Permitting program with best management practices for shale gas wells to safeguard public health

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Abstract:

The development of shale gas resources in the United States has been controversial as governments have been tardy in devising sufficient safeguards to protect both people and the environment. Alleged health and environmental damages suggest that other countries around the world that decide to develop their shale gas resources can learn from these problems and take further actions to prevent situations resulting in the release of harmful pollutants. Looking at U.S. federal regulations governing large animal operations under the permitting provisions of the Clean Water Act, the idea of a permitting program is proposed to respond to the risks of pollution by shale gas development activities. Governments can require permits before allowing the drilling of a new gas well. Each permit would include fluids and air emissions reduction plans containing best management practices to minimize risks and releases of pollutants. The public availability of permits and permit applications, as occurs for water pollution under various U.S. permitting programs, would assist governments in protecting public health. The permitting proposals provide governments a means for providing further assurances that shale gas development projects will not adversely affect people and the environment.

Keywords: shale gas; pollutants; toxic chemicals; air emissions; permitting program

1. Introduction

Due to concerns about sufficient, affordable energy supplies, the United States has embraced the development of its unconventional hydrocarbon resources including shale gas. The development of these resources using hydraulic fracturing and horizontal drilling has been controversial. Some people feel that the production activities are accompanied by too many health and environmental (collectively referred to as "health") damages (Osborn et al., 2011). To encourage production, the U.S. Congress exempted hydrocarbon development from a number of federal environmental and public safety laws (Centner, 2013; Roberson, 2012). With the absence of these federal safeguards, U.S. state governments have needed to determine what health, safety, and environmental provisions are needed to respond to the risks posed by shale gas extraction (Grinberg, 2014). In general, states allowed production of shale gas to commence before developing comprehensive regulatory safeguards and oversight to respond to all of the expressed concerns (Jackson, 2014; Weinstein, 2013).

With the advent of hydraulic fracturing, various U.S. state governments did not always provide proficient oversight (Rawlins, 2013). Pollution events involving damages to properties and people and the impairment of water and air resources from shale gas wells suggest that the U.S. regulatory framework was too lax (Ely vs. Cabot Oil & Gas Corporation, 2014; Justiss Oil Company vs. T3 Energy Services, Inc., 2011). State legislatures did not always allocate sufficient funds to enable regulatory agencies to hire sufficient personnel (Wiseman, 2014c). This meant the regulatory agencies were delayed in developing essential regulations to safeguard health and performing inspections of wells located over vast distances (Wiseman, 2014a). Budgetary constraints meant that most state governments lacked the personnel necessary to meaningfully enforce their regulations, meaning that firms failing to obey regulatory proscriptions did not suffer any consequences (Fershee, 2014; Wiseman, 2014b). Governments also lacked satisfactory regulations dealing with the structural integrity of older producing wells and abandoned wells (Jackson, 2014).

An example disclosing this conundrum has been reported by Robertson (2013). The state of Ohio had twenty-one oil and gas inspectors in its Division of Mineral Resource Management for investigating citizens' complaints, enforcing and overseeing gas well construction and waste disposal activities, and providing oversight for plugging of wells and site restoration. Assuming the inspectors divided the work equally, each inspector would have been responsible for reviewing and processing 33 drilling permits, 17 wells being plugged, 22 new oil and gas wells, and 2,354 production reports in one year. Given that wells are scattered over considerable areas and the timeliness of an inspection depends on when the well is being drilled or plugged, an inspector might need 39 work days just to inspect each well once.

An examination of governmental responses to negative externalities disclose six factors suggesting that U.S. state governments have underinvested in the protection of people: (1) interference with safety requirements due to economic objectives, (2) time lapses and externalities associated with new technology, (3) lack of scientifically-based maximum contaminant levels and exposure information, (4) obsolescence of management approaches, (5) difficulties in proving damages, and (6) lax oversight and preemption (Centner and Eberhart, 2015). Given this underinvestment, governments should consider developing additional procedures to reduce health damages. Shale gas should only be perceived as a sound environmental option if accompanied by tight regulation (Meng, 2014; Stamford and Azapagic, 2014).

