

Health impacts of unconventional natural gas development:

A comparative assessment of community information needs in New York, North Carolina, and Ohio

Authors:

Katrina Smith Korfmacher, PhD
Environmental Health Sciences Center
University of Rochester

Kathleen M. Gray, MSPH, Megan Hoert Hughes, MEM
Center for Environmental Health and Susceptibility
University of North Carolina at Chapel Hill

Erin Haynes, DrPH, Sarah Elam, BA
Center for Environmental Genetics
University of Cincinnati

Final Project Report

Drafted: January 4, 2014

Published online: September 15, 2014

ACKNOWLEDGEMENTS

The authors thank the National Institute of Environmental Health Sciences, which supported this assessment through a collaborative supplement grant to the University of Rochester's Environmental Health Sciences Center (P30 ES01247). The Center for Environmental Genetics (P30ES006096) at the University of Cincinnati and the Center for Environmental Health and Susceptibility (P30ES010126) at the University of North Carolina at Chapel Hill also supported the project. We thank all the interviewees who participated in our study, and the many individuals who reviewed our materials and previous drafts of this report. This report is the responsibility of the authors and does not necessarily represent the views of the funder.

INTRODUCTION

Unconventional natural gas development (UNGD) has expanded rapidly in recent years in areas with shale gas resources (USEPA, 2014). We use the term UNGD to refer to the process of shale gas extraction that includes horizontal drilling and hydraulic fracturing (or “fracking”) to extract natural gas, as well as associated above-ground operations. Many communities welcome the economic development promised by the growth of UNGD. At the same time, many residents, community groups, and health professionals have questions about the potential health impacts of UNGD (Ferrar et al., 2013; Brasier et al., 2011; Kriesky et al., 2013). However, public health concerns have not figured prominently in the policy discourse until recently (Witter et al, 2013; Goldstein et al., 2012; Finkel, 2011; Schmidt, 2011).

UNGD presents challenges for education and outreach. These challenges are heightened by the rapid growth and limited past experience with UNGD, the diversity of practice, geology, environment, and community contexts, and the uncertainties surrounding potential environmental health impacts. For these reasons, with support from the National Institute of Environmental Health Sciences, Community Outreach and Engagement Cores (COECs) associated with three Environmental Health Sciences Core Centers—at University of Rochester, University of North Carolina-Chapel Hill and University of Cincinnati—conducted a comparative assessment of diverse community stakeholders’ understanding of and desire for information about potential health impacts of UNGD in New York, North Carolina and Ohio. Each state has distinct community, environmental, political, and economic characteristics, but all are at similar stages of shale gas exploration: expecting to experience initiation and/or rapid growth over the next several years. The goal of this project was to inform both the development of outreach materials to meet communities’ identified information needs on the health effects of UNGD and research scientists of communities’ research priorities in this area. The assessment centered on a set of key questions:

- 1) What are communities’ primary health concerns?
- 2) What research do communities believe is needed to address these concerns and inform sound decision making?
- 3) How have community members sought information about health impacts and what sources of information are considered most credible?
- 4) As future information is generated through research, what are the best (i.e., most effective, credible) ways to share this new information?

METHODS

In order to answer these questions, we conducted 43 interviews, between September 2012 and March 2013, with a range of stakeholders in the three states. We focused on ‘informed residents’—including government/business/community leaders, land owners, educators and environmental activists—who had expressed some interest in and made an effort to educate themselves about the prospect of UNGD in their regions. We started with existing contacts and used a snowball method to identify others. In total, forty-eight people were interviewed (five of the interviews included two interviewees) with 16 interviews in New York, 13 interviews in North Carolina, and 14 interviews in Ohio. Interviews were conducted in-person or via telephone, lasted up to 75 minutes, and were audiotaped, with participant consent. Audiotapes were transcribed verbatim, and established methods for content analysis were applied (Miles et al. 2013; Rubin, 2012). All study procedures were approved by the

University of Rochester’s Research Subjects Review Board (RSRB 00044143; umbrella study RSRB 00044034) and exempted from further review by the Institutional Review Boards at the University of North Carolina at Chapel Hill (IRB 12-2049) and the University of Cincinnati (IRB 2012-3161).

In terms of analysis, the results were organized under common themes. Descriptive categories were assigned to identify participants’ roles and their positions on UNGD, relying primarily on participant self-categorization for each (Table 1). For roles, interviewees’ self-described labels were aggregated into five categories: citizens/landowners (CL); environmental organizations (EN); local government (LG), which included local government staff, elected officials and Chamber of Commerce members; outreach and education professionals (OE); and public health professionals (PH). We also categorized the interviewees by “position” (opposed, neutral or supportive) on the development of UNGD in their areas (Table 2). Despite the limited number of interviews, analysis of transcripts indicated that saturation was reached with respect to key themes, which are described in more detail below.

