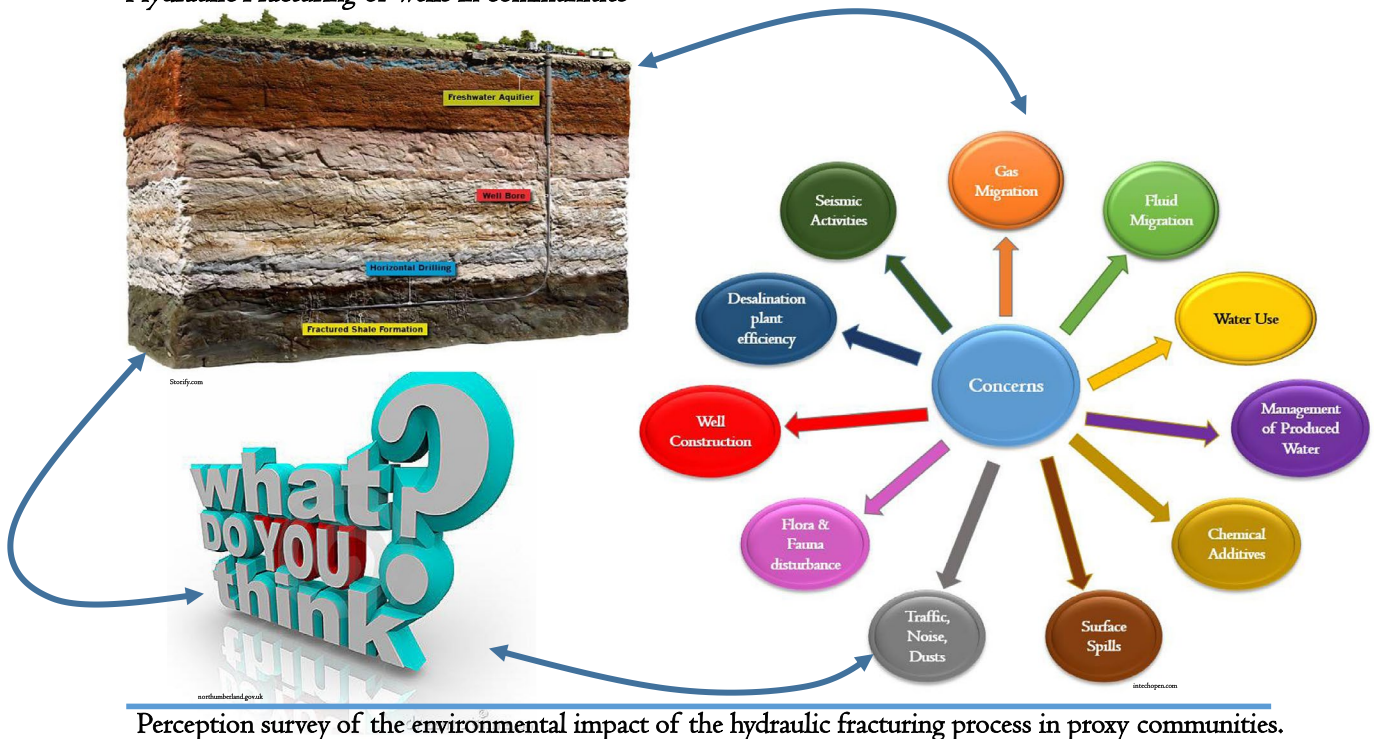


Hydraulic Fracturing of wells in communities



ENVIRONMENTAL MANAGEMENT & CONSERVATION | RESEARCH ARTICLE

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ENVIRONMENTAL MANAGEMENT & CONSERVATION | RESEARCH ARTICLE

Environmental health risk perception of hydraulic fracturing in the US

Richard Olawoyin^{1*}, Charles McGlothlin¹, Donaldson F. Conserve² and Jack Ogutu³

Abstract: The advent of new technologies such as directional drilling (D^2) and the hydraulic fracturing technique (HF_{tech}) has made it possible to enhance energy production from petroleum reserves. The procedures involved have however aroused public sentiments and triggered the debate on the economic importance of petroleum recovery processes. Public perceptions of the environmental health consequences of these processes have been fuzzy. Public survey was conducted using the United States as a case study to foster the development of the most effective policy relative to environmental health sustainability and energy independence. Participants ($n = 1243$) were surveyed on the prevalence and concerns for HF_{tech} in proxy communities in 2015. Key to the perception inquiry was the knowledge of respondents on HF_{tech} and the concerns relative to the exploration processes. Ordinal logistic regression and Poisson regression ($P\lambda$) were used to interpret the responses obtained from the participants. The study determined mixed public view for HF_{tech} based on the analyses conducted. Young men, on average, had the least degree of concerns, while older residents (60+ years old) are more inclined to have

ABOUT THE AUTHOR

Richard Olawoyin joined Oakland University, Rochester, Michigan, in January 2014 from Pennsylvania State University and he has previously worked in the upstream and downstream sectors of the petroleum industry as a geologist, geophysicist, and safety and environmental health scientist. His research emphases are on: Human Health Exposure Risk Assessment (Assessing the effects of—Heavy Metals, Organic Solvents, Persistent Organic Pollutants, and Polycyclic Aromatic Hydrocarbons on humans). The author is a certified environmental professional (CEP) and a professional member of the International Medical Geology Association. Other research interests include NanoEHS (nanotechnology) and Statistical Techniques in Health and Safety Engineering. He is on the chemometrics review panel for the National Science Foundation, a program evaluator for ABET, a reviewer for multiple high-impact national and international journals, and a recipient of the NASA-funded space grant on Nanotechnology. He is on the disaster response team of the American Red Cross.

PUBLIC INTEREST STATEMENT

Hydraulic fracturing is beneficial to national economies as it provides energy security, jobs, and improves access to remote communities. However, there are numerous safety concerns associated with the entire process of oil and gas recovery from the deep formations. In this study, an IRB (Oakland University)-approved survey was conducted to assess the risk perception of citizens living in and around petroleum production areas in the US. It was found that the level of risk perception by different demographic groups is based on public engagement and the source of information on the process. This body of work provided recommended solutions for engaging communities of operation in early identification and characterization of environmental concerns and risk communication for the purpose of implementing effective remediation and safety of industry workers and the community.



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friends who support HF_{tech} in the communities (p -value = 0.082). Through this study, a clearer global profile of perceived public risks can be developed in countries using HF_{tech}, in determining risk acceptability and proper governance for shale gas development. The detailed survey carried out is important for the development of effective strategies for managing risky decisions to emerging energy development issues while balancing the need for a sustainable environment.

Subjects: Environment & Health; Environment & Resources; Environment & Society; Environmental Health & Safety; Environmental Studies & Management; Risk Assessment

Keywords: perception; communities; hydraulic fracturing; oil and gas; environmental health impact

1. Introduction

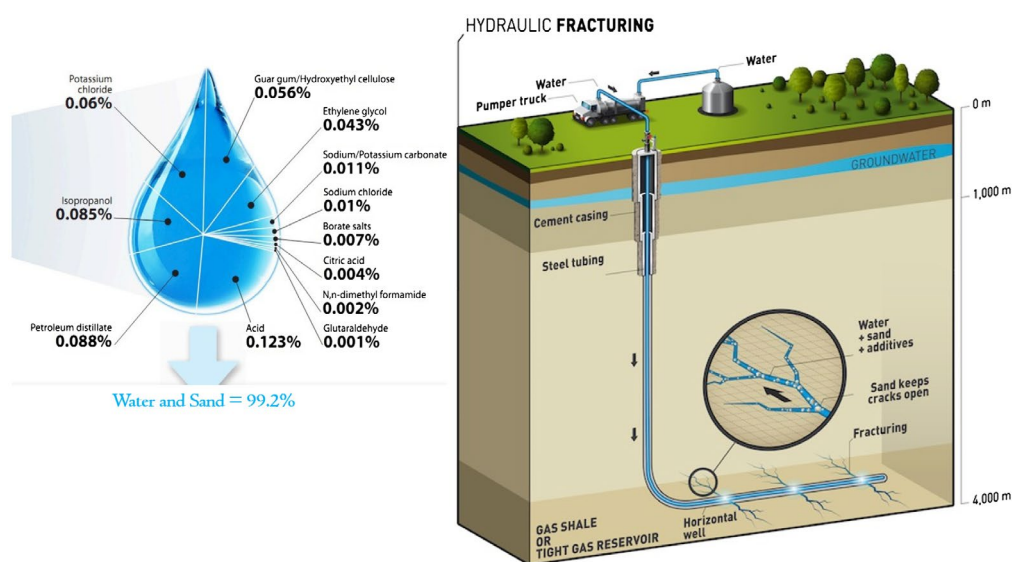
Modern technological improvements for unconventional oil and gas explorations have made deep formations accessible through 3-D micro-seismic, multi-component analyses (4C) and D^2 , coupled with pressure pumping, a process called high-volume hydraulic fracturing technique (HVHF_{tech}) (Olawoyin, Wang, & Oyewole, 2012). HF_{tech} used for the purpose of well stimulation and natural gas development (NGD) is expanding into residential areas and school districts across the country in areas with rich petroleum deposits in shale formations, the consequence of which has generated controversies in many communities, including the host communities, and among professionals (environmental, medical, public health, politicians, and academia) about the potential adverse effects or benefits of HF_{tech} and related processes of gas development (Bamberger & Oswald, 2012; Ferrar et al., 2013; McDermott-Levy, Kaktins, & Sattler, 2013). Public outlook studies of energy-related subjects are usually narrowly focused during public debates (Bolsen & Cook, 2008). There are major concerns with HF_{tech} and all of these concerns interconnect with the support or opposition for the process and other methods used to generate energy from source (Graham, Stephenson, & Smith, 2009).