While several issues accompany the development of shale gas reserves, the two major health concerns involve the pollution of water and air resources. In the absence of a federal permitting system, wells have been developed without complete consideration of the associated health risks. For example, the Texas permitting application for new wells fails to request documentation of any environmental quality except applicants must set and cement sufficient surface casing to protect usable-quality water strata (Texas Railroad Commission, 2008).

The lack of fully developed transparent permitting programs for gas wells may be contrasted with the permitting system required for addressing water pollution from concentrated animal feeding operations. Under the Clean Water Act, each farm with the requisite number of animals must secure a permit that meets federal requirements. These permits employ flexible best management practices to reduce releases of pollutants into surface waters to reasonable amounts. In a similar manner, a permitting system could be used to address health damages associated with toxic fluids and air emissions that accompany shale gas extraction. To assist governments around the world in devising appropriate regulations to protect people's health, this paper proposes oversight of shale gas development through a permitting program incorporating best management practices.

2. Dangers and risks associated with shale gas production

Although numerous issues have been raised about potential damages from shale gas development, two have been prominent: (1) the pollution of water and land resources by toxic fluids and (2) emissions of air pollutants. The identification of potential contamination problems provides a foundation for developing management practices to address health concerns.

2.1. Toxic fluids

Most hydraulic fracturing is slickwater fracturing that involves the use of large amounts of water and sand with smaller amounts of other substances and chemicals. Several tons of chemicals are normally used to fracture a well and flowback fluids containing other elements from the rock strata pose pollution issues (Werner et al., 2015). The concern is that toxic chemicals and flowback released during well development and operation will contaminate land, enter the groundwater, or be released into surface waters. The pollution of water resources also includes pollutants in the air that may be deposited on land and surface waters during a precipitation event. A mishap in Texas in April 2015 forcing the evacuation of residents demonstrates the concerns that people may be harmed (Schrock, 2015).

To fracture shale underneath the ground and maximize production, drilling firms employ a number of different chemicals to aid in the recovery of natural gas (Vidic et al., 2013). These may include an acid, biocide, breaker, brine, corrosion inhibitor, crosslinker, demulsifier, friction reducer, gel, iron control, oxygen scavenger, ph adjusting agent, scale inhibitor, and surfactant (Pennsylvania Consolidated Statutes, 2012). Approximately 200,000 liters of chemicals may be used per well (Howarth and Ingraffea, 2011). While some of the chemicals used are not dangerous, others are toxic so that releases of fluids from a well may lead to contamination. Table 1 sets out some of the known toxic substances that may be accidentally released from well sites.

Researchers from several universities collaborated to identify scenarios that could lead to water contamination by fluids accompanying hydraulic fracturing (Vengosh et al., 2014). The first and major concern is that toxic materials may contaminate shallow aquifers in areas adjacent to shale gas development. This generally involves the leakage of methane gas. Multiple reports by persons with groundwater wells near shale gas operations have claimed that methane gas was present in their tap water (Adair et al., 2012). While it is common for aquifers in regions of methane-bearing shales to contain some methane (McKay et al., 2011), concentrations in areas with gas wells may be greater due to leaking well casings (Osborn et al., 2011). A study in Pennsylvania found that methane concentrations in drinking water wells of homes near natural gas wells were six times higher on average than concentrations for water wells of homes farther away (Jackson et al., 2013). Baseline testing is recommended to discern the presence of methane and other gases in groundwater. Water sources are tested before wells are drilled so that the data can serve as a reference point for determining whether gas wells drilled at a later date are contaminating water sources.

A second concern is that spills, leaks, and the disposal of fracturing fluids and inadequately treated wastewaters will cause contamination. While only 0.5 percent of wells may experience a spill (Gross et al., 2013), with more than one million oil and gas wells in the United States (USEPA, 2014c), there may be 5,000 spills per year. Moreover, other sources estimate considerably higher spill-rate estimates, and mixtures of chemicals may cause individual chemicals to become more mobile (USEPA, 2015). Safety procedures are needed to respond to these problems. While state governments have adopted provisions to augment health and safety, evaluations of the provisions have routinely concluded that they are insufficient (Wiseman, 2014a). Furthermore, given that firms fracturing wells are not disclosing all of the chemicals used due to trade-secret exemptions, regulators lack information as to what chemicals might be a source of contamination (Konschnik and Boling, 2014). Given past experiences with MTBE, PCBs, and hazardous wastes, it cannot be determined whether any of the toxic chemicals used in fracturing are causing problems (Rawlins, 2014).