Table 1: Role by State (number of interviews representing each role given as a percentage of total interviews from that state)

	Public Health Professional		Local Government		Environmental Group		Citizen/Landowner		Outreach/Education Professional		Total n
	n	%	n	%	n	%	n	%	n	%	
NY	1	6%	2	13%	5	31%	6	38%	2	13%	16
NC	2	15%	1	8%	4	31%	4	31%	2	15%	13
OH	4	29%	2	14%	5	36%	1	7%	2	14%	14
Total	7	16%	5	12%	14	33%	11	26%	6	14%	43

Table 2: Position by State (number of interviews reflecting each position given as percentage of total interviews from that state)

	Opposed		Neutral		Supportive		Total n
	n	%	n	%	n	%	
NY	6	38%	7	44%	3	19%	16
NC	6	46%	6	46%	1	8%	13
OH	8	57%	4	29%	2	14%	14
Total	20	47%	17	40%	6	14%	43

In order to help identify patterns in themes among different groups of interviewees, we coded and counted mentions of certain key issues (e.g., the number of interviews in which water quality was mentioned as a health concern). The interpretation of these counts is limited by the small number of interviews, but they provide additional context for quotations and summaries of themes provided below. Where relevant, the number (and percentage) of interviews in which these themes were mentioned is provided.

COMMUNITY HEALTH CONCERNS

Our data show a wide range of health concerns related to UNGD, encompassing determinants of health as well as specific disease outcomes. Participants were particularly focused on exposures through air and drinking water, cumulative impacts, uncertain or long-term effects, and the distribution of impacts on different populations. From our interviews, it was apparent that how community members define ‘health impacts’ varies greatly, with most framing them in terms of changes in health determinants (such as environmental quality) rather than specific disease outcomes. Along those lines, the top health issues of concern for most interviewees were impacts related to water, air, trucking, and quality of life. Interviewees also mentioned a number of other environmental changes that could affect human health, including noise and light from drilling operations, road damage, and changes in landscape/land cover. Although interviewees were asked to address both negative and positive potential health impacts, a majority of comments addressed potential threats to health. However, nearly a quarter of all interviews also referred to one or more positive impacts on health, such as the potential for improved health care resulting from the associated economic development. Not surprisingly, those supportive of UNGD had the fewest health concerns, while those opposed to UNGD, especially those with self-described scientific backgrounds, articulated an array of potential health concerns. (Tables at end of section show health concerns by state, role and position.)

Water and Health

Nearly all interviews mentioned **potential impacts on water** as a human health concern. Although it was not always clear how interviewees expected water to be impacted by UNGD, or how, in turn, human health might be affected, contamination of drinking water (particularly in private wells) dominated the comments about water quality, with two-thirds mentioning **contamination of groundwater**. Interviews described a number of potential threats to groundwater, including well casing failures, injection wells, and migration of hydraulic fracturing fluids through naturally-occurring fissures in shale formations or abandoned wells. They also described concerns about the ability of government and industry to adequately monitor installation of casings, the longevity of casings, or other potential threats (like earthquakes) to the integrity of casings.

These concerns were evenly distributed across all three states, and respondents focusing on this issue included all of those who identified as environmental group members, all public health professionals, and all “opposed” to UNGD. A neutral representative of an environmental group from New York said, *“There’s a whole area of water concerns from start to finish with fracking and plenty of opportunity for things to go astray, for people nearby to really be impacted.”* Zeroing in on more specific concerns about groundwater, an opposed environmental advocate from North Carolina said, *“There’s also...the long-term potential for groundwater contamination, even if the well was cased correctly, even if it’s all done correctly, the standards that I’m seeing from other states, those wells are built to last 40 years, 60 years, but this groundwater resource has been there for millions of years. And it doesn’t have*

any capacity to clean itself. And so if you punch a hole, that is going to become a conduit for contamination...you're eliminating that future resource for generations and generations and generations."

A majority of interviews discussed **threats to surface water**, and various routes of contamination were mentioned. For example, just over half of all interviews specifically expressed concerns about accidents and over a third mentioned wastewater disposal. Several of those who were strongly supportive of UNGD acknowledged the potential for accidents. A supportive Cooperative Extension educator in New York said: *"So in terms of the negatives I think that the negative that everybody agrees on is...the potential for particularly a surface spill. I think that no one disagrees with the notion that if you're handling large volumes of toxic chemicals, at some point, some of it will be spilt [sic] somewhere and that's just a general understanding that it will happen and the consequences there will be...that some waterway or surface water will be contaminated with toxic chemicals. So, that's one of the certainties that there will be certain negative impacts with possible health consequences to human beings and to livestock more likely."* Threats to surface water also raised concerns about trans-boundary issues; that is, even if individual landowners, localities, or states banned or tightly regulated UNGD practices in their areas, they might be impacted by pollution from activities in upstream jurisdictions.

