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Review Paper

The implications of unconventional drilling for natural gas: a global public health concern

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ABSTRACT

Unconventional drilling for natural gas by means of high volume horizontal hydraulic fracturing (fracking) is an important global public health issue. Given that no sound epidemiologic study has been done to assess the extent of exposure-related adverse health effects among populations living in areas where natural gas extraction is going on, it is imperative that research be conducted to quantify the potential risks to the environment and to human health not just in the short-term, but over a longer time period since many diseases (i.e., cancers) appear years after exposure. It should not be concluded that an absence of data implies that no harm is being done.

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The world's insatiable appetite for energy continues unabated. China retains its position as the world's largest energy consumer followed by the United States, India, Russia, and Japan.[1] While oil and coal remain the predominant energy sources worldwide, 34% and 30%, respectively, the search for clean, safe, efficient, economic alternatives is a high priority for both industrial and emerging nations. Natural gas (24% of the world's energy source), hydropower (6% of the world's energy source) and nuclear energy (5% of the world's energy source) are promoted as cleaner energy alternatives.[2] Of course, there are pros and cons to each of these energy sources.

Natural gas, a non-renewable resource, has a clean reputation compared to other fossil fuels. Specifically, natural gas burns more cleanly than the other fossil fuels, emitting less carbon dioxide than coal or oil when combusted. For many reasons, the global demand for natural gas remains very strong. Primarily because of perceived economic incentives, as well as recent technological innovations, natural gas has emerged as a key energy source for industrial uses and for electricity generation around the world.

Most natural gas is currently extracted from conventional deposits, where it has migrated from a source rock and been trapped, typically found in porous rock such as sandstone. A significant type of unconventional gas deposits is found distributed in relatively impermeable rock formations such as shale. Shale gas, once extracted, is identical to conventional natural gas. For years, extracting natural gas from vast shale deposits was too costly and technologically-challenging. Such was the case until a new, unconventional drilling technology, horizontal drilling and high volume hydraulic fracturing of shale (generally referred to in the media as fracking or

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hydraulic fracturing), was introduced. Hydraulic fracturing, used in combination with several other recent key technologies such as directional drilling, slickwater, and clustered multiwell pads, has enabled natural gas extraction from geologic formations of extremely low permeability. This method of production entails injecting large volumes of fracturing fluid (comprised of water, sand, and chemicals) several thousand feet underground creating or re-opening cracks or fissures in the shale formation, thus releasing trapped gas.

The United States, in particular, has aggressively embraced unconventional drilling technology; its experience should serve as an example to other countries considering embracing this procedure. Proponents argue that drilling is America's best chance to become energy-self sufficient, while its detractors maintain that shale gas development should be avoided at all costs. Others taking a more cautious position say that the potential risk to the environment and human health should be investigated and safeguarded before more wells are drilled. Ironically, the shale gas boom has positioned the United States to become an overall net exporter of natural gas.[3] Indeed, the natural gas industry now has a glut so vast that import facilities are applying for licenses to export gas to Europe and Asia.[2]

Environmental concerns

There is a growing concern that the serious and dirty downside to natural gas needs to be addressed before irreparable damage is done to the environment and to human health. For example, there are significant concerns surrounding its implications for the climate. Natural gas is mostly methane, a potent greenhouse gas, which when emitted raises concerns about contributing to global warning. Studies have shown that approximately 3.6–7.9% of the methane from shale gas production escapes to the atmosphere in venting and leaks over the lifetime of a well.[4] Recent studies by the National Oceanic and Atmospheric Administration have indicated that methane is leaking at rates even higher than previously anticipated.[5] These methane emissions are estimated to be more than twice as great as those from conventional gas. Experts maintain that unless methane emissions get under control, the planet will be headed toward a global warming tipping point within the next 15–35 years.[6]

