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Hydraulic fracturing and the management, disposal, and reuse of frac flowback waters: Views from the public in the Marcellus Shale☆

Gene L. Theodori[a,*], A.E. Luloff[b], Fern K. Willits[c], David B. Burnett[d]

[a] Department of Sociology, Sam Houston State University, Box 2446, Huntsville, TX 77341, USA
[b] Department of Agricultural Economics, Sociology, and Education, The Pennsylvania State University, 114 Armsby Building, University Park, PA 16802, USA
[c] Department of Agricultural Economics, Sociology, and Education, The Pennsylvania State University, 113 Armsby Building, University Park, PA 16802, USA
[d] Global Petroleum Research Institute, Texas A&M University, 710 Richardson Building, 3116 TAMU, College Station, TX 77843, USA

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ABSTRACT

Issues associated with the public's views on hydraulic fracturing and the management, disposal, and reuse of frac flowback wastewaters are empirically examined in this paper. The data used in the analyses were collected in a general population survey from a random sample drawn from 21 counties located in the geological Central Core and Tier 1 of the Marcellus Shale region in Pennsylvania. Differences in the information reported by survey respondents living in high well-density counties (20 or more wells per 100 square miles) and their counterparts living in low well-density counties (fewer than 20 wells per 100 square miles) were examined. Substantive findings from the overall sample, as well as statistically significant differences between the two groups of respondents, are reported. The results contained in this paper should prove beneficial to members of the general public, community leaders, oil and gas industry representatives, government and regulatory agency personnel, environmental and non-governmental organization representatives, and other interested stakeholders.

1. Introduction

Technological advances in horizontal drilling and multi-stage hydraulic fracturing were two primary factors that contributed to the unprecedented shale gas boom during the past decade in the United States [1,2]. Horizontal drilling techniques and hydraulic fracturing methods developed, tested, and refined in the Barnett Shale during the late 1990s and early 2000s were rapidly employed in shale gas basins across the nation (e.g., Fayetteville, Woodford, Haynesville, Marcellus, Utica, Eagle Ford). According to the Energy Information Administration (EIA), the statistical and analytical agency of the U.S. Department of Energy, shale gas contributed roughly one third of the total U.S. natural gas production (7.8 tcf of 23.0 tcf) as of 2011 [3]. Further, EIA estimates shale gas production will constitute approximately one half (50.5 percent; 16.7 tcf) of the projected 33.1 tcf total domestic natural gas production in 2040 [3].

A barrage of controversy accompanied this tremendous surge in shale gas production [4,5]. At the center of the debate is the well stimulation/completion process known as hydraulic fracturing [6–9]. Shale gas development relies heavily on multi-stage hydraulic fracturing stimulation to maximize commercial viability. Wells are hydraulically fractured by flushing large quantities of "frac fluid" – a mixture of freshwater, proppants, and small amounts of friction reducers and other chemicals – into them at extremely high pressure levels to create small cracks, or "fractures," in the shale formations. Doing this allows natural gas to flow more freely through the reservoir and, in turn, increases recovery. Frac jobs commonly use 1–3 million gallons of water per gas well; in some cases, water use may exceed 5 million gallons per frac [10].

After a frac job is completed, the pressure is released and, along with the natural gas, the well generates frac flowback and produced waters. Frac flowback is the term used to describe injected water that returns to the surface during the first few weeks of production. Produced water refers to the water naturally present in the formation brought to the surface throughout the production process [2]. Both frac flowback and produced waters generally contain

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* Corresponding author. Tel.: +1 936 294 4143.
E-mail address: gtheodori@shsu.edu (G.L. Theodori).

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high levels of total dissolved solids (TDS) and other contaminants. Operators must manage and dispose of flowback and produced waters using methods in compliance with state and local regulatory requirements.

Until recently, energy producers used several methods to manage and dispose of flowback and produced wastewaters from shale reservoirs, including underground injection, surface discharge, municipal wastewater treatment plant discharge, commercial industrial wastewater treatment discharge, and beneficial reuse [2]. Underground injection is the primary wastewater management/disposal method employed in the vast majority of shale gas basins [2]. Beneficial reuse remains the management/disposal method least adopted and diffused throughout the industry [11]. However, in efforts to conserve freshwater resources, reduce social and environmental impacts, improve public confidence, and minimize costs, operators have recently begun to treat and reuse flowback and produced waters in subsequent drilling and hydraulic fracturing operations [2,12].

