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Statistical analysis of compliance violations for natural gas wells in Pennsylvania

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HIGHLIGHTS

- Violation notices for natural gas wells in PA were compiled from the DEP from 2000 to 2014.
- Compared violation rates among operators to identify ones with above average records.
- Conventional wells have higher odds of violation than unconventional ones.
- Shale wells are more likely to have violations with potential to contaminate water.
- Small operators have higher odds of having a violation over large operators.

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ABSTRACT

Regulatory inspection and violation reports provide insight into the impact of natural gas extraction on the surrounding environment, human health, and public safety. Inspection reports for natural gas wells in Pennsylvania were collected from the Pennsylvania DEP Compliance Report from 2000 to 2014. Analysis of 215,444 inspection records for 70,043 conventional and unconventional wells was conducted in order to compare the odds of violations occurring under different circumstances. Logistic regression models were used to estimate the probability of violations occurring for both conventional and unconventional wells. When inspected, conventional wells had 40% higher odds of having a violation. However, unconventional wells had higher odds for environmental violations related to waste discharge as well as cementing and casing failures. Large operators had 40% lower odds of having any violation than smaller operators. While larger operators had fewer violations, a few of the largest companies had rates of violation much higher than the average for all operators, with some reaching violation rates as high as 1 in 4 active wells. A well also has a higher chance of being in violation if it is in the first year (85%) or second year (109%) since its spud date.

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1. Introduction

The rapid growth of unconventional natural gas extraction through hydraulic fracturing in recent years has been a source of concern in the United States. Technological advances in the drilling process, namely hydraulic fracturing and horizontal drilling, have made the extraction of natural gas from the previously inaccessible shale cost effective. Hydraulic fracturing uses large volumes (2–5 million gallons of water for each fracturing operation) of pressurized water with chemical additives and a proppant (typically sand) to create fractures within the rock in order to allow the trapped gas to diffuse to the well (Clark et al., 2013; NY State Department of Environmental Conservation, 2015; Rozell and Reaven, 2012).

The Marcellus shale formation, one of the largest unconventional gas deposits in the United States, underlies approximately two-thirds of the state of Pennsylvania with an estimated area of 54,000 square miles (Energy Information Administration, 2014; Kargbo et al., 2010; PA Department of Environmental Protection (PADEP), 2013; Soeder and Kappel, 2009). The Marcellus shale is estimated to hold up to 131 trillion cubic feet of technically recoverable natural gas (Energy Information Administration, 2013). Since shale gas exploration in Pennsylvania began in 2004, there

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have been over 9500 unconventional wells drilled as of 2015 (Amico et al., 2015). In 2013, the U.S. Energy Information Administration reported that the state of Pennsylvania was the fastest growing natural gas producing state, with a 72% increase in production between 2011 and 2012 (Energy Information Administration, 2013). By 2014, the state had doubled its 2012 production, making it the second largest producing state in the U.S. after Texas (Energy Information Administration, 2015a).

Regulation of the shale gas industry is primarily handled at the state level (Richardson, 2013), so the Pennsylvania Department of Environmental Protection (DEP) oversees the regulation of natural gas production in the state. The DEP makes electronic records of all inspection reports and notices of violation accessible to the public on their website.

Researchers have studied the different aspects of the drilling and development processes in order to assess the risks associated with shale gas and to find any gaps in state regulations of the industry. The treatment, disposal, and potential discharge into surface water of industrial brines produced from the hydraulic fracturing process have been a great source of environmental concern (Beaver, 2014; Rozell and Reaven, 2012; Wilson and Van Briesen, 2013). Rozell and Reaven (2012) found the risk associated with hydraulic fracturing wastewater disposal to be orders of magnitude greater than any other water contamination pathway from natural gas development. However, the work of Rozell and Reaven took place before municipal wastewater treatment plants stopped accepting waste from shale gas activity. The replacement of this practice by various combinations of treatment, reuse, and underground injection may have subsequently reduced risks (Ferrar et al., 2013; Lutz et al., 2013). Hydraulic fracturing wastewater generally has very high concentrations of salts and total dissolved solids (TDS), as well as levels of radionuclides, metals, and organic compounds that could be harmful to human health (Abualfaraj et al., 2014; Blauch et al., 2009; Dresel and Rose, 2010; Haluszczak et al., 2013; Hayes, 2009).