There also is the question of what exactly is being injected into the wells. Hydraulic fracturing for shale gas from a single well relies on pumping as much as five million gallons of water mixed with tons of chemicals (many known to be toxic) and solids (sand) under high pressure to create fractures and open joints into the shale formation, thus releasing the flow of gas to the surface. Gas operators in the US are allowed to protect their proprietary formulas and they do not have to disclose the chemical compounds used in the fracking process. This makes it difficult, if not impossible, to monitor for chemical compounds that may be ending up in the environment after the well is hydrofracked. Thirty to seventy percent of the fracking fluid will resurface bringing back with it toxic substances, including heavy metals, naturally occurring radioactive materials (NORMs), and seriously toxic and volatile organic compounds including benzene, a known carcinogen. Colburn et al. identified almost 1000 chemical products and nearly 650 individual chemicals used in natural gas operations, many of which have the potential to cause adverse health effects as well as to potentially cause deleterious effects to the environment.[7] Yet, the industry remains steadfast in protecting their proprietary formulas, and the federal government to date has not intervened.

As the wells continue to be drilled, high volume horizontal hydraulic fracturing has attracted increased scrutiny from lawmakers, environmentalists, and public health advocates in part because of fears that the chemicals used in the process could contaminate underground sources of drinking water. Concerns about the impact on the environment are complicated by the fact that the natural gas industry in the US has obtained exemptions or exclusions from key parts of major federal environmental laws designed to protect air and water. Due to the very large volumes of toxic materials used in unconventional drilling over large areas involving tens of thousands of wells, there is a very real issue of possible contamination of surface and underground water.

In the large Marcellus shale, two important watersheds that supply millions of people with drinking water are at risk. Dimock, Pennsylvania, for example, was the centre of a fierce debate over the environmental and public health impacts of unconventional natural gas extraction. The EPA sampled well water at dozens of homes and the initial test results did not show levels of contamination that would present a health concern. However, some residents are suing Cabot Oil & Gas Corporation over a contaminated aquifer with explosive levels of methane gas. The residents assert that their water is polluted with drilling chemicals. The company denies the charge.[8] In August of 2012 Cabot reached settlements with 32 of 36 Dimock families who were suing for damages. Other cases are still pending.

A related key issue that needs to be addressed is what to do with the wastewater, the byproduct of the drilling process. Presently, wastefluids can be held temporarily in reserve pits for drilling muds, fracking fluids, flowback, and contaminated water that surfaces with the gas during the extraction process. Many of the chemicals are considered to be hazardous; e.g., benzene has been identified in the wastewater and in air emissions near natural gas operations.[9] Benzene, while toxic to all humans, has been shown to contribute a disproportionate risk of leukaemia in young children.[10] Disposal of this toxic brew should be of concern to all of us, not just those living in close proximity to the drilling rig, because of the potential for harm to humans and to animals. The flowback can be taken to sewage plants, but it is widely acknowledged that sewage plants are not equipped to handle the contaminants. In some instances there have been reports of directly dumping the untreated wastewater into rivers and streams and there have been reports of wastewater being sprayed on rural roads and forests.[11] In some parts of the United States (e.g., West Virginia) it is legal to spray wastewater on the land. Heavy truck traffic along these roads often kicks up dust, thus further spreading chemical contamination Further, particulate matter from diesel truck traffic interacts with sunlight to form tropospheric, or ground-level ozone, a hazardous respiratory irritant that increases risks of morbidity and mortality.[12]

The New York Times, in its analysis of more than 30,000 pages of federal, state and company records relating to more than 200 gas wells, found that radioactive wastewater from the drilling process has been discharged into rivers that supply drinking water to millions of people in Pennsylvania and Maryland. At least twelve sewage treatment plants in three states have discharged waste that was only partly treated into rivers, lakes and streams, the Times reported. Further, gas has seeped into underground drinking water supplies in five States (Colorado, Ohio, Pennsylvania, Texas, and West Virginia).[13]

Currently, the U.S. Environmental Protection Agency (EPA) does not regulate the injection of fracturing fluids under the Safe Drinking Water Act. This exemption is referred to as the 'Halliburton Loophole'. Although the Safe Drinking Water Act, originally passed by Congress in 1974 and amended in 1986 and again in 1996, authorizes the EPA to set national health-based standards for drinking water to protect against both naturally-occurring and man-made contaminants that may be found in drinking water, the oil and gas industry was granted this exemption in the Energy Policy Act of 2005. This loophole has been the subject of controversy and currently there is not mandatory public disclosure at either the state or federal level.

