease.

In addition to the potential for harm to the environment, epidemiological studies are providing evidence of potential harm to health. Exposure to ozone, particulate matter, silica dust, benzene, and formaldehyde is linked to adverse respiratory health effects, particularly in infants and children.[7] Recent empirical evidence shows an increase in adverse birth outcomes (e.g., preterm birth, low birth weight) in areas with active drilling, especially among women living close to gas wells.[8] Also documented is an increase in hospital utilization rates (admissions for cardiac and neurologic conditions in particular) among those living in proximity to wells,[9] and mental health problems have been shown to be associated with proximity to drilling sites.[10] Adverse effects must be understood in context of proximity to drilling sites, the nature of the exposure, exposure pathways, route of exposure, and length of time exposed. There must be an understanding of potential confounding factors, especially behavioral factors, such as tobacco smoking, diet, and occupation history.

Although some symptoms and diseases may appear fairly quickly, others will take more time to develop. Diseases with long latency periods (e.g., cancer, chronic respiratory illness, impaired cognition, neurologic impairment) will not be evident for years and will depend on the nature and duration of the exposure. For example, to what extent will the chemicals used in UGD have the potential to negatively affect the endocrine system? Colborn[11] evaluated hundreds of chemicals used in the drilling and extraction process and found that more than one third of these chemicals were endocrine disruptors, which could produce adverse developmental, reproductive, neurologic, and immune effects in humans. The hydraulic fracturing process releases toxic and cancer-causing chemicals such as benzene, toluene, and xylene (BTEX). To what extent will exposure lead to reproductive, metabolic, neurologic, and other diseases, especially in children and pregnant women?

Since our article was published, oil and natural gas prices have plummeted to record lows. There is a global glut of oil and gas, and the United States has become a net energy exporter thanks to the shale gas boom. Yet, there are valid, nagging concerns about UGD, prompting many countries (e.g., Bulgaria, France, Germany, Netherlands, Scotland, Spain, Wales) and states (e.g., Maryland, New York, and municipalities in areas of California, Colorado, Texas) to issue a moratorium on hydraulic fracturing, citing the need for more empirical evidence about the consequences of UGD.

As nations debate the merits of UGD, there needs to be a strong public health and environmental presence in the debate. Baseline health data need to be collected before drilling to assess changes in disease incidence over time. Biomonitoring studies to document ambient air quality during the drilling and extraction phases of UGD need to be done to assess the impact on air pollution. Chemicals used in the process must be disclosed to assess the potential for harm to human health. There needs to be a better way to manage flowback wastewater so as not to pollute water sources.

In our 2011 article, we called for a balance between the need for energy with the protection of the public's health. Five years later, mounting empirical evidence shows harm to the environment and to human health from UGD, and we have no idea what the long-term effects might be. We again stress the importance, indeed urgency, to focus on fair and sensible energy policies, and to be mindful of the implications that such policies have on our environment and on population health. Ignoring the body of evidence, to us, is not a viable option anymore. AJPH

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A Public Health of Consequence: Review of the October 2016 Issue of *AJPH*

In this issue of AJPH, Farley's editorial "Asking the Right Questions: Research of Consequence to Solve Problems of Significance"[1] provides a helpful lens through which we can both think about scholarship of consequence and view the original research articles in this month's issue of *AJPH*. Farley's piece starts with a delightful quote from Thomas Pynchon: "If they can get you asking the wrong questions, they don't have to worry about the answers." This quote well illustrates the concept that has sometimes been referred to as "lamppost bias"; that is, unless we are looking for answers in the right places we are unlikely to find solutions to some of the more pressing public health problems of our time. Farley offers four priorities for research that asks the right questions. Here is a brief comment on each, with-reference to some of the articles in this issue of *AJPH*.

UBIQUITOUS PROBLEMS

First, Farley suggests that to improve population health, we should be tackling ubiquitous problems—doing less for more people. This core principle of population health science posits that substantial improvements in population health are likelier through acting on exposures that are shared by many. This is simply and elegantly illustrated by Kennedy et al.[2] Cost-related nonadherence to treatment dropped from 5.4% to 3.6% among seniors after the implementation of Medicare Part D and from 9.1% to 7.9% among adults aged 26 to 64 years after the implementation of the Affordable Care Act (ACA). Kennedy's analysis shows that Medicare Part D and the ACA did a little bit, but for a large number of people. These data highlight the potential of large-scale policy change, with both utility for real-life evaluation of active policy and guidance for future research and policy development.

THINKING FORWARD, WORKING BACKWARD

Second, Farley offers the interesting concept of thinking forward and working backward; namely, identifying policy prescriptions that can improve health or minimize social divides and then using these policies as a guide to the questions that may attend their implementations. As a practical example, Wendel et al.[3] recruited students from elementary schools in Texas, calculating body mass index (BMI) before and after a two-year period of using standing desks. Despite some challenges to the intervention implementation, a 5.3% difference in BMI percentile change occurred among students in a stand-biased classroom compared with students in the control classroom. Will standing desks in elementary schools have a substantial impact on childhood obesity? This study is unable to answer that question but offers an opportunity to work backward and evaluate the idea and its feasibility for widespread implementation.

LEARNING BY WATCHING

Third, we can learn and observe by watching. Articulating a principle akin to using natural experiments (the subject of another invited commentary in this section[4]), Farley suggests that in a large heterogeneous country, broader-based action can be informed by the impact of particular jurisdictions, as illustrated by Falbe et al., who evaluated the impact of the tax on sugar-sweetened beverages in Berkeley, California.[5] This first US jurisdiction to implement such a tax in March 2015 resulted in a 21% reduced in sugar-sweetened beverage consumption, while consumption increased in comparison cities; water consumption increased more in Berkeley than in comparison groups. Can excise taxes on sugar-sweetened beverages make a dent in obesity across the country? Perhaps. The

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