Impacts of contaminated water on agriculture and wildlife were mentioned in over a third (16) of all interviews, with specific concerns related to human consumption of plants or animals that came in contact with waste or flowback water. A neutral Cooperative Extension Educator in New York said, *"There's also been some concern about health risks related to animals and what it means because we are a farming community....Is there going to be an impact on livestock?"* These concerns included the well-being of the animals themselves, the health of consumers, and the economic impacts on farmers and those dependent on income from hunting or fishing. As another New York interviewee (an opposed business owner) noted, *"Fishermen and sportsmen, those that don't have huge tracts of land, are very much in favor of limiting the poisoning of the rivers and the forest, because that impacts their ability to not only catch healthy fish but [to] eat healthy game and fish."*

A fifth of interviewees noted **water quantity** as a key concern, voiced most often by interviewees from Ohio (with nearly half of Ohio interviews mentioning water quantity), where the impacts on agriculture from a 2012 drought were fresh in people's minds. As an opposed representative of an Ohio environmental group said, *"The drought in Ohio, the 100 degree heat in July, the way even really in just northwest Ohio wells ran dry...they're looking for water to be piped in for drinking, and this much water is being destroyed to serve one industry that is highly unregulated, and it's highly destructive, and it's a boom bust."*

Air and Health

Air quality issues were also mentioned by the vast majority of interviewees, particularly air pollution from evaporation of volatile chemicals from holding ponds, fugitive emissions from wells, and diesel emissions from trucks, equipment, compressor stations, and silica sand. As the leader of a non-profit described as a "science-based environmental justice group" in North Carolina said, *"Toxic air emissions actually began to emerge as probably closer to a well-documented health risk than groundwater contamination."* One environmental group representative from New York explained that he was more concerned about air impacts because it was feasible to mitigate water quality concerns through better technology, regulation, and practice. Overall, nearly two-thirds of interviews mentioned some health concerns related to trucks. Although only six of these specifically mentioned diesel emissions contributing to air pollution, many of the non-specific comments about trucks included air

quality concerns (along with traffic, accidents, spills, and road damage). As an opposed public health professional in Ohio said, *“A ton of traffic, lots and lots of traffic. I think that’s what people complain about the most: the noise and the traffic. Your air quality starts to go down because you’ve got so much diesel in the exhaust.”*

Silica sand was also mentioned in a number of interviews. Although sand is not usually thought of as an air quality issue, the risk of inhaling silica particles was mentioned largely in the context of inhalation by workers or people living near sand mining, transport, or storage facilities. A neutral public health representative in Ohio said, *“There’s a place only a mile from where I live where they’re stockpiling a lot of this [silica sand]. And you get anywhere near there on the road and there are all sorts of sand on the road. We know that silica exposure could be detrimental – I don’t know what that exposure has to be. I know that a worker...gets exposed so badly that the best protection equipment doesn’t protect them adequately. So I do worry about what’s happening potentially locally around storage stock piles like this.”* Yet another Ohio interviewee concurred, saying, *“Oh yeah, that’s a big work place hazard. That probably is, from my understanding, is the number one occupational health hazard involved with fracking...inhaling all the silica.”*

As with water quality, **cumulative and transboundary impacts** of air pollution were discussed. A municipal official in New York said, *“And there’s quite a bit of concern here about what wind will come our way and what water will come our way from that drilling outside of our borders.”* In North Carolina, a concerned citizen with a scientific background said, *“I think a lot of the people...when they look at a map of where the shale is located, they say, “oh good, I’m not gonna be involved.” And we need to get them to understand that, yes, you will be, because we all have to breathe the air and drink the water and, you know, drive in the traffic and all the other things.”*