Third, improper wastewater disposal and spills may be causing the accumulation of metals and radioactive elements in stream, river, and lake sediments (Warner et al., 2013; Vengosh et al., 2014). Given the costs of disposing well wastewaters in deep injection wells, a number of alternative disposal methods were tried including treating wastewater at municipal wastewater (sewage) treatment plants and using oil and gas brines for deicing roads. A number of the practices have been stopped due to their association with elevated naturally occurring radionuclide levels in nearby soils and streams (Vengosh et al., 2014). However, these activities show inadequate regulatory oversight in forestalling contamination of land and water resources. More can be done to improve the effectiveness of the management of dangerous wastes (Rahm et al., 2013).

Another issue is whether the withdrawal of large amounts of fresh water in an area may alter the ecology with adverse repercussions for plant and animal species and ecosystem services (Sovacool, 2014; USEPA, 2015). The efficient use of water is important in areas where water is scarce and in areas where it is costly to dispose of produced water (Gallegos et al., 2015; Lester et al., 2015).

2.2. Air emissions

A number of activities and equipment failures can lead to unnecessary air pollutants being released during shale gas development that adversely affect health and contribute to global warming (Table 2). The U.S. Environmental Protection Agency (USEPA) lists several harmful pollutants being emitted from shale gas development including benzene, toluene, ethylbenzene, and xylenes, criteria pollutants, ozone precursors such as nitrous oxides and volatile organic compounds (VOCs), and methane (USEPA, 2013a). Emissions for shale gas extraction are contributing to health problems such as increased risk of eye irritation and headaches, asthma symptoms, acute childhood leukemia, acute myelogenous leukemia, and multiple myeloma (McKenzie et al., 2012). A list of some of the most common non-methane VOCs emitted from shale gas development that may cause adverse health effects are set forth in Table 3.

The most obvious concern is the release of natural gas: methane. The leakage of methane from production to final usage is estimated to be as high as 2.8% of the U.S. domestic natural gas production (Moore et al., 2014). Methane has a global warming potential of 28−34 times that of carbon dioxide over a 100-year time frame (Moore et al., 2014). The large quantities of air pollutants from shale gas extraction for the Dallas-Fort Worth, Texas region were estimated to contribute more to the area's VOCs than the combined emissions from cars, trucks, buses, and other on-road mobile sources (Rawlins, 2013).

The second category of major air pollutants accompanying shale gas extraction occurs from the venting and flaring of methane and other gases at individual wells, which can release more than 60 pollutants into the air including methane and cancer-causing benzene (Eldean, 2014). Gases are vented or flared because the costs of collecting them are prohibitive. The EPA estimates that one-half of new oil wells co-produce natural gas that in some instances is flared or vented (USEIA, 2013; USEPA, 2014b). In, 2012, the USEPA adopted new federal emissions standards for the oil and gas industry that limit some releases of gases from shale gas wells (USEPA, 2012a). The new regulations reduce situations where gases at a well are vented into the atmosphere. Rather than venting gases, the regulations encourage the combustion of the gases by "flaring." Rules requiring a high-temperature oxidation process to burn combustible components in escaping gases can further minimize vented gas during a well completion and reduce air emissions (USEPA, 2014b). The federal regulations only apply to new gas wells, so wells producing oil are exempted (USEPA, 2014a; USCFR, 2015).

The third category of air pollutants comes from equipment used in the development and transport of natural gas. Research shows considerable VOC emissions from diesel engines, process heaters, combustors, treaters, dehydrators, condensate tanks, and pneumatic devices (USEPA, 2012c, 2013a, 2014c; Warneke et al., 2014). For nitrous oxides, major emissions come from drilling rigs, compressor engines, artificial lift engines, and heaters. Additional fugitive emissions come from leaks in oil and gas pipelines from wellheads to the compressor stations. U.S. federal regulations enunciate new source performance standards that limit VOC emissions during well completion by requiring the use of green completion technologies in qualifying situations. It is estimated that these new requirements will result in a 95% reduction of VOC emissions and a 99.9% reduction in sulfur dioxide (USEPA, 2012a). Other regulations limit emissions of VOCs from a new single oil or condensate tank to four tons per year and limit releases of benzene, toluene, ethylbenzene, and xylenes from a single dehydrator to one ton per year (USEPA, 2014b).