The purpose of this paper is to empirically explore issues associated with hydraulic fracturing and the management and disposal of frac flowback wastewater. Here, survey data gathered in Pennsylvania's Marcellus Shale region were analyzed to investigate respondents' levels of familiarity with: (1) the process of hydraulic fracturing; (2) the management and disposal of frac flowback wastewater; and (3) frac flowback wastewater treatment technology. Further, we examine the contribution made to self-reported knowledge of hydraulic fracturing by eight different sources and the amount of trust in each of the same sources to deliver unbiased, factual knowledge about the topic. Building upon previous research on the public's perception of produced water by Theodori and his colleagues [13,14], we assess the level of agreement that treated wastewater from hydraulic fracturing operations could safely be used for selected purposes. Finally, we evaluate the association between level of familiarity with frac flowback wastewater treatment technology and the proposed potential uses of treated wastewater. Differences in information reported by respondents living in high well-density counties (20 or more wells per 100 square miles) and their counterparts living in low well-density counties (fewer than 20 wells per 100 square miles) are examined.

2. Data collection

Between June and October 2012, a random sample of individuals living in 21 counties located in the geological Central Core and Tier 1 of the Marcellus Shale region in Pennsylvania were contacted by telephone or mail and asked to participate in a survey of resident opinions concerning natural gas development.[1] All counties included in the sampling frame had experienced at least some Marcellus Shale drilling, but the density of such wells varied widely. To secure opinions from respondents within this region that reflected gas-industry activity differences, the sample was chosen to reflect the views of individuals living in counties with "low" well densities (fewer than 20 wells per 100 square miles) and those living in counties with "high" well densities (20 or more wells per 100 square miles). Coincidentally, 50% of the total population in the 21 counties included in the sample fell in the low well-density counties and 50% fell in the high well-density counties.[2]

The telephone survey was conducted over the period June 11, 2012, to August 30, 2012, using state-of-the-art CATI software designed to maximize completed surveys from the limited and finite random sample pool over an extended period of time. This meant repeated calls to each unique number at various times of the day and days of week and repeated callbacks to those individuals who expressed interest in participating, when reaching them due to busy schedules was a challenge. Calls continued until 200 completed interviews were obtained from each of the well-density county categories. The overall telephone survey completion rate was 27%.[3]

For the mail survey, 800 names and addresses of persons with listed telephone numbers were randomly selected from the low well-density counties, and 800 names and addresses were randomly selected from the high well-density counties. An initial mailing, including a cover letter and a printed questionnaire, was sent to these sample members in July 2012, followed by three follow-up reminder letters with duplicate questionnaires over the next three months. A total of 43 questionnaires in the low well-density counties and 52 questionnaires in the high well-density counties were returned as undeliverable. Since one objective of the larger study was to examine the differential effects of results from telephone and mail surveys [16,17], the same protocol used in the conduct of the telephone survey was used in the mail survey. Hence, only the first 200 replies received from each of the well-density categories were included in the current analysis, resulting in an overall usable response rate of 27%.[4]

3. Measurement of variables

The questions/items used in the mail and telephone surveys were identical in wording and in the instructions given to the respondents. The ways in which the specific questions/items used in this analysis were measured are specified below.

[1] Geologists differ in their estimates of the exact size and location of the Marcellus Shale region. The current research focused on the area defined by Bernstein Research as the Central Core and Tier 1 in Pennsylvania [15]. The Core and Tier 1 areas were defined in terms of depth, thickness, porosity, thermal maturity, and silica content of the shale – factors that play into the economics of the gas yield. In addition to the 20 counties so defined, Washington County was added to the sampling frame because of the high incidence of drilling that had already taken place there.

[2] Well density data (indicated in parentheses) were compiled on March 23, 2012. Counties included in the low well-density category were: Bedford (.1), Blair (1), Cambria (1), Cameron (4), Centre (5), Clearfield (11), Clinton (10), Indiana (5), Lackawanna (.4), Somerset (2), Sullivan (10), and Wayne (.5). The high well-density counties included: Bradford (93), Fayette (24), Greene (75), Lycoming (42), Susquehanna (61), Tioga (65), Washington (69), Westmoreland (20), and Wyoming (27).

[3] Two thousand random telephone numbers were entered into a telephone bank. Of the 2000 telephone numbers, 496 were unusable (393 were non-working/disconnected/other; 43 were computer/fax lines; 60 were business lines/nonresidential). Hence, the usable telephone survey sample was reduced to 1504. Of these, 400 individuals completed the survey, resulting in a 26.6% completion rate. Two hundred and five individuals answered their telephone and either refused initially ($n = 174$), refused mid-survey ($n = 19$), suspended their effort and agreed to finish the survey at a later time ($n = 8$), or scheduled a callback ($n = 4$). The remaining 899 telephone numbers were all dialed 10 or more times and ended with no answer or with various answering machine/voicemail connections.

[4] While far from ideal, a 27% response rate for a general population mail survey is not atypical. Despite efforts to increase responses through attention to survey length, form, content, and the employment of multiple mailings and various incentives, response rates have increasingly declined across time [18,19]. However, recent studies have challenged the presumption that low response rates imply inaccurate findings. Indeed, past and ongoing research suggests that findings of studies with low rates of response tend to differ little, if at all, from those with higher rates of participation [19–23].