The purpose of this study is to determine the public perception relative to the potential environmental risks (ER), exposures, and health consequences from HF_{tech} in the United States. An IRB (#576841)-approved survey of US residents was conducted in 2015, which focused on commonly observed sources of environmental concerns similar to extant literature. Specifically, the level of respondents' perception of the significance of HF_{tech} was explored. Public concerns on environmental issues are broad with wide-ranging phenomena and multi-dimensional variables (Alibeli & White, 2011). It is crucial to clearly define the exploration process, the dimensions of public concerns, and characteristics of survey participants in order to effectively explain the perception of each individual and the degree of concern for environmental quality (EQ).

1.1. Petroleum well stimulation

This involves stimulating reservoirs of tight formations (such as shale and sandstone), for optimal recovery of oil and/or gas, by creating cracks (fractures) in the rock matrix and allowing a free flow of the fluid through the wellbore, and collected on the surface (Olawoyin, Madu, & Enab, 2012). HF_{tech} is becoming more prevalent in the petroleum extractive industry as the demand for energy increases worldwide. The importance of HF_{tech} cannot be overemphasized; it has been used to recover over 600 trillion cubic feet (Tcf) of natural gas and 7 billion barrels of crude oil since the technology was developed approximately 70 years ago (U.S. Energy Information Administration [US EIA], 2013). The United States has a natural gas reserve estimate of approximately 1,800 Tcf which is technically recoverable and estimated to sufficiently supply energy to the United States for upwards of 116 years (David, 2013; U.S. Department of Energy [US DOE], 2009). The US energy production is projected to increase about 50% due to natural gas production by 2035 (US EIA, 2013).

Figure 1. HF_{tech} fluid composition in the United States shale play courtesy [Carbonwaters and stratafrac].



1.1.1. The hydraulic fracturing technique (HF_{tech})

Advancement in technology and human ingenuity has made it possible to perform D^2 maneuvers and create cracks in rock formations at depth (using HF_{tech}) to recover deeply buried gas deposits from formations with low permeability (Colborn, Schultz, Herrick, & Kwiatkowski, 2014). A perforating gun is typically passed down through the directional drilled hole and then detonated, after which a cocktail of fracturing fluids are pumped into the formation at very high pressure to further extend the cracks and prevent it from shutting in. The hydraulic fluids required for the stimulation process are primarily made up of water ($\approx 93\%$) (Olawoyin et al., 2012), proppant—mostly silica sand which is $\approx 6\%$ in total volume and emulsifiers, acids, inhibitors, and cross-link breakers ($\approx 1\%$) Figure 1. Use of proppant is essential in the process since they keep developed fractures open for the purpose of fluid transport through the formation. This however requires large amount of sand (most high quartz content). The quantity of proppant required to complete a fracturing job largely depends on the number of stages that are necessary for a particular well operation. HF_{tech} often takes place at a fast pace, with well completion target of approximately 21 days from the initiation of HF_{tech} (Olawoyin et al., 2012). HF_{tech} is used after other exploration processes are completed, including the development of the well pad and well drilling.

1.2. Environmental health impact

HF_{tech} as part of the entire process of NGD involves procedures with varying degrees of environmental impacts, depending on the prevalent field conditions that may continue at a location for an average of 25 years (Werner, Vink, Watt, & Jagals, 2015). These processes have probable ER, capable of causing undesirable human health effects upon exposure, through susceptible route of entry to the human body, from contaminated environmental materials. The assessment and control of human exposures to external environmental factors (air, soil, water, food, hygiene, light, and noise) and the consequences to human health is known as environmental health (World Health Organization [WHO], 2015). Potential environmental health problems relative to HF_{tech} activities have been reported (Lauver, 2012; McDermott-Levy & Kaktins, 2012; Olawoyin, 2015).

Environmental health hazards (EH_{Haz}) and negative human health outcomes have been directly associated to NGD in multiple qualitative studies (Fryzek, Pastula, Jiang, & Garabrant, 2013; Steinzor, Subra, & Sumi, 2013). These EH_{Haz} include: disposal of flow back or wastewater (Adgate, Goldstein, & McKenzie, 2014; Eaton, 2013; Vidic, Brantley, Vandenbossche, Yoxtheimer, & Abad, 2013); chemical contaminations of usable water by HF_{tech} (Coram, Moss, & Blashki, 2014; Maule, Makey, Benson, Burrows, & Scammell, 2013; Tillett, 2013); natural gas migration into shallow aquifers from the

fractured shale formations (Osborn, Vengosh, Warner, & Jackson, 2011); increases in naturally occurring organic contaminants (NOOC); increase in levels of naturally occurring radioactive materials (NORM) due to fracturing of the shale rock formation (consequently becoming technological NORM (TENORM), which may be present in the drill cuttings or as residuals in pits or tanks) (Railroad Commission of Texas [RCT], 2015); air pollution from fugitive gas emissions as a consequence so the HF_{tech} (McKenzie, Witter, Newman, & Adgate, 2012); and exposure of the population to hydrogen sulfide and benzene above health-based risk levels (Hailey, McCawley, Epstein, Arrington, & Bjerke, 2016) NGD has also been associated with birth defects, preterm birth (negative), low birth weight, neural tube defects, fetal growth (negative), and congenital heart defects (McKenzie et al., 2014; Rabinowitz et al., 2014) based on geocoded maternal addresses relative to well locations at the time of birth (Hill, 2013). Cardiology, neurology, urology, and dermatology inpatient prevalence rates were found to have significant associations with number and proximity of wells (Jemielita et al., 2015).

Static water bodies are common around wastewater pits; this may also present EH_{Haz} to residents in the community since water-borne pests such as mosquitoes can proliferate the area due to favorable breeding habitat (WHO, 2015; Zou, Miller, & Schmidtman, 2006). Longitudinal studies are lacking to assess the chronic effects of exposures to environmental contaminations due to well stimulation activities (McDermott-Levy et al., 2013) that may result in human health effects such as endocrine disruption, reproductive defects, nervous system problems, and cancer (Colborn, Kwiatkowski, Schultz, & Bachran, 2011; Finkel, Hays, & Law, 2013; Witter, Tenney, Clark, & Newman, 2014). However, NGD operations have been connected to elevated occurrence of endocrine-disrupting chemicals, such as oestrogen, antioestrogen, and antiandrogen in surface and underground water (Kassotis, Tillitt, Davis, Hormann, & Nagel, 2014). Harmful changes to EQ (due to air, soil, water, odor, and noise pollution) have been reported as consequences of HF_{tech} (Colorado Department of Public Health and Environment, 2010). NGD relative to HF_{tech} has been reported to impact human health including respiratory and gastrointestinal diseases, liver and kidney problems, and defects of the brain, sensory organs, and the immune system (Colborn et al., 2011; Colorado Department of Public Health and Environment, 2010; McDermott-Levy et al., 2013; Saberi, 2013); it has also raised food safety concerns in some communities (Bamberger & Oswald, 2012). It is important to note that, for ethical reasons, there are no studies to provide evidence into the actual exposure doses/concentrations and environmental toxicity and metabolic exposure pathways of HF_{tech} chemicals based on human health outcomes.

A few studies observed the effect of the HF_{tech} on animals. In one study, it was determined that the total number of cows in a dairy farm reduced, as well as milk production per cow, relative to increased HF_{tech} activities in the Marcellus Shale area of Pennsylvania, though a casual relation between HF_{tech} activities and production decline was not determined (Finkel, Selegan, Hays, & Kondamudi, 2013). Similar outcomes were presented concerning animal illnesses and fatality in active NGD areas of the Marcellus shale (Ferrar et al., 2013). Another study observed brook trout with respect to potential risk routes from HF_{tech} (Weltman-Fahs & Taylor, 2013) while in a related study, stress and increased lesions were observed in the gills of exposed fish to spills from HF_{tech} fluids in Kentucky (Papoulias & Velasco, 2013).