Several states have pressed for full disclosure of chemicals used in hydraulic fracturing fluid and drilling muds, which eventually prompted the industry to agree in principle to increase transparency of the chemical compositions used in natural gas operations. However, this agreement remains voluntary and excludes those chemicals considered by the company to be proprietary. A recent study from Harvard University found the industry self-reporting chemical disclosure website FracFocus to have serious flaws, with much of its information unreliable and incomplete.[14] In the United States, drilling remains determined by state governments and regulated at the state level, with many of the rules and regulations drafted by the oil and gas industry.

Other environmental issues that must be addressed include the potential for aquifer depletion. Given that huge amounts of water are used in the drilling process, it is not unrealistic that an unintended consequence may be droughts and diminishing water levels in some local aquifers. Additionally, air quality is a serious concern. The quality of air is jeopardized partly because fumes containing toxic hydrocarbons such as benzene, toluene, and xylene are released in the air. Residents living near active wells have complained of noxious odours emanating from the drilling area.

Adverse health effects

The paucity of scientific evidence looking at the public health impact of natural gas extraction complicates the issue. It is difficult to formulate policy and regulations in a vacuum absent data. While there have been anecdotal reports of adverse health effects ranging from minor to serious among those living in close proximity to shale gas drilling, there is a paucity of objective, evidence-based epidemiologic research. To date, for example, there have been no extensive epidemiological studies that assess how the unconventional extraction of natural gas might affect human health. This being said, a small-scale study looking at animal health raised some serious concerns that need to be further investigated.[15] In the absence of studies on human health, animal studies can shed light on the potential harmful effects of drilling. Like the canary in the coal mine, cows, horses, poultry, and other wildlife can be used as sentinels to foreshadow impacts to human health. Animals tend to suffer more direct exposure and have shorter life and reproductive cycles.

Regarding adverse effects on human health, there have been numerous anecdotal reports of respiratory, neurological, reproductive, dermatological, gastrointestinal, and other health complications that are attributed to natural gas operations. Without data from epidemiologic studies, the industry will continue to deny that the gas production process is harmful to human health, and individuals living and working in proximity to shale gas drilling sites will continue to assert that operations are causing illnesses and diseases that prior to drilling were not present. While some negative health effects appear fairly quickly after exposure, others take more time such as cancers, harm to the reproductive and nervous systems, and developmental effects. Of concern is that endocrine-disrupting chemicals may alter developmental pathways, manifesting decades after exposure or even transgenerationally by altering epigenetic pathways. Researchers have identified many potential endocrine-disrupting chemicals in the hydraulic fracturing fluid and the authors know about many of their implications.[16,17]

Policy implications

The economic needs of society need to be appropriately balanced with the protection of the environment and public health. At present, the natural gas industry operates in a world where health and environmental safety measures are self-regulated and laws in the United States are protective of the industry rather than for those living in close proximity to drilling sites. Despite an EPA study of groundwater contamination near Pavillion, Wyoming that suggests a pathway for exposure,[18] no state has adequate regulations on production, particularly related to the disposal of the toxic wastewater fluids despite the massive issuing of drilling permits across the country. Environmental remediation has become the reactionary norm not only in the United States, but also in too many parts of the world.

There are a host of questions and concerns that the industry and policy makers need to address in order to fully assess the potential for harm from unconventional natural gas development. Clearly, there is a need to know much more about the chemicals introduced into the environment during shale gas extraction. There needs to be methodologically well-designed studies upon which policy recommendations should be made. With regard to the public health implications of shale gas development, it should not be concluded that an absence of data implies that no harm is being done. The burden of proof should not be the public's to bear.

Domestic and global reaction

Response to the potential for harm to human and animal health has been varied within the United States and

internationally. In the US, the EPA is studying the safety of hydrofracking, but its final report is not expected until 2014. Meanwhile, many states have taken action including New York State, which has imposed a moratorium on drilling (unlike neighbouring Pennsylvania where drilling continues unabated). Gov. Andrew M. Cuomo's proposal, announced in June 2012, was to permit hydraulic fracturing only in communities that express support for this technology and to limit drilling to the deepest areas of the Marcellus Shale formation in an effort to reduce the risk of groundwater contamination. However, a statewide moratorium is still in effect until the results of a health review, led by the New York State Department of Health's Commissioner, are complete. Vermont, in a symbolic move, banned the use of hydraulic fracturing even though there is very little shale gas in this state. In Ohio, however, property owners in the rural counties of the upper Ohio River Valley, are negotiating lucrative mineral leases. The nation's largest energy companies have spent billions of dollars in leasing so far in anticipation of gas development in the Utica Shale, which lies beneath this part of the state.