Another category of VOC emissions consists of compressors that push natural gas through pipelines to market. U.S. federal provisions adopted in 2014 focused on VOC emissions from two types of compressors located in the natural gas production segment and the natural gas processing segment up the point at which the gas enters the transmission and storage segment (USEPA, 2012a). Centrifugal compressors with wet seals must reduce VOC emissions by 95% and reciprocating compressors must have regular maintenance to keep them from leaking VOCs. However, compressors used in the transmission, storage, and distribution segments of gas delivery are not covered by this federal requirement so that VOCs from shale gas development remain a source of pollution (see Table 1).

A fifth source of air pollutants comes the release of VOCs and non-methane hydrocarbons from fracturing fluids and produced water (Center for Sustainable Shale Development, 2013; Colborn et al., 2014; Werner et al., 2015). To counter the evaporation of these hydrocarbons, closed-loop systems are advocated (Center for Sustainable Shale Development, 2013). While some firms are voluntarily moving to closed-loop systems, the volatilization of gases from fracturing fluids, flowback, and produced water remains a source of air pollution.

A number of researchers have analyzed the presence of air emissions from shale gas wells and some of the research suggests that wells are not subjecting people to excessive levels of air pollutants (Bunch et al., 2014; Bloomdahl et al., 2014). However, the research did not look at all of the various types of VOCs emitted from wells. Rather, the research only analyzed VOCs with federal and state health-based air-comparison values. A majority of these standards fail to consider the long-term exposure affects of emissions due to the absence of data. Because there are other VOCs being emitted from wells as well as combinations of VOCs that are not covered by federal and state health-based air values, the research does not confirm the absence of adverse health effects from shale gas wells (Werner et al., 2015). This has led some to recommend additional regulation of pollutant sources (Olaguer, 2012). This might include reporting of emission events, more aggressive deployment of control strategies, use of oxidation catalysts on stationary engines, and requirements on management practices.

3. Governmental failures in protecting health

The logistics of oversight of shale gas extraction activities raises questions about the adequacy of protection of health (Colborn et al., 2014; Shonkoff et al., 2014; Wiseman, 2014a). In facilitating the creation of jobs and economic activities, have state legislatures neglected to look at long-term health consequences? Research suggests that given the risks for health damages, there has been an underinvestment in regulatory controls to protect people (Adgate et al., 2014; Burleson, 2013; Centner and Eberhart, 2015; Steinzor et al., 2012).

3.1. Notable limitations

A major anti-health stance taken by state legislatures has been to exempt firms from reporting the use of toxic chemicals used in fracturing wells. While generalized information is available from material safety data sheets filed for wells, emergency and medical personnel as well as landowners may not know the exact chemical combinations used at wells until they qualify for the release of additional information. New U.S. federal regulations governing drilling on federal lands adopted in 2015 continue with exemptions for disclosure of information; however, they qualify the exemption through a requirement involving competitive harm (US Department of the Interior, 2015). Most other industrial activities have to report the use of toxic materials under the U.S. Emergency Planning and Community Right to Know Act (U.S. Code, 2012). State legislatures might consider assuaging some of the health concerns of the public by requiring information of all chemicals used in hydraulic fracturing be available to the public.

Legislative animosity to health issues has been incorporated in state laws that preempt local governments from regulating shale gas extraction. Several state legislatures have decided that they do not want local citizen participation and governance to address health issues regarding shale gas activities (Table 4). The justification for limitations on democratic governance is that the economic well-being of the state is dependent on allowing shale gas extraction to proceed unimpeded by local regulations. In Colorado, the preemption of local regulation of shale gas development has led groups to advocate the right to local self-governance through a state constitutional amendment (Colorado Community Rights Network, 2014).