Industrial and occupational exposures to HF_{tech} materials and chemicals are also of emerging concerns. The use of quartz sand as proppant presents imminent hazards to exposed workers (especially blender operators and sand movers) based on the respirable crystalline silica (RCS) contents (Esswein, Breitenstein, Snawder, Kiefer, & Sieber, 2013). The mechanical process involved with preparing the proppant for use generates RCS dusts that are of potential occupational health concerns to the exposed field workers (Esswein et al., 2013; Olawayin, 2015). Exposures to RCS increase the risk of tuberculosis and induce other negative health effects in humans, such as autoimmune diseases, lung cancer, and silicosis (Laney & Weissman, 2012).

Environmental epidemiological data tools are capable of establishing the correlation that exists between acute and/or chronic diseases affecting human health and the corresponding toxic environmental exposures, e.g. from HF_{tech}. The existence of significant ER poses threats to human health such as toxic chemical exposures in environmental media (Osborn et al., 2011) from HF_{tech} process. This could “potentially” lead to premature deaths, developmental disabilities, organ malfunction (Perry, 2012), and several other complications plaguing human health. Many Americans express concerns daily over the possible link between environmental pollution from energy sources and the occurrence of diseases such as cancer and respiratory problems. More importantly, in recent decades, there has been an increasing number of Americans with fear of proximity to environmental health risks from exploration process to them, their families, and neighborhood. This creates panic, anxiety, and stress on ordinary citizens. While some are apprehensive of the possibility that their health has been impaired already, others are frightened of the potential consequences on their health if the environmental pollution becomes pervasive. These concerns are widely shared, especially around areas with physical activities that have experienced environmental disasters in the past.

Like every other issue in the American society, HF_{tech} has its proponents and antagonists (Mackie, Johnman, & Sim, 2013). Those in support of the process argue that the ability to use HF_{tech} for NGD has led to industry expansion, economic gains, energy independence, higher employment, improvement in research and development, and reduction in green house emissions (Engelder, 2011; Olawoyin et al., 2012). Others have raised concerns over the potential risks to human health and the impacts on the environment (Boudet et al., 2014; Olawoyin et al., 2012). These concerns aroused from frustrations felt by many residents and health professionals due to the non-disclosure of the chemical makeup of the hydraulic fracturing fluid cocktail (Peduzzi & Harding, 2013). More generally, environmental health risks are viewed universally among all demographic groups as an aggravated trigger to the deterioration of human health.

2. Determinants of Public Concern for the HF_{tech}

In the United States, numerous studies have been conducted that examined public concerns on wide-ranging environmental issues (Yeager, Larson, Krosnick, & Tompson, 2011), while others have focused on international environmental concerns (Clements, 2012). Globally, extant studies have determined the level of public concern on environmental effects due to industrialization to be closely related to factors such as socio-demographic variables (such as gender, age, race, education, and income) (Clements, 2012; Dietz, Dan, & Shwom, 2007; Liu, Vedlitz, & Shi, 2014; McCright & Dunlap, 2011); political affiliations (Clements, 2012; Wood & Vedlitz, 2007); and differences in citizen’s environmental value and convictions (Boudet et al., 2014; Clements, 2012; Twenge, Campbell, & Freeman, 2012; Wheeler et al., 2015).

2.1. Socio-demographic factors and concern for EQ

Study assessing the correlation between socio-demographic variables and public concern for EQ essentially centers on ascertaining the varieties of individuals with most concerns for the environmental impacts, such as HF_{tech}. This approach involves specific socio-demographic characteristics such as age, race, gender, educational level, income, religion, employment status, and place of residence (Boudet et al., 2014; Liu et al., 2014; Wheeler et al., 2015; Whittaker, Segura, & Bowler, 2005). Many empirical research studies examining the gender-EQ relationship show moderate to robust gender variances, with women having the most concerns for EQ than men (Biel & Nilsson, 2005). This gender gap may be explained by three causes: (1) varying viewpoints during socialization processes and parenthood for females and males (Boudet et al., 2014), (2) gender-based differences in the home and at work (Stoutenborough, Shi, & Vedlitz, 2015), and (3) diverse value development practices for females and males (Wheeler et al., 2015).

Earlier studies have reported on age-EQ relationship and effect, indicating that younger citizens express more concerns for EQ than older people (Kanagy, Humphrey, & Firebaugh, 1994). The explanation for the effects of age on youth’s EQ perception as compared to the older generation was shown to be based on the availability of information through education (Liu et al., 2014),

experience, and generational change (Boudet et al., 2014). Social variables such as employment status, income, and educational level have also been compared to concerns for EQ in previous studies (Wheeler et al., 2015). Such studies used the Maslow's hierarchical theory of human needs (Maslow, 1970) to explain the association between social class satisfaction and EQ concerns. The hypothesis suggests that well-educated and high-income earners are more inclined to better understand and analyze issues that may potentially affect the environment. The probability is high for this social group to have post-materialistic perception; the aspirations for material possessions and economic developments are minimized with more emphasis on environmental sustainability and quality of human life (Inglehart, 1995).

There are contrasting reports on race-EQ relationships. These disparities in perception of environmental concerns between Caucasians, African-Americans, and other races have led some to believe that concern gaps exist between the race groups. Based on extant studies, Caucasians were shown to be more likely to have increasing concerns for EQ than other races (Wheeler et al., 2015). Other studies have refuted the existence of concern gap between races (Mohai, 2003). Alternatively, other studies found African-Americans to be pro-EQ and more sensitive to environmental issues, especially on the local level (Mohai & Bryant, 1998; Whittaker et al., 2005). Socio-demographic variables for the assessment of favorability or opposition to novel energy technologies such as HF_{tech} have been presented in other literature (Ansolahehere & Konisky, 2009; Firestone & Kempton, 2007; Jacquet, 2012; Liu et al., 2014). Socio-demographic characteristics such as higher income level, minorities, women, and higher educational attainment are commonly negatively associated with support for NGD, while Caucasian males have consistent insignificant risk perception of the NGD process (Jacquet, 2012; Liu et al., 2014).

2.2. Political ideology and environmental concern

Political affiliation and ideology are important determinants that may strongly influence citizen's perception toward EQ (McCright & Dunlap, 2011; Wheeler et al., 2015). Contrarily, some studies have found weak relationships between individual's political inclination and EQ concerns. Political ideology typically represents a set of core philosophies and principles relative to the relationship between industry and the government. The perspective shared among conservatives and liberals is significantly different, as affiliations with specific political group may have strong effects on the perception formed of HF_{tech}. Observations from earlier studies have found that political liberals are more concerned about the environment (Hinich, Liu, Vedlitz, & Lindsey, 2013; Liu et al., 2014; Whittaker et al., 2005) and have strong oppositions to HF_{tech}. However, they strongly support environmental protection, increased regulations, and reduction of socioeconomic disparity. The political conservatives have shown more support for energy development, including the use of HF_{tech} (Pew Research Center [PRC], 2012), and they are in favor of smaller role of the government in regulating business activities in the society. Individual's political alignment may be influenced or structured by inherent belief systems and cultural values, which all together could define the perception latitude. These beliefs could develop through human-nature interactions which influence human attitudes, intentions, behavioral activities, and perceptions (Tillett, 2013).

2.3. Studies on public perception of HF_{tech}

An individual's learned experiences, culture, and socioeconomic standing are essential in stimulating the perception of EQ in the community of inhabitation (Israel, Wong-Parodi, Webler, & Stern, 2015). This individual perception can be enhanced by gathering more information on imminent exposures, which would consequently enable the development of inclusive perception of the entire EQ. Perception in this context can be defined as the idiosyncratic method of obtaining, processing, constructing, and formulating cognitive information from single or multi-faceted external sources. The development of questionnaires to assess organized information (perception) is quintessential in categorizing the developments leading to access of obtaining, processing, and formulating personal beliefs from the privacy information.

Studies have attempted to assess the public (favorable and unfavorable) perception of HF_{tech}. Majority of Americans are unaware of this process, while approximately 26% of the population are familiar with the process (PRC, 2012). Increased familiarity with the subject has resulted in increased opposition (Brooks, 2013). At the states level, more people tend to be more familiar with the process due to the different activities involving HF_{tech} common to the different localities. Sixty-four and 41% of residents in the states of Ohio and Pennsylvania (PA), respectively, consider the benefits of using HF_{tech} to surpass the risks involved with the process (Quinnipiac University, 2012a). Uncertainties about the potential environmental and health impacts of HF_{tech} have shaped many perceptions, which have triggered strong support for the process in places like Ohio, and conversely, there has been stiff opposition to the development of natural gas wells using HF_{tech} in other areas like in the New York State (Quinnipiac University, 2012b).