Quality of Life Issues

Over half of the interviews raised one or more health concerns connected with **quality of life changes** they expected to see in communities as a result of UNGD. Local government officials were most likely to report quality of life concerns, followed by outreach/education professionals, citizens/landowners, and public health professionals. Among supporters of UNGD, the health concerns most commonly noted were quality of life issues. These issues included specific concerns like increased traffic, housing costs and crime rates, as well as more general comments about the impacts of “boom and bust” cycles of development and loss of “rural character.” In elaborating on these potential changes, a municipal official in New York referenced, *“Huge increases in substance abuses that the hospitals see. Huge increases of sexually transmitted diseases. Increases in drinking and DWIs. Increases in road accidents, trucking accidents, car accidents, pedestrian accidents. Toxic substances. All of those are a health impact of a different sort and probably more immediately prevalent than these water and air things.”* An environmental advocate in North Carolina said, *“One of the things that you’d expect in a boom-bust economy is these floods of transitory migrant workers coming in—mostly men without their families with them—and...you get these sort of shocking statements about, ‘well, what about the sex trade and the public health dimensions of that?’”*

Over a third of the interviews expressed concerns about effects on public health or health care systems, and a subset of interviews identified a need to better engage the public health community in decisions related to UNGD. In addition, many interviews expressed concern about the ability of government and industry to adequately monitor drilled wells. The same environmental advocate from North Carolina said, *“If you bring shale gas extraction into a region or into a state economy, it is a boom-bust cycle. And that has a whole set of implications for local government finance, for community*

dynamics, but also for public health...I think public health in boom-bust economies...[is] buffeted by a different set of constraints and shocks than public health in an economy that has fairly stable economic activities as the main drivers in that economy."

Other interviewees expressed concerns about increased community conflict and stress. Conflict was attributed to divisions between those who supported and opposed shale gas extraction and between those who signed leases and earned money versus those who did not own their mineral rights. A concerned resident in North Carolina said, *"I guess we would call it the social side of this business...that's where you have adjacent landowners who may be very good friends or may even be family members and one chooses to participate and sign an agreement with the gas company and one chooses not to participate, but you know, the traffic affects both of them."* Some interviewees simply described this conflict as a community change; others explicitly described it as a threat to community members' mental health.

Most interviewees recognized that community changes could have both benefits and negative impacts on community health, and that these depend on the pace and management of drilling. However, there were different opinions about what the net impacts would be. In terms of community benefits, a supportive landowner in New York said, *"A healthy society is also a wealthy society. You know if business is here and would be doing well people can afford to go to the doctors, afford to go to the dentists and get good healthcare... you have community centers, okay, so you're taking your kids...by giving jobs you are taking your kids off the streets, they are not selling drugs. You lessen that by keeping them busy, giving them careers that they can take someplace...you might lose that quaint touch of your village. But here's the quaint touch that we've lost of our village here right now as it stands...My kids don't live here. They had to go elsewhere to find jobs. I own a company. One time I had 23 employees, I have 5."* A supportive Chamber of Commerce member from Ohio said, *"It's just phenomenal because some of the companies that are coming to town of course initially bring their own people with them, because they are trained and have the experience...so those folks are either staying in the hotels, but when the hotels fill up they are looking for homes to rent...and people are renting their homes for a very good price. And it's jacked up a bit because the realtor includes cleaning services, and garbage pickup, and laundry...so it really is a win-win for everybody."*

As further described below, interviewees recognized that the changes brought on by UNGD would have varied effects on different members of the community. One, a neutral member of an environmental group and a landowner in Ohio, said, *"That [increase in housing demand] is great for landowners who have rental property, for those people at the bottom of the socioeconomic scale not so great."* Other interviews noted that with expected economic growth, low-income residents would be better able to afford health care. One interviewee cited an example from another state in which gas drilling companies helped fund a new community health clinic.

Public Health and Health Care

Two-fifths of interviews mentioned specific issues related to public health systems, including emergency management, health care resources, challenges to health care providers, and the limited capacity of government agencies. There were also concerns about training emergency responders to deal with new kinds of hazards such as chemical spills, explosions, and radiation and whether they would be given sufficient information by the drilling companies to know what hazards might exist during emergency response. These concerns did not arise only in the hypothetical, but also in some areas that had already experienced development of UNGD. An environmental group representative in Ohio noted, *"We had a meeting with our emergency management people here in Washington County...and they say*

they're working in the blind because they don't know what chemicals are there. Now they can try to figure it out, and they can call in and get the information, but in the meantime this spill that may have occurred is going into the ground, and they don't know what it is. And they don't know whether to go near it, because they don't want to hurt their people either."