A final limitation regarding adequate governmental oversight is the under-enforcement and even nonenforcement of existing regulations (Earthworks, 2012). Governmental oversight of activities involved with the extraction of shale gas is difficult given the pace of new technology and new information concerning carcinogenicities of various chemicals. Legislators and regulators have not been able to keep up with responding to problems (Hurdle, 2015). In efforts to reduce public expenditures, governments have cut regulatory budgets of agencies that enforce laws and regulations governing health. Agency staffs and training programs are inadequate for the tasks that should be performed. For the USEPA, the U.S. Government Accountability Office found the agency was constrained in reviewing state regulations due to inadequate staffing (U.S. GAO, 2014).

In the absence of sufficient personnel, enforcement actions only occur in a few cases. While most firms engaged in shale gas production may attempt to follow safety precautions mandated by law, situations arise where expenses can be reduced by cutting corners or declining to invest in additional safety precautions. When governments have few enforcement actions, a business firm may save money by declining to invest in safety due to small probability that any problem will occur or that any penalty will be imposed.

Reported litigation of citizen lawsuits against polluters and governments suggests that governments are unwilling or unable to enforce environmental quality requirements. A study by the Environmental Law and Policy Center found that states generally do not aggressively pursue enforcement actions against violators (Dexter, 2010). An example is a lawsuit in which a state agency allowed the polluting company to draft a complaint and propose a settlement for violations involving mercury discharges under which the state fined the company US $100,000 despite the fact that the company gained more than US $1 million in not complying with federal mercury discharge limitations (Friends of the Earth, Inc. vs. Laidlaw Environmental Services (TOC) Inc., 2000). As noted by the U.S. Supreme Court, governmental civil penalties do more than promote compliance: they also deter future violations. However, "a threat [of penalties] has no deterrent value unless it is credible that it will be carried out" (Friends of the Earth, Inc. vs. Laidlaw Environmental Services (TOC) Inc., 2000). For violations where penalties are too low, firms may be inclined to proceed with an activity and pay the fine if they are caught. Given that governments are not pursuing enough enforcement actions, they are not deterring sufficient violations (Konschnik and Boling, 2014).

3.2. Need for shale gas pollutant regulations

Governments often forgo adopting meaningful health regulations due to objections to their costs by business-oriented interest groups and the omission of concern for long-term health problems (Konisky, 2007; Higgenbotham et al., 2010). Moreover, political pressures and rushed legislative sessions often curtain the adoption of first-best policy instruments by state governments creating distortions in environmental choices (Kunce and Shogren, 2005). The dangers presented by gas wells are compounded by the failure of governments to take actions to fully protect citizens from accompanying harmful externalities. To garner business activity, a government competes to have the most lenient regulations resulting in insufficient measures to protect human health. This is known as a “race to the bottom” involving the lack of controls over risks and polluting activities (Glicksman, 2006; Pursley and Wiseman, 2011; Spence, 2013).

In the United States, individual state governments have not always taken appropriate actions to protect downstream air and water resources (Sigman, 2005; Faure and Johnston, 2009). In the absence of a minimum federal standard, an upstream state government does not have a strong incentive to take into account the harm to downstream out-of-state residents (Ostrow, 2011). While state governments may have the ability to design pollution regulations that balance localized benefits and costs, they often fail to account for the negative externalities in the form of water pollutants and harmful air emissions that affect persons in other states. The placement of harmful substances in these resources may result in socially inefficient outcomes. These circumstances recommend federal oversight to protect people from health risks.

While the hydrocarbon industry has been successful at securing numerous exceptions to federal regulations thereby reducing costs, the question is what damages and costs are being placed on people as health costs? The exceptions remove checks and balances incorporated in federal law to protect persons and the environment. Reported contamination events and risks associated with toxic chemicals and air pollutants accompanying shale gas development suggest that current permitting requirements are insufficient. While they delineate requirements for site preparation and drilling, they omit adequate requirements on the release of water and air pollutants.

4. Employing permits to reduce pollutants

Because existing regulations over shale gas development fail to appropriately consider the external costs of polluting activities, they diminish economic efficiency. But the addition of regulations to control pollutants is accompanied by costs. The issue is how to ascertain that firms involved in shale gas production activities are taking appropriate actions to reduce the risks of releasing pollutants that harm others. A meaningful way to oversee the release of pollutants is through a permitting program that contains pollution reduction plans incorporating provisions to minimize releases of pollutants.