The U.S. Environmental Protection Agency's (EPA) draft hydraulic fracturing risk assessment report examined the potential impacts on drinking water resources from various stages in the hydraulic fracturing water cycle (U.S.EPA, 2015). While the study did not find any evidence of systemic impacts on drinking water sources from shale gas activities, they identified several mechanisms that would potentially contaminate drinking water. These mechanisms are generally accidents such as spills of hydraulic fracturing fluids and produced water, fracturing directly into drinking water supplies, and inadequate treatment of wastewater. However, the number of identified cases of any of these scenarios is quite small when compared to the total number of shale gas wells drilled in the U.S. (U.S.EPA, 2015).

Substantial amounts of water (2–5 million gallons) are required in order to fracture a single well. Water withdrawals required for shale gas extraction can be a stress on fresh water supplies (Small et al., 2014; Soeder and Kappel, 2009). Recently, more and more operators are choosing to recycle produced wastewater, reducing the amount of fresh water needed for each operation and mitigating issues regarding treatment and disposal of flowback water and production brine (Lutz et al., 2013). The percentage of flowback water recycled for hydraulic fracturing in the Marcellus shale increased from 13% before 2011 to 56% in 2011 due to the changes in regulations and constraints on other treatment and disposal options (Lutz et al., 2013). According to PA DEP records, this percentage increased to 87% as of 2012 (Brantley et al., 2014).

Another issue arising from shale gas development is the potential for methane migration into fresh groundwater supplies (Jackson et al., 2013; Osborn et al., 2011; Vidic et al., 2013). While many studies have examined incidents of elevated methane levels in drinking water, the way in which methane migrates into groundwater supplies is still unclear. A recent study of 11,309 samples of dissolved methane from domestic water wells in Northeast Pennsylvania found no significant increase in methane concentrations with proximity to oil and gas wells (Siegel et al., 2015). In another study of water wells in NE Pennsylvania, Molofsky et al. (2013) found that elevated methane concentrations were better correlated with geologic features rather than shale gas activity. Ingraffea et al. (2014) suggest looking at well casing failures in order to better understand methane migration from shale gas wells. The study analyzed over 75,000 compliance records in order to determine the difference in frequency of well casing failures between conventional natural gas and shale gas wells by designating any inspection that mentioned wells casings or cementing as a “casing failure”. This study found a six-fold higher incidence of cementing and casing impairments for unconventional shale gas wells than for conventional natural gas wells. They also found that the risk of casing impairments increased 1.57 times for unconventional wells relative to conventional wells for all wells drilled after 2009.

Other researchers have studied the Pennsylvania compliance reports to analyze trends and frequency of inspection and violations in the shale gas industry. Manda et al. (2014) evaluate the likelihood of environmental violations at multi-well pads versus single-well pads. The study found that environmental violations were more likely to occur on multi-well pads than on single-well pads. However, taking the total number of wells into account revealed that there were fewer violations per well on pads with multiple wells.

Brantley et al. (2014) reviewed notices of violation issued by the PA DEP through 2013 and found that almost 20% of shale gas wells in the state had received notices of violation. Of those violation records, 3.4% of all violations issued were related to construction issues, while 0.24% were relate to methane migration. They also identified 161 instances between 2008 and 2012 where natural gas activity was implicated in contamination (Brantley et al., 2014). The study identified 32 major spills and leaks (> 400 gal.) in Pennsylvania between 2009 and 2013. Of those 32 incidents, 8 were spills of flowback or produced water ranging from 4200 gallons to over 57,000 gallons (Brantley et al., 2014).

Rahm et al. (2015) examined compliance records in Pennsylvania in order to estimate risk and identify its drivers. In this study, 3267 shale gas violations between 2007 and 2013 were evaluated. The researchers conducted a regression using the monthly rate of violation normalized to the number of new wells drilled in that time period as the dependent variable with several geographical, seasonal, temporal, and regulatory variables. The results of their regression model suggested that a policy change in 2011 requiring senior administrator approval within the DEP for all notices of violation issued to unconventional shale gas operators was responsible for a 45% decrease in the rate of certain environmental violations. It should be noted, however, that this policy was quickly rescinded after receiving criticism in the media. Rahm et al. (2015) attribute the decrease in violations to the policy change even though it was only briefly implemented, as it indicates a general restructuring within the DEP and the way in which violations were issued. The researchers also found a higher rate of environmental violations from spills and erosion with unconventional wells, while conventional wells had higher rates of cementing/casing failures and site restoration violations (Rahm et al., 2015).

The goal of this research was to analyze compliance data for factors that are associated with high violation rates. In this regard, we (1) compared violation rates of different types between conventional and unconventional wells in order to determine if there is any increased risk associated with the relatively new practice of unconventional shale gas development, (2) determined the factors

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