The development of specific perception about HF_{tech} based on media coverage is dependent on the message, medium, and the motivation of the news observer. Most survey respondents have access to the news from broader coverage medium such as the newspaper (Driedger, 2007) and Internet feeds (Krimsky, 2007). In this study, 46% of respondents obtain the news from Internet newsfeeds, while 24% of respondents view the news from their television sets. These media present information, especially the negative impacts of HF_{tech}, on the environment thoroughly and convincingly (Cacciatore et al., 2012), catering to the interests of the news network patronage. The principal factors responsible for forming these perceptions were assessed through this study design and deduced from related studies. In a study of public concerns over the HF_{tech}, through the elicitation of interested and affected parties (IAP), researchers used Internet-based snowball sampling technique to collect responses on the concerns for HF_{tech} from IAP (Israel et al., 2015). In a related study, the “top of mind” associations of public perceptions of HF_{tech} were assessed (Boudet et al., 2014). The perception of the economic importance of HF_{tech} (Hultman, Rebois, Scholten, & Ramig, 2011; Visschers & Siegrist, 2013), together with related media hype and personal experiences through the different NGD stages (which may or may not lead to substantial changes in the community), has enduring impacts on residents’ perceptions (Boudet et al., 2014; Jacquet, 2009, 2012).

3. Methodology and analysis

Socio-demographic variables, political affiliation and ideology, and inherent beliefs are possible factors that could influence individual perception of EQ. These factors have been determined to have measurable relationships with public perception from extant studies. This study attempts to assess the level of effects to which these factors have, as compared to large bodies of studies on environmental concerns. However, this study is specific to the concern for HF_{tech}. Related perception surveys have suggested that younger, more educated citizens, liberals, non-Caucasians, and those with stronger personal beliefs express the most concern for EQ. Other studies have also reported different observations.

In this study, data were obtained from adults (>18 years old, randomly sampled) in the United States through a national public perception survey to observe individual-level bases of public concerns for the hydraulic fracturing process. The samples represent a subset of statistical population of residents in the US, with equal opportunity of selection for participation in the study.

3.1. Survey method and procedure

The research team consists of researchers from Oakland University (OU)—Rochester, Michigan and the University of North Carolina—Chapel Hill. The 2014–2015 national survey was reviewed and approved by the Institutional Review Board of Oakland University (IRB—#576841) and supported by the Oakland University Research Committee (URC). The survey was conducted through a web-based computer survey system (Survey Monkey Audience database) and implemented by the Environmental Health and Safety program (EHS) at OU. The survey was conducted from September 2014 to April 2015 and it included 1,243 complete surveys. The questionnaire included the participants’ socio-demographic information, political affiliation and ideology, and personal beliefs about EQ.

3.1.1. Dependent variable

For this study, the dependent variable is the degree of participants' concern for EQ. Perceived EQ is a multi-faceted concept; therefore, it is imperative to meticulously formulate survey questions that will effectively assess public concerns for EQ and ER. The specific components of perceived EQ and ER assessed in this study were defined as the level at which individuals perceive environmental effects from HF_{tech} activities. To quantify respondents' EQ concerns for HF_{tech}, few questions were integrated into the survey to determine their level of concern for changes to the community, changes to the environment, living standard, regulation inadequacy, and health conditions.

3.1.2. Independent variables

The influential factors such as socio-demographic characteristics (age, educational level, gender, income, and race), respondents' self-expressed political inclination and ideology, and personal beliefs were considered as independent variables in this study.

3.2. Analysis and results

The survey data had two basic question types (A and B). The survey contained four questions with rating scale responses for Type-A questions (AQ); respondent rated the level of concern from 1 to 5. The other type of questions, Type-B questions (BQ), allowed respondents to "Check all that apply" based on concerns for EQ from the use of HF_{tech}. Participants' responses were modeled relative to the demographic data collected. The demographic data were categorical in nature, which allowed for the creation of a "reference group" for each demographic variable. Comparisons were made between the responses of the other groups in each demographic variable, with respect to the reference group. The demographic data collected and reference group used in the models are presented in Table 1.

For AQ, the ordinal logistic regression (OLR) was used for data analysis. For this to be a valid approach, assumptions were made on the rating $5 > 4$; $4 > 3$, etc. The OLR allowed for the demonstration of the demographic data collected with the survey results and how it corresponded to the rating responses. It also indicated interactions among the demographic data, which could lead to further insights into the data. The Poisson regression ($P\lambda$) was used for the data analysis of BQ; the total number of "checks" in each question were assessed. In this case, OLR does not apply due to inconsistencies in the number of boxes checked by respondents. Since the response for this model is a count of checked boxes, $P\lambda$ is more appropriate for the "count" or "rate" data. The "stepwise" regression method was applied on all of the models to maintain model hierarchy, by inserting and removing each demographic category into the model, until the final model consisted of only statistically significant terms or insignificant variables that belong to a significant interaction among the demographic variables. Each term was evaluated to ensure confidence that it belonged in the model and not due to an "outlier".

Table 1. Demographic data used for reference group in analyses

Modeled	Reference
Ethnicity	Caucasian
Time at residence	10+ years
Education	College grad
Family size	Three
Outdoors activity	No
Age	30–44
Gender	Female
Income	\$50,000–\$74,999
US Region	Midwest

The correlations and variance inflation factors (VIF) among the different variables and interactions were examined. After removing potential outlier data, it was discovered that the VIF was not required. An example of why a statistically significant term was removed would be that the cell count for a particular combination of variables was small, under 6. The main focus in this study was on statistically significant interaction terms. Based on the representative sample size ($n = 1,243$), having a group in an interaction group of 3 indicates there is a statistically significant interaction. However, the number of respondents in a category creates some degree of uncertainty relative to the interactions. If there is an outlier in a group that consists of 20–500 respondents, it will be difficult to identify this from the data. An outlier in a group of 5 respondents can create bias in the results and models. Under 6 was chosen as a cut-off because a “cell size” of 5 and below is a cut-off for some of the tests the software can accommodate. As a means of testing the quality of the models, each response was run using $P\lambda$ and OLR against 4 variables, randomly generated to give a random model. This provides the means to test the model predictability of outcomes against random chance.

3.2.1. Poisson regressions ($P\lambda$)

Minitab version 17.2.1 was used for data analysis. The data analyzed based on $P\lambda$ provide two tables. First table, the *Deviance Table*, acts like an ANOVA table. It indicates if one of the groups in the demographic variables or interactions is significantly different from the reference group. The second table, the *Table of Coefficients*, shows which of the groups in the variables and interactions are significantly different and gives an idea on the differences from the reference group. By making several comparisons, pairwise error rate and the experiment-wise error rate were observed. If the pairwise error rate is set to 5.00%, there is 95% confidence that the differences observed are true. However, if 10 comparisons were made, it will be approximately 59.87% (0.95^{10}) certain that every comparison is correct. Therefore, 59.87% is the experiment-wise error rate. If it is desired that the confidence level is set at 95%, all the comparisons made would be true; then, the pairwise error rate would be set to 0.51%. In that case, a confidence level per comparison of 99.48% will be used.

In the Poisson models, there are many significantly different groups in each variable or interaction. Some interactions and terms in the models have been highlighted to emphasize the logic and importance in the modeling techniques. From the Table of Coefficients, a negative coefficient indicates that the group has a lower average response than the reference group and a positive coefficient has a higher average response.

3.2.1.1. $P\lambda$ analysis question 1 (Q1). Which of the following are you most concerned about to make you sick, relative to the hydraulic fracturing process? The question was abbreviated to “Disease Issues”.

Respondents were given the choices in Table 2 for Q1:

From the different variables in the model, it was determined that time at residence, family size, outdoor activity, age, income, and gender were important to this model. Family size and outdoor activity were significant independent contributors.

Table 2. List of responses for first “click all that apply” question regarding disease issues

Potential responses for disease issues question

Methane gas leaks/oil spills
Dust from moving trucks
Light, noise, water, and air pollution
Drilling workers preexisting disease burden
Water used for fracturing
Drilling chemicals
Waste materials from the fracturing process
I am not concerned

Time at residence, gender, family size, age, and income were also important for some statistically significant interaction terms in the models. These interaction terms complicate the interpretation of the model; however, they also enhanced the precision in the models. Residents between the age group of 18–29, with 5 or more members in the household, tend to have more concerns for the EQ, which is similar to the level of concern within the age group of 60+ with no family member in the household (Figure 2). The significant differences occur between the none-groups and the >5 groups. In the general model, age was not independently significant (p -value = 0.320) as compared to gender. On average, males had fewer concerns about disease issues (p -value = 0.001). However, observing the interaction between age and gender, young women (age: 18–29) were found to have more concerns about disease issues than young men (Figure 3).