4.1. Merits of a permitting program

A permitting program with pollution reduction plans enumerating best management practices (BMPs) constitutes an effective way of designing and enforcing pollution control with the internalization of negative externalities. Adopting such a permitting regime for shale gas development can balance the rights and responsibilities of both regulators and regulatees (i.e., firms of the hydrocarbon industry). Regulators would protect human health and the environment while regulatees would operate with minimal interference to avoid additional costs.

A permit is a condition involving the preapproval of environmental and health standards by a government to reduce pollution damages. The delineation of BMPs in permits can help ensure that the development of shale gas resources minimizes the use of toxic materials, lessens the production of waste, and prevents or minimizes adverse health impacts (Eshleman and Elmore, 2013). Establishing BMPs can streamline the existing regime for shale gas development while creating a flexible approach supporting increased productivity. While considering economic and technical feasibility, BMPs can be gradually and pragmatically strengthened to progressively reduce pollution. Flexibility in setting standards allows for the regime to evolve concomitantly with scientific and technological capacities and for regulatees to choose between various practices. In this manner, BMPs can be employed to encourage industry innovation and efficiency by directly modifying the behavior of the hydrocarbon industry (Driesen, 2004).

Enhancing BMPs as economic circumstances change and advances in scientific knowledge develop is a key characteristic of the program (Adair et al., 2012). Yet if the industry decides what management practices to employ to reduce negative externalities, regulatees may have too much leeway and adopted practices may not be sufficiently prescriptive. In contrast, a governmentally-imposed command-and-control regime may impose overly strict prohibitions on regulates that fail to encourage the industry to act beyond compliance with the dictated standards. Command-and-control provisions also do not stimulate innovation or encourage the reduction of pollutant levels below those prescribed. Responsiveness to scientific and technological changes and improvement of standards should be attributes incorporated into a permitting program.

A permitting program also needs enforcement powers to control compliance with prescribed BMPs. Having enforcement mechanisms in place would enable punishment for breaches of these practices, would deter further violations and, most importantly, would prevent harm and adverse effects on human health. Yet the flexibility given to operators to select and implement BMPs increases the administrative burden of assessing each regulatee's compliance (Richardson et al., 2013). Another characteristic of permitting programs is the availability of more transparent information. Greater information can positively influence an industry's behavior (Olmstead and Richardson, 2014). Overall, a permitting program based on BMPs would offer heterogeneity and flexibility in practices for the hydrocarbon industry, a coherent system of control for governments, and public accountability.

4.2. Looking at permitting regulations for animal waste

To explore the issue of responding to negative externalities associated with shale gas development, the regulatory responses for other industries can offer ideas on structuring more meaningful permitting provisions. Particularly insightful are the regulations governing water pollution by wastes from concentrated animal feeding operations (CAFOs). Approximately 18,000 of the largest animal production farms in the United States are known as CAFOs. They are regulated as point sources of pollution under the U.S. Clean Water Act and approximately 6,500 CAFOs have secured permits in accordance with federal law (USEPA, 2013b).

In the late 1980s, unacceptable levels of water pollution lead environmental groups to initiate legal action to force the federal government to enforce the provisions of the Clean Water Act pertaining to CAFOs. Subsequently, federal CAFO regulations of animal waste imposed additional permitting requirements on the largest CAFOs to address water contamination by solids, fecal coliform, and pathogens in animal waste (USCFR, 2015). The regulations incorporated provisions to allow the sustainable practice of using manure as fertilizer for crop production.

The CAFO regulations adopted by the EPA in 2003 were contentious and the EPA was sued by both agricultural and environment groups that claimed the new provisions violated federal law (Centner, 2011). Both groups were correct with some of their arguments, and the EPA was again forced to amend its federal CAFO provisions (Centner and Newton, 2008). In 2008, EPA issued revised rules (USEPA, 2008). Additional litigation resulted in yet another set of revised regulations in 2012 (USEPA, 2012b). Due to legal challenges, the federal government needed 23 years to revise its regulations governing animal waste. The experiences show that successfully defining a set of valid regulations governing waste disposal is challenging.