In Europe, France, in 2011, became the first country to ban unconventional drilling for natural gas followed by Bulgaria. South Africa lifted a seventeen-month moratorium on drilling in September of 2012, and in the United Kingdom, after two small earthquakes attributed to natural gas operations rocked Lancashire, the process was suspended in June of 2011. However, in April 2012, a governmental advisory committee recommended that fracking for shale gas could resume in the UK with stronger controls enforced. This recommendation was met with a furious outcry with anti-fracking groups angrily denouncing the report.[19]

Some countries are only starting to develop shale gas reserves and remain largely in the exploration phase. China is in the early stages of implementing US technology to develop what has been estimated as the largest technically recoverable shale gas resource of any country in the world. Poland, which currently imports more than 80% of its natural gas from Russia, allegedly has substantial gas reserves. Chevron has permits to explore more than one million acres in southeast Poland. Mozambique, Tanzania, and Kenya have rich deposits and each country is attracting interest among the world's largest energy companies. Africa is posed to be the next huge growth area for natural gas extraction.

Given the real potential for harm, the international community has been called to proceed with caution. The precautionary principle was used to advocate, which asserts that the burden of proof for potentially harmful actions rests on the assurance of safety in areas of scientific uncertainty ('first, do no harm').[20] Inherent in the principle is that preventive action should be taken in the face of uncertainty, the burden of proof should be shifted to the proponents of an activity, alternatives to possibly harmful actions need to be explored, and there should be increased public participation in decision-making. There have been numerous versions of the principle; however, one of the most widely publicized is the Wingspread Declaration, which states: 'When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not established scientifically. In this context the proponent of the activity, rather than the public, should bear the burden of proof'.[21] This principle has influenced the way science informs policy in many countries and with many issues throughout the world.

The difficulty with determining the risks associated with hydraulic fracturing lies in the vast quantity of health and environmental imponderables, as well as a serious lack of transparency in various aspects of the practice itself. In addition to inadequate chemical disclosure, synergistic qualities of these toxic substances in drilling and flow-back fluids are not fully understood. Because of this, it has been suggested that the burden of proof for potentially harmful actions rests on the assurance of safety in areas of scientific uncertainty. It is imperative that research be conducted to quantify the potential risks to human health not just in the short-term, but over a longer time period since many diseases (i.e., cancers) appear years after exposure.

Economic considerations must not be ignored, as many countries may stand to benefit from a cheap, domestic energy source. However, recent research based on data from 65,000 shale wells suggests that well and field productivities exhibit steep declines, production costs in many plays exceed current gas prices, and maintaining production requires ever-increasing drilling.[22] This provides yet further reasons to proceed with caution and not be whirl-winded by notions of an 'energy game changer'.

Concluding thoughts

Until research is properly conducted, the unconventional development of natural gas from shale formations should not occur in places where it is currently prohibited, e.g., New York and Maryland. In places now under development it should be constrained with strong regulations in direct proportion to inspection capability and closely monitored for its impact on the health of populations. There is one comprehensive epidemiologic study currently underway by Geisinger Health Systems that may help to shed some light on the health implications of unconventional natural gas development. This *in silico* epidemiologic study will analyse at 2.6 million electronic health records of patients in 31 Pennsylvania counties for respiratory, cardiovascular, cerebrovascular, and pregnancy outcomes. Research should also investigate other aspects of hydraulic fracturing, including the economic and societal impacts, as well as other environmental assessments including the greenhouse gas footprint of natural gas produced from shale formations.

Natural gas has been in shale formations for millions of years; it isn't going anywhere and will be around for future generations. Society owes it to those living in areas with both active and planned drilling to study the potential for harm (to the environment and to human and animal health) and to act to reduce those factors that are shown to increase the risk of disease and even death.

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