Young men, on average, had the least degree of concerns (p -value 0.005). In this case, there was a greater divergence between genders than the other age groups, confirming the gender gap as presented in other extant research studies. This divergence makes the interaction significant. Respondents that indicated interests in outdoor activities with their family (Figure 3) identified more disease issues than their counterparts (p -value = 0.000). Since there are more terms in the model, the “adjusted correlation coefficient” (R^2_{adj}) was used, which takes into account the number of variables in the model and has been adjusted for the number of predictors in the model. The R^2_{adj} value for this model is 7.03%. For comparisons, the model for the data that was randomly generated had R^2_{adj} of 0.32%.

The Deviance Table suggests that one or more of the groups within a demographic variable or interaction term is significantly different from the others. However, the Table of Coefficients (Table 3) shows which group is statistically significantly different from the other groups in that demographic variable or interaction term. In Table 3, all the groups that are significantly different than the reference group at a 95% confidence interval have been labeled with asterisks. From Table 3, it was

Figure 2. Average number of “disease concerns” by age and family size.

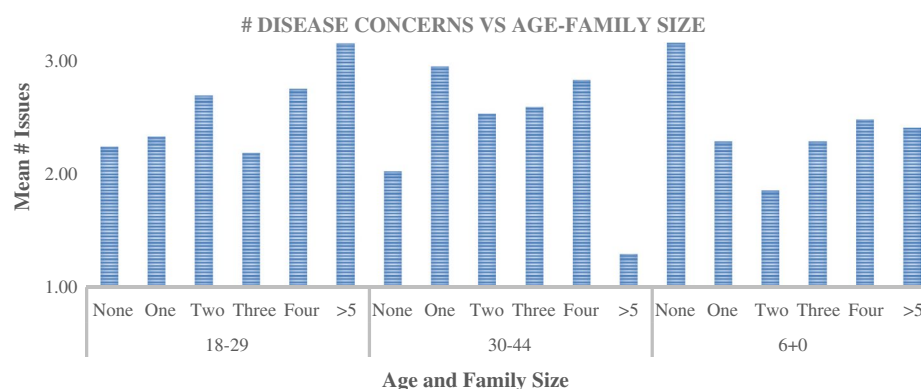


Figure 3. Pollution concerns for HF-based gender and activities.

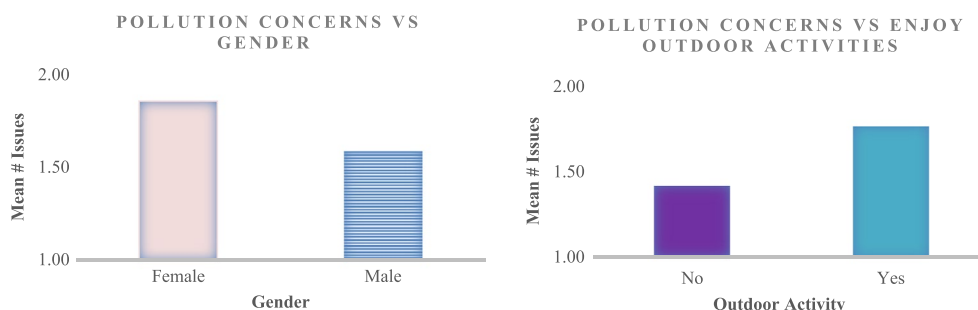


Table 3. Table of coefficients for Poisson regression referring to community issues data

Term	Coef	SE Coef
Constant	0.34	0.149
<i>Time residence</i>		
Less than 1 year	-0.07	0.109
1-2 years	0.037	0.085
3-4 years	-0.072	0.093
5-6 years	0.005	0.102
*7-8 years	*0.284	*0.104
9-10 years	-0.123	0.115
<i>Family size</i>		
None	-0.204	0.144
One	0.218	0.116
Two	-0.01	0.122
Four	0.11	0.142
*More than five	*-0.661	*0.217
<i>Outdoors activities</i>		
Yes	0.344	0.08
<i>Age</i>		
18-29	0.186	0.161
60+	-0.052	0.128
<i>Gender</i>		
*Male	*0.471	*0.148
<i>Gender*income</i>		
*Male \$0-\$9,999	*-0.599	*0.225
*Male \$10,000-\$24,999	*-0.599	*0.173
*Male \$25,000-\$49,999	*-0.365	*0.148
*Male \$75,000-\$99,999	*-0.488	*0.157
*Male \$100,000-\$124,999	-0.113	0.193
*Male \$125,000-\$149,999	*-0.491	*0.203
*Male \$150,000-\$174,999	*-0.914	*0.269
*Male \$175,000-\$199,999	*-0.935	*0.375
*Male \$200,000 and up	*-0.66	*0.226
*Male Prefer not to answer	*-0.764	*0.163
<i>Income</i>		
\$0-\$9,999	0.146	0.133
*\$10,000-\$24,999	*0.426	*0.112
*\$25,000-\$49,999	*0.327	*0.1
*\$75,000-\$99,999	*0.301	*0.103
\$100,000-\$124,999	-0.045	0.151
*\$125,000-\$149,999	*0.334	*0.147
*\$150,000-\$174,999	*0.68	0.152
\$175,000-\$199,999	0.307	0.273
*\$200,000 and up	*0.414	0.152
Prefer not to answer	0.331	0.098

(Continued)

Table 3. (Continued)

Term	Coef	SE Coef
<i>Time residence*gender</i>		
Less than 1 year Male	-0.08	0.155
1-2 years Male	0.045	0.131
3-4 years Male	-0.235	0.147
*5-6 years Male	*-0.381	*0.169
*7-8 years Male	*-0.437	*0.17
9-10 years Male	0.288	0.189
<i>Family size*age</i>		
None 18-29	0.171	0.215
*None 60+	*0.535	*0.177
One 18-29	-0.321	0.193
One 60+	-0.218	0.148
Two 18-29	0.097	0.19
Two 60+	-0.2	0.161
Four 18-29	-0.002	0.233
Four 60+	-0.036	0.201
*More than five 18-29	*0.945	*0.297
*More than five 60+	*0.753	*0.281
<i>Age*gender</i>		
*18-29 male	*-0.405	*0.128
60+ male	-0.092	0.106

*Indicates statistical significant values.

observed that people who enjoy outdoor activities have a higher level of concern than those that prefer to stay indoors (Figure 3). It was found that time at residence, family size, income, age, and gender were all involved with the interactions.

3.2.1.2. *Pa analysis question 2 (Q2)*. Which problems are most important to you and your community? For each set of issues listed before, please select which ones are most important to you personally. Click all choices that apply. The question was abbreviated to "Community Issues".

Respondents were given the choices in Table 4 for Q2; significant terms have been labeled with asterisks:

Table 5 shows how each group from the socio-demographic categories compares to the reference group. Homes with two residents have less concerns about EQ in their community (p -value = 0.071). People who enjoy outdoor activities have more unfavorable perception for the HF_{tech} than those that enjoy being indoors (p -value = 0.012). The R^2_{adj} for this model and the randomly generated data are 3.83 and 0.00%, respectively.

3.2.2. Ordinal logistic regression

Four questions were asked under this category using the rating response (1-5).

- (1) Estimate the degree of change (1-5) you feel that your community has experienced since the beginning of the hydraulic fracturing activities compared to when there was none.
- (2) Can you indicate to what extent the hydraulic fracturing activities adversely impact your business (es), job(s), or communities?

Table 4. List of responses for second “click all that apply” question referring to community issues

Potential responses to community issues

Ground water pollution or disaster/spills
Economic change or new disease burden
Population increase or risk indication and communication
Air pollution or stress/mental health or no problem

Table 5. Table of coefficients for P_λ model of community issues data

Term	Coef.	SE Coef.
Constant	0.476	0.102
<i>Family size</i>		
None	0.0007	0.0835
One*	−0.1639*	0.0736*
Two	−0.0294	0.077
Four	0.0613	0.0995
More than five	−0.048	0.122
<i>Outdoors activity</i>		
Yes*	0.2152*	0.0867*
<i>Gender</i>		
Male*	−0.1478*	0.048*

*Indicates statistical significant values.

(3) Ranging from 1 to 5, how likely are the people you know in support of hydraulic fracturing?

(4) To what extent (ranging from 1 to 5) do you regard laws and regulations that protect your immediate environment from HF_{tech} as adequate?