For CAFOs that need permits, federal regulations require producers to establish BMPs to address water pollution that are delineated in the operator's National Pollutant Discharge Elimination System permit (USCFR, 2015). Each permit must set forth a nutrient management plan that employs a field-specific assessment of the potential for nitrogen and phosphorus transport from the field. In addition, an operator’s plans must address the method of application of nutrients on each field to achieve realistic production goals while minimizing nutrient movement to surface waters. With these requirements, producers who overapply manure violate their permit and may incur liability.

The relevance of the CAFO regulations to shale gas extraction is their use of a permitting program and the delineation of BMPs. Mandatory permits for farms producing non-hazardous manure suggest that gas wells using toxic chemicals and producing flowback and produced waters containing carcinogenic materials that enter water and air resources might also be regulated by a permitting program. Experiences with pollutants from CAFOs showed that activities in one state can adversely affect surface waters flowing to other states. Given the interstate flow of pollutants from CAFOs, uniform federal regulations were desirable. The same applies to pollutants from shale gas production.

4.3. Pollutant reduction plans

A permitting program for shale gas development to reduce releases of pollutants would be achieved by requiring each gas well to have a fluids and air emissions reduction plans. A permit that includes these plans would be required prior to the commencement of drilling and would consider all of the aspects of the development of a gas well. Thus, it would be similar to a special permit used by zoning authorities to oversee new development. A special permit does not encompass the power to make exceptions from regulations but rather encompasses the power to authorize specific uses under stated conditions.

The requirements for the pollutant reduction plans would be modeled after water pollution requirements. One possible directive taken from U.S. federal law that could be adopted for permitting gas wells is to:

> require controls to reduce the discharge of pollutants to the maximum extent practicable, including management practices, control techniques and system, design and engineering methods, and such other provisions as [the regulatory agency] . . . determines appropriate for the control of such pollutants (U.S. Code, 2012, title 33, § 1342).

This requirement calls for the reduction of pollution without prescribing specific controls or technologies. This allows permittees to select and adopt methods and technology of their choice so long as they meet the required reductions of pollutant releases. A second directive adopted from the CAFO regulations for the sustainable practice of land application of manure could provide further guidance for reducing pollutant releases (USCFR, 2015, title 40, § 412.4). The directive would require that the fluids and air emissions plans at a well site:

> Provide a site-specific assessment of the potential for harmful pollutants to exit the site into surface waters or the air, and address the form, source, amount, timing, and method of preventive measures that can minimize pollutants while achieving realistic production goals.

Again, the requirement would not impose mandatory controls or technologies but rather requires well operators to consider how pollutants might best be minimized to prevent health damages. In this manner, the plans enable operators to consider specialized circumstances of sites and retain flexibility in limiting risks of pollution. Drilling firms would be able to employ new practices and technology that facilitate meeting the health standards set for pollutant releases. Whenever a firm's request for a permit conforms to the permitting regulations and safeguards the interests of the public, it would be granted and the well could be developed. The firm desiring to drill a gas well would have the responsibility of developing the fluids and air emissions reduction plans.

4.4. Devising BMPs to account for changes

To meet the minimization of pollutants, fluids and air emissions reduction plans would incorporate BMP requirements that retain flexibility. This is important because non-flexible regulatory provisions are costly and detract from economic performance. The flexibility of BMPs can be established through regulations that require pollutant reduction plans to meet applicable limitations and standards, and a glance at the CAFO regulations illustrates how this can be achieved. CAFOs are required to have nutrient management plans that, to the extent applicable:

> (i) Ensure adequate storage of manure, litter, and process wastewater . . .; (iii) Ensure that clean water is diverted, as appropriate, from the production area; (iv) Prevent direct contact of confined animals with waters . . .; (v) Ensure that chemicals and other contaminants handled on-site are not disposed of in any . . . system unless specifically designed to treat such chemicals and other contaminants; (vi) Identify appropriate site specific conservation practices to be implemented . . . to control runoff of pollutants . . .; (vii) Identify protocols for appropriate testing of manure . . . and soil; (viii) Establish protocols to land apply manure . . . in accordance with site specific nutrient management practices that ensure appropriate agricultural utilization of the nutrients . . .; and (ix) Identify specific records that will be maintained to document the implementation and management of the minimum elements . . . (USCFR, 2015, tit. 40, § 122.42).