The responses to these questions were analyzed using the OLR. It was determined that combinations of ethnicity, income, education, US region, age, and gender were the only factors that had significant associations on the responses. There were no significant interactions between the variables. Appendix A shows the Table of Coefficients for the OLR model.

3.2.2.1. OLR analysis question 1 (Q1). On OLR-Q1, ethnicity, income, US region, and Gender were all significant. Respondents that identified as African- (non-American) (p -value = 0.009), Hispanic/Latin American (p -value = 0.050), and Mexican Decent (p -value = 0.009) had higher levels of concern for EQ due to the HF_{tech} than the reference group (Figure 4). Males were more inclined to have lower levels of concern than females (p -value 0.003). Respondents in the income level of \$0–\$9,999 were significantly different from the reference group (p -value = 0.004). The South Atlantic region had a statistically significantly different level of concern than the reference category (p -value = 0.023).

The diagnostics for this model was good. Sixty-five percent of the data pairs were concordant, compared to the model that includes only randomly generated data, which is 48.3% concordant. This means that the model is able to predict individual response in the data-set 65% of the time.

3.2.2.2. OLR analysis question 2 (Q2). For OLR-Q2, it was determined that ethnicity, income, US region, and gender were all significant. Africans (p -value = 0.047), Asian/Islanders (p -value = 0.066), African-Americans (p -value = 0.000), Hispanic/Latin American (p -value = 0.014), Mexican Decent

Figure 4. Mean response to local impact of HF by ethnicity.

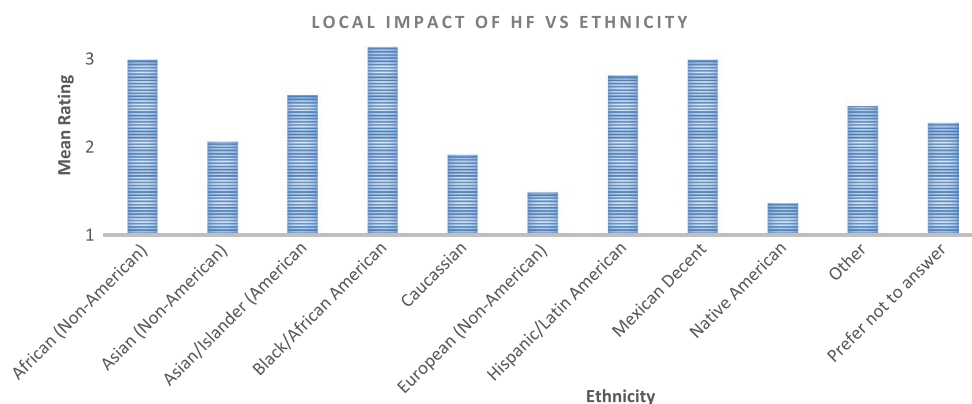
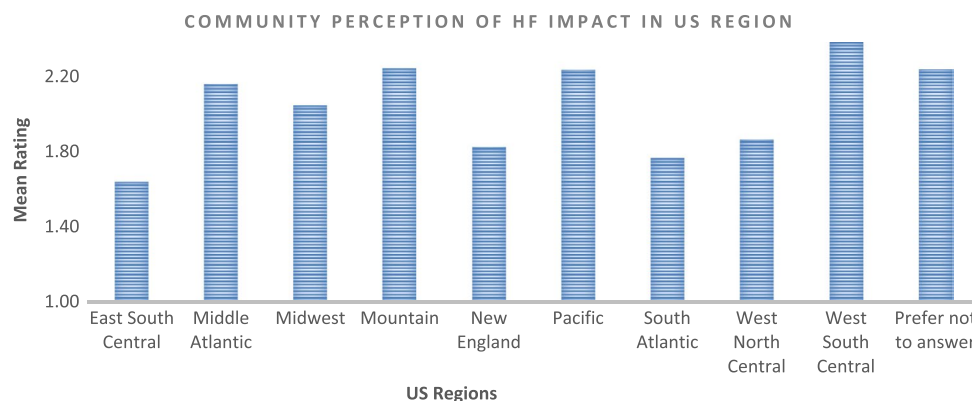


Figure 5. Mean response to community impact of HF by US region.



(p -value = 0.001), and other ethnicities (p -value = 0.025) reported higher levels of concern for the impact of the HF_{tech} on their community than the reference group. Males reported lower levels of concern (p -value = 0.000).

Lower income respondents, \$0–\$9,999 (p -value = 0.047), \$10,000–\$24,000 (p -value = 0.040) prefer not to respond (p -value = 0.039), reported significantly higher levels of impact. Residents in the Middle Atlantic region, (p -value = 0.029), Mountain region (p -value = 0.002), and Pacific regions (p -value = 0.011) reported higher levels of impact; the significantly different group is the West South Central, with the highest community concerns, Figure 5. The diagnostics for this model is similar to the OLR-Q1. 62.3% of the data pairs, compared to 50% for randomly generated data, were concordant suggesting that the model is able to predict the response of a person in the data-set 62.3% of the time.

3.2.2.3. OLR analysis question 3 (Q3). In OLR-Q3, education, gender, age, and US region were determined to have significant impact on the ratings. People that attended trade schools had friends with significantly more support for HF_{tech} (p -value = 0.008), Figure 6.

Males had more friends with stronger support for HF_{tech} in communities (p -value = 0.001) than females (Figure 7). Respondents from East South Central (p -value = 0.016) and West South Central (p -value = 0.069) were more likely to have friends who support the HF process. Middle Atlantic (p -value = 0.053), Mountain (p -value = 0.099), and Pacific (p -value = 0.007) respondents were less likely to have friends with significant support for HF_{tech}. Older respondents, 60+ years old, are more inclined to have friends who support HF_{tech} in the communities (p -value = 0.082), Figure 7. Similar to OLR-Q1 and OLR-Q2, the diagnostics remained consistently good. In comparison with randomly generated data (51.9% concordant), the OLR-Q3 data pairs were concordant 61.0% of the time.

Figure 6. Mean responses of respondents by educational attainment level.

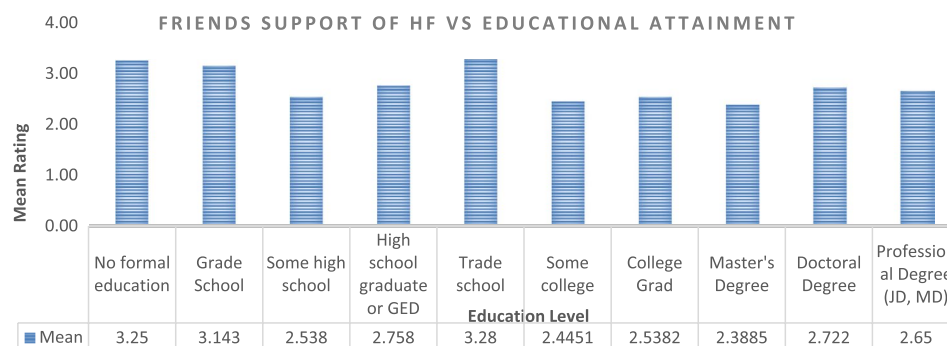


Figure 7. Average response for friend support of HF_{tech} by age and gender.

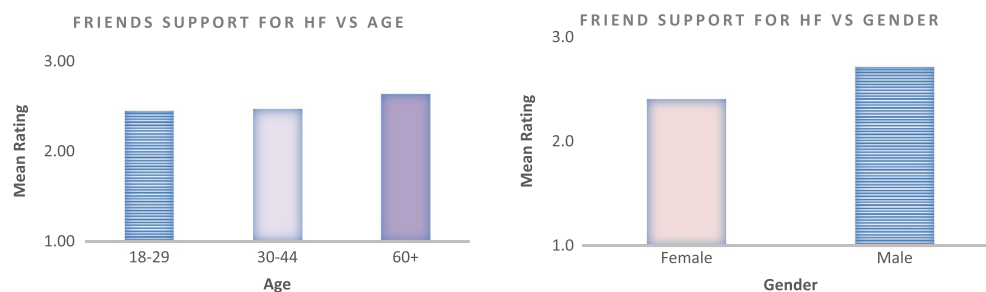
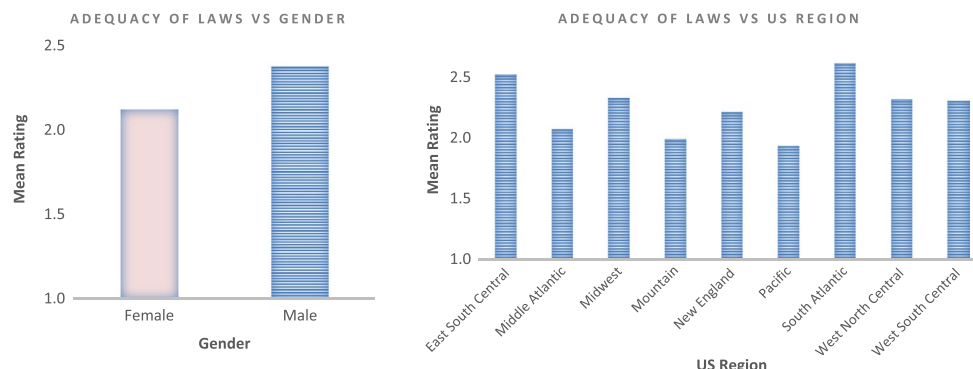


Figure 8. Mean response to the adequacy of laws versus gender and by US region.



3.2.2.4. OLR analysis question 4 (Q4). Ethnicity, education, gender, and US region had significant associations with respondents' perception relative to the adequacy of HF_{tech} laws and regulations, as determined in OLR-Q4.

Asians (non-American) (p -value = 0.005) and African-Americans (p -value = 0.016) were more likely to have favorable views of the adequacy of the HF_{tech} laws and regulations. In the education category, high school graduates (p -value = 0.001) and those with some high school (p -value = 0.003) had significantly higher ratings than the reference category. On the OLR-Q4, males had a higher rating (Figure 8) than females (p -value = 0.004). The Mountain, Middle Atlantic (p -value = 0.068), and Pacific (p -value = 0.005) regions had significantly lower ratings than the reference category (Figure 8). The diagnostics for the OLR-Q4 model showed that 61.7% of the data pairs were concordant compared to 53.2% for randomly generated data model.

3.3. Correlations

As a final step in the analysis, correlations between the responses were examined. Self-reported political views were observed from the responses. The survey respondents ($n = 1,243$) reported their

Table 6. Table of correlations among different responses

	Disease issues	Pollution issues	Community experience	Local HF impact	Friends support HF	Adequacy of laws
Disease issues	1.000					
Pollution issues	0.450*	1.000				
Community experience	0.274	0.209	1.000			
Local HF impact	0.288	0.289	0.694*	1.000		
Friends support HF	-0.342	-0.211	-0.102	-0.084	1.000	
Adequacy of laws	-0.323	-0.140	-0.131	-0.084	0.429*	1.000
Politics	0.350	0.290	0.186	0.200	-0.462*	-0.403*

*Indicates statistical significant values.

respective political inclinations as either conservative or liberal. The variables were coded as liberal = 1; conservative = 0. Table 6 shows the correlations between each pair of responses; significant correlations are labeled with asterisks. The results of the political correlations are in the last row, "politics".

While the correlations are statistically significant, most have higher levels of statistical significance, p -values < 0.001. The high level of significance comes from the large number of respondents in each correlation.

As shown in Table 6, there are 5 correlations with a correlation coefficient (r) > 0.400. Positive correlation ($r = 0.45$) between respondents with the number of disease issues and pollution issues was found in this study. The highest r value indicates a positive correlation between local impact of HF_{tech} and community experience ($r = 0.69$). This suggests that residents with sensitive perception to the degree of change mostly feel that HF_{tech} has negative impact on the community. There is also a positive correlation between respondents with the most potential to have friends who support HF_{tech} and adequacy of laws ($r = 0.43$). Since the political affiliations were coded as conservative "0" and liberal as "1", the negative correlation coefficients exist for politics vs. friend support of HF_{tech} ($r = 0.46$) and politics vs. adequacy of laws ($r = 0.40$). This translates to conservatives having a positive correlation to friends who support HF_{tech} and adequacy of existing laws and regulations, as deduced from the correlation analysis.

4. Conclusion

Pro-environmental perception and the development of effective public policy for safely implementing HF_{tech} can be enhanced by understanding public concerns relative to environmental management and preservation. In a research assessing environmental attitude in a 17-year time period from 1973 (Jones & Dunlap, 1992), the study examined whether social determinants of individuals in the society have changed relative to concerns for EQ. It was determined that these social factors remained constant over the period. In the changing world with novel inventions and advent of new technologies, such as D^2 and HF_{tech}, it is important to re-examine the effects of socio-demographic characteristics, political ideologies, and individual beliefs, relative to how they shape people's perceptions.

This study was conducted by surveying a representative sample of the US population to understand the residents' perception based on the introduction of HF_{tech} to different communities across the continental United States. The study also aims to foster the discussions on how residents perceive the risks to their communities and family health. Respondents were drawn from diverse socio-demographic and political groups; the level of concerns for HF_{tech} was examined relative to EQ. Using regression models, analyses were conducted to measure respondents' concerns for EQ, and explain the effects of the influencing factors responsible for the formed opinions. The data analyses confirm

the significance of socio-demographic, economic, and political views in explaining the public perception of HF_{tech}. The analyses indicated a positive relationship between gender–age and environmental concern due to HF_{tech}, revealing that younger females in the United States have more concerns about the HF_{tech} and the consequences to EQ than males and older adults. This is consistent with results from other studies assessing gender perception and EQ (Clarke et al., 2015; Kanagy et al., 1994). Positive relationships exist for income–environmental concern relationship, indicating that income level seems to have some effect on citizens’ perception of the HF_{tech} examined in this study. Middle Atlantic, West South Central, Mountain, and Pacific regions of the US oppose the HF_{tech} more than other regions. In a related survey (Sovacool, 2014), it was determined that respondents from the Western and NE areas of the United States are strongly opposed to the use of HF_{tech}, consistent with outcomes from other studies (Hinich et al., 2013; Liu et al., 2014). It was determined in this study that respondents’ political affiliation and ideology, together with personal beliefs, are significantly important factors that influence residents’ concerns for the EQ of their respective communities, due to the use of HF_{tech}. Political conservatives have more favorable perceptions for HF_{tech} than liberals as shown in the regression outcomes of the data analysis. These political inclinations and ideologies exhibit more robust influence on individual perceptions than the socio-demographic characteristics observed in the model. However, race and gender variables demonstrate statistically significant influence on the perception of EQ due to the use of HF_{tech} in the United States.

There are no straightforward answers to the question of whether to focus on environmental preservation or energy production. However, a modest balance between the two will require more research, improved industry–community engagement, enhanced risk communication strategies, and commitment built on trust by all interested and affected parties (IAP). It has been shown that active engagement is effective in identifying issues relative to preferred policy development. The competence and expertise of oil and gas operators, together with how process risk is routinely communicated with host communities, which ultimately builds trust and social license to operate, may also play important roles in the formation of perceived knowledge of the HF_{tech} (Anderson, Scheufele, Brossard, & Corley, 2011; Clarke, Evensen, Jacquet, & Stedman, 2012).

The outcomes of this study are quintessential and may be utilized to:

- Develop policies that would be helpful in alleviating the community’s concerns and to sustain the things that work properly.
- Establish the consensus in the community, which can be an effective tool in promoting public awareness, enhancing residents’ safety, and getting the residents more engaged in the decision-making planning for the benefit of the entire community.
- Build the framework for community effort that addresses resident’s concerns and
- Explore better solutions through risk identification, characterization, mitigation, and elimination by researchers and government policy agencies.
- Emphasize the importance of tailoring UNG development risk information to different demographic groups, using group segmentation strategies defined broadly in terms of the risk assessments and residents characteristics.
- Assess the information needs of each population segment and the feasible methods of communicating the environmental hazard and hazard adjustment information for UNG development, through community action groups.
- Organize interagency participation in hydraulic fracturing risk awareness and communication.
- Develop coalition of multiple stakeholders through collaborations, resource sharing, and community planning to establish a comprehensive risk mitigation program, which will include discussions on UNG development regulations for the protection of the people and the environment.

To a large extent, the measure of EQ determines the general well-being of residents in the community. Accessibility to clean air, unpolluted portable drinking water, uncontaminated food sources, and non-exposure of humans to environmental toxicants is essential for human viable habitation, environmental protection, and environmental sustainability. Misperceptions of the effects of HF_{tech} could potentially have significant impacts on public health and socioeconomic status of the country at large. The common overall perception that fossil fuel is dirty and all processes leading to its exploration/recovery pose significant risks to human health and EQ decline might restrain many from participating in the appreciation of the technology/techniques which otherwise could potentially have insignificant harmful effects to humans and the environment. Efforts to appraise and improve the community's discernment (through proper risk communication) of whether or not there are substantial environmental health risks ensuing from exploration processes could lead to appropriate hazard identification, improved community health and economic benefits to the community, and to the industry.