The most salient point of the CAFO BMPs is that there is no established standard or technology prescribed. This means that CAFO operators can make adjustments to their operations to incorporate new technology and activities that account for new developments and cost savings. This is clearly important for shale gas extraction as new technology and safety information become available (Hou and Al-Tabbaa, 2014).

Second, the regulations show that governments can prescribe BMPs that take into account different sites. Regulations do not have to prescribe the same requirements for individual permitted operations, which allows for additional oversight of shale gas wells located in vulnerable areas (Mendoza-Cantú et al., 2011). This allows distinctions in requirements for the use of fracturing chemicals at gas wells with different geologic formations, aquifer conditions, and proximity to surface waters. For air emissions, each permit can account for topographical and meteorological conditions of individual wells.

Third, the CAFO BMPs contain requirements in generalized terms for situations likely to cause pollution and documentation to show compliance. Similar generalized requirements can be incorporated into a fluids reduction plan for shale gas extraction activities. Each plan would contain BMPs that reduce risks of contamination events. Likewise, BMPs can be required for air emissions that accompany the sources of pollutants identified in Table 2. Each well can be required to have an air emissions reduction plan that reduces to the extent possible the air pollutants emitted from shale gas production. The adoption of best practices might increase the cost of a typical well by about 7 to 10 % (International Energy Agency, 2012; Wang et al., 2014).

For shale gas production, the BMPs would cover each stage of activities required to extract and market natural gas. The stages include well pad and infrastructure preparation, drilling, construction of pipelines and facilities, hydraulic fracturing, flowback and produced water, connection to the distribution system, and distribution of natural gas to consumers. A few of the most significant BMPs are listed in Table 5. Further examples are available from a website listing hundreds of practices available to reduce risks and damages from shale gas development (Getches-Wilkinson Center, 2013). Following the National Pollutant Discharge Elimination System permitting provisions of the Clean Water Act, permit applications and approved permits would be available to the public. The transparency of information on a well, including toxic chemicals introduced to a site, would enable workers, the public, and property owners to take timely responses to accidents and pollution incidents.

5. Conclusion

The negative externalities accompanying shale gas production have caused many problems for neighbors, communities, and the public. With respect to health issues, the U.S. federal government has failed to take appropriate actions to safeguard human health. Rather, it has exempted hydrocarbon activities from several laws intended to protect people. This has meant that the individual U.S. state governments have needed to implement laws and regulations to oversee safe production activities. Yet, due to a number of reasons, state governments have also been remiss in safeguarding the health of Americans. Despite multiple projections by the medical community about the potential health damages from these pollutants, governments have declined to adopt simple safeguards in the form of a permitting system containing BMPs to reduce the risks of damages (Finkel et al., 2013; Rafferty and Limonek, 2013; Shonkoff et al., 2014; Werner et al., 2015).

Shale gas is a source of energy that can contribute to the well-being of an economy. It can especially be beneficial for countries that want to reduce dependence on foreign sources of energy. However, in the development of affordable energy supplies, businesses and governments have a responsibility to protect people and property from excessive pollutant loadings. Firms producing shale gas have responsibilities to communities and the people they affect. Firms releasing toxic chemicals and harmful air emissions should be held accountable for their negative externalities. Experiences from the United States show that in the absence of sufficient supervision of shale gas development activities, firms release excessive amounts of pollutants to cause health maladies. The experiences also show that as other countries consider developing their shale gas resources, they can employ their legal systems to offer greater protection to people and the environment to avoid some of the negative situations that have been reported from the United States.

Given the risks of health damages from shale gas production activities, this paper suggests governments employ a permitting program employing pollutant reduction plans with best management practices to limit pollutant releases to acceptable levels. The regulation of water pollution from concentrated animal feeding operations in the United States discloses how governments can offer greater protection against health damages that accompany shale gas development activities. A permitting program under which each well delineates fluids and air emissions reduction plans would offer additional health protection. Each permit would demarcate best practices for the various sources and activities that reduce pollutants to the extent possible. Furthermore, a country's permitting regulations would incorporate the zoning devise of special permits to oversee specialized circumstances and allow well development to proceed upon the documentation of practices and technology that safeguard public health. Appropriate governmental oversight can allow shale gas to be developed while protecting public health.

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