Author's Contribution

RO developed the project, reviewed the literature, analyzed the data, and drafted and revised the manuscript. CM advised on interpretation of the results and revised the manuscript. DC reviewed the literature and assisted with reviewing the analyzed data. RO, CM, DC, and JO reviewed the design of the study protocol. RO and CM provided guidance on statistical methods. DC contributed to the questionnaire development and conducted literature searches. All the authors approved the final version of the manuscript.

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Study approval

The study was approved by the Oakland University Institutional Review Board on the Protection of Human Subjects (Review category #7, Expedited Review IRB #576841, August 28, 2014).

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Appendix A. Table of coefficients for Ordinal Logistic Regression Data sets

	Community experience with fracking				Local fracking impact				Friends support for fracking				Adequacy of laws			
Ethnicity	Coeff	SE Coef	Z	P	Coeff	SE Coef	Z	P	Coeff	SE Coef	Z	P	Coeff	SE Coef	Z	P
African (Non-American)	2.379	0.915	2.60	0.009	2.092	1.054	1.98	0.047	*****	*****	*****	*****	1.598	1.127	1.42	0.156
Asian (Non-American)	-0.397	0.566	-0.70	0.483	-0.114	0.589	-0.19	0.846	*****	*****	*****	*****	1.494	0.529	2.82	0.005
Asian/Islander (American)	0.430	0.431	1.00	0.318	0.814	0.443	1.84	0.066	*****	*****	*****	*****	0.070	0.405	0.17	0.863
Black/African American	0.558	0.376	1.48	0.138	1.490	0.393	3.79	0.000	*****	*****	*****	*****	0.785	0.325	2.42	0.016
European (Non-American)	-0.652	0.538	-1.21	0.225	-0.867	0.532	-1.63	0.103	*****	*****	*****	*****	0.433	0.390	1.11	0.268
Hispanic/Latin American	0.871	0.445	1.96	0.050	1.150	0.469	2.45	0.014	*****	*****	*****	*****	-0.042	0.402	-0.11	0.916
Mexican Decent	1.468	0.559	2.62	0.009	1.823	0.561	3.25	0.001	*****	*****	*****	*****	-0.805	0.547	-1.47	0.141
Native American	-0.471	0.664	-0.71	0.479	-1.219	0.806	-1.51	0.130	*****	*****	*****	*****	0.534	0.556	0.96	0.336
Other	0.161	0.358	0.45	0.653	0.836	0.374	2.23	0.025	*****	*****	*****	*****	0.149	0.344	0.43	0.664
Gender																
Male	-0.444	0.150	-2.95	0.003	-0.666	0.160	-4.18	0.000	0.442	0.130	3.40	0.001	0.369	0.129	2.86	0.004
Income																
\$0–\$9,999	1.077	0.370	2.91	0.004	1.122	0.378	2.96	0.003	*****	*****	*****	*****	*****	*****	*****	*****

(Continued)

Appendix A. (Continued)

	Community experience with fracking				Local fracking impact				Friends support for fracking				Adequacy of laws			
Ethnicity	Coeff	SE Coef	Z	P	Coeff	SE Coef	Z	P	Coeff	SE Coef	Z	P	Coeff	SE Coef	Z	P
\$10,000–\$24,999	0.215	0.302	0.71	0.477	0.655	0.319	2.05	0.040	*****	*****	*****	*****	*****	*****	*****	*****
\$25,000–\$49,999	0.202	0.267	0.76	0.449	0.148	0.285	0.52	0.603	*****	*****	*****	*****	*****	*****	*****	*****
\$75,000–\$99,999	–0.359	0.273	–1.32	0.188	–0.103	0.288	–0.36	0.719	*****	*****	*****	*****	*****	*****	*****	*****
\$100,000–\$124,999	–0.504	0.321	–1.57	0.117	–0.495	0.341	–1.45	0.147	*****	*****	*****	*****	*****	*****	*****	*****
\$125,000–\$149,999	–0.220	0.338	–0.65	0.515	0.336	0.356	0.94	0.346	*****	*****	*****	*****	*****	*****	*****	*****
\$150,000–\$174,999	–0.518	0.463	–1.12	0.264	–0.602	0.502	–1.20	0.231	*****	*****	*****	*****	*****	*****	*****	*****
\$175,000–\$199,999	–0.188	0.561	–0.34	0.737	–0.836	0.702	–1.19	0.234	*****	*****	*****	*****	*****	*****	*****	*****
\$200,000 and up	–0.454	0.395	–1.15	0.251	–0.201	0.390	–0.51	0.607	*****	*****	*****	*****	*****	*****	*****	*****
Prefer not to answer	0.310	0.263	1.18	0.238	0.560	0.271	2.07	0.039	*****	*****	*****	*****	*****	*****	*****	*****
US region																
East South Central	–0.651	0.440	–1.48	0.139	0.543	0.432	1.26	0.209	0.895	0.373	2.40	0.016	0.236	0.356	0.66	0.508
Middle Atlantic	0.226	0.260	0.87	0.384	0.596	0.273	2.18	0.029	–0.430	0.222	–1.94	0.053	–0.407	0.223	–1.83	0.068
Mountain	0.445	0.303	1.47	0.142	0.975	0.318	3.07	0.002	–0.442	0.268	–1.65	0.099	–0.396	0.268	–1.48	0.139
New England	–0.284	0.347	–0.82	0.413	0.090	0.355	0.25	0.800	–0.409	0.294	–1.39	0.164	–0.282	0.302	–0.93	0.350
Pacific	0.171	0.241	0.71	0.479	0.654	0.257	2.55	0.011	–0.551	0.206	–2.68	0.007	–0.595	0.211	–2.82	0.005
South Atlantic	–0.623	0.275	–2.27	0.023	–0.200	0.291	–0.69	0.492	–0.054	0.221	–0.25	0.806	0.329	0.216	1.52	0.128
West North Central	–0.225	0.311	–0.73	0.468	0.286	0.349	0.82	0.414	0.086	0.274	0.31	0.754	0.079	0.275	0.29	0.775
West South Central	0.537	0.271	1.98	0.048	0.458	0.296	1.55	0.121	0.492	0.271	1.82	0.069	0.028	0.262	0.11	0.916
Education																
Doctoral Degree	*****	*****	*****	*****	*****	*****	*****	*****	0.014	0.320	0.04	0.965	–0.236	0.313	–0.75	0.452
Grade School	*****	*****	*****	*****	*****	*****	*****	*****	0.844	0.685	1.23	0.218	–0.157	0.732	–0.21	0.831
High school graduate or GED	*****	*****	*****	*****	*****	*****	*****	*****	0.228	0.258	0.88	0.377	0.845	0.253	3.34	0.001
Master's Degree	*****	*****	*****	*****	*****	*****	*****	*****	–0.258	0.180	–1.43	0.153	–0.254	0.180	–1.41	0.160
No formal education	*****	*****	*****	*****	*****	*****	*****	*****	0.704	0.916	0.77	0.442	0.333	0.961	0.35	0.729
Professional degree (JD or MBA)	*****	*****	*****	*****	*****	*****	*****	*****	0.114	0.308	0.37	0.712	–0.359	0.312	–1.15	0.250

(Continued)

Appendix A. (Continued)

	Community experience with fracking				Local fracking impact				Friends support for fracking				Adequacy of laws			
Ethnicity	Coeff	SE Coef	Z	P	Coeff	SE Coef	Z	P	Coeff	SE Coef	Z	P	Coeff	SE Coef	Z	P
Some college	*****	*****	*****	*****	*****	*****	*****	*****	-0.252	0.177	-1.43	0.153	0.112	0.175	0.64	0.523
Some high school	*****	*****	*****	*****	*****	*****	*****	*****	0.240	0.535	0.45	0.654	1.412	0.482	2.93	0.003
Trade school	*****	*****	*****	*****	*****	*****	*****	*****	0.986	0.374	2.63	0.008	0.144	0.336	0.43	0.668
AGE																
18–29									-0.0613549	0.1975	-0.31	0.756				
60+									0.27248	0.157	1.740	0.082				

Measures of association:

(Between the response variable and predicted probabilities)

	Community Experience with Fracking			Local Fracking Impact			Friends Support for Fracking			Adequacy of laws		
	Pairs	Num-ber	Percent	Pairs	Num-ber	Percent	Pairs	Num-ber	Percent	Pairs	Num-ber	Percent
Concordant	98927	65.0		Concordant	152816	62.3	Concordant	149640	61.00	Concordant	160785	61.7
Discordant	51759	34.0		Discordant	90975	37.1	Discordant	92303	37.60	Discordant	95477	36.7
Ties	1482	1.0		Ties	1577	0.6	Ties	3425	1.40	Ties	4184	1.5
Total	152168	100.0		Total	245368	100.0	Total	245368	100.0	Total	260446	100.0

Note: Significant terms are in bold.



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