Several interviewees noted concerns about the workers without health insurance burdening local health systems and about increases in diseases, particularly sexually transmitted infections. Other concerns related to the demographics of the new workforce (anticipated to be young single males from out of state) included increased violence and DUI-related accidents. Others expressed occupational health concerns. An Ohio physician said about drilling workers: *"They do require some extra medical attention. There were lye burns through muscles and tendons. I don't know what they're using the lye for, but that's real alkaline and burns right through muscles and tendons."*

Many interviewees mentioned unique challenges to health care providers, including lack of knowledge of the kinds of chemical exposures and hazards to which workers and residents might be exposed. A related theme that generated strong responses from all three states was the regulation preventing physicians from sharing information about chemical exposures (commonly known as the "gag rule") in effect in Pennsylvania. As a concerned resident in New York said, *"the other thing that I can't but mention...that gag rule in Pennsylvania on the doctors, that puts up such a huge red flag...why are they imposing a gag rule on the doctors?"* Related to the gag rule on physicians was the belief that non-disclosure agreements (contracts under which gas companies provide remediation to affected residents on the condition that they not share information about the damages) prevent health professionals from being able to monitor and manage health impacts. In North Carolina, a concerned resident with a scientific background added, *"How are we going to learn what's wrong if the people affected can't talk?"*

Respondents in New York and North Carolina also highlighted a **need to better engage the public health community** in decisions about UNGD. They noted that public health leaders have not been "at the table," underscoring that public health impacts may not be fully considered, with a public health representative in North Carolina saying, *"Our state health director has not been invited to sit on any research...or legislative committees or rule-making committees. She's been left out. And then we have 85 other health directors in our state who don't have fracking really as an issue—maybe one or two other counties—so this body, which normally protects public health is not really invested or vested in this."* Another North Carolina respondent said, *"Almost all of the state and federal advisory bodies have paid almost no attention to making sure that public health is well-represented on any panels...that's pretty obvious it hasn't been taken seriously."* These interviews also suggested potential roles for health departments, such as storing and sharing data related to UNGD operations. A supportive Cooperative Extension educator from New York said, *"It's not part of their charge but...the assumption was that the local health department was gonna be responsible for holding the data related to water testing of private wells."* Another New Yorker, a supportive landowner, said *"...wish the Department of Health would go out in New York State and say, 'OK, we are going to have information. We are going to do something with it.'"*

Concerns were also voiced in all three states about the **adequacy of regulations as well as capacity of agencies to monitor and enforce regulations**. *"They are radically understaffed to send inspectors out to these wells, the fracking wells and the injection wells to do any sort of credible job. So I'd say that's a pretty big question mark. The will and the capability of the state to adequately enforce regulations even on the books, let alone what's really going to be most protective of people's health and property rights,"* said an environmental group member in Ohio. A community member in North Carolina said, *"You know if we have the regulations in place, who's going to enforce them? And then these people*

that come in here, you know, you have competent contractors and drillers and you have people that are incompetent. You have what you call “fly-by-nights.” And you definitely wouldn’t want some of those people in here destroying the environment.” A landowner in New York who was supportive of UNGD showed more faith in the system but still underscored the need for active enforcement, saying, *“We’re not going to avoid some of those health risks. All we can do is hope that the DEC [Department of Environmental Conservation] does their job in working with protections and inspections on these sites.”* A final theme was coordination among agencies, as a public health representative in New York said, *“I don’t know how much the different divisions and agencies are talking to each other. I know I would like to see more communication.”*

Vulnerable Populations

Without prompting by interviewers, participants from all three states raised issues of **unequal impacts and vulnerable populations** in the context of health issues surrounding UNGD. Typically, they were referencing workers and low-income or rural residents as having unique exposures. They noted that some of these groups might be affected by multiple exposures (via water, air, etc.) and both research and regulatory strategies could be directed to assure protection of particularly vulnerable groups of people. Interviewees representing all positions raised concerns about distribution of costs and benefits, with a neutral Cooperative Extension educator in New York saying, *“Well, we know in Pennsylvania this is already...the case, there will be winners and losers and that you can expand that to economic issues, maybe health issues, but there is clearly gonna be folks that benefit more than others.”*

The most frequently identified group of concern was **workers**, with nearly a quarter of interviews mentioning specific occupational health concerns. Over a third of interviews from Ohio, the only state in this study in which active UNGD is occurring, mentioned worker health, as did over a third of public health professional interviews. Worker health concerns primarily included exposure to hydraulic fracturing chemicals, toxic air emissions, and silica sand. A small number of people mentioned the potential for explosions, spills, and accidents involving mechanical equipment. For example, an Ohio physician noted hearing about areas with active UNGD that had seen *“blast injuries, crush injuries, 30% increase in their ER [Emergency Room] utilization when they started fracking over there. If you’re not getting hurt, you don’t need more ER utilization right?”*

After workers, **low-income residents** were identified as a subpopulation of concern. These residents were viewed as less likely to own enough land to benefit from leasing or extraction fees or to own a business that would experience the positive effects of a development ‘boom.’ *“A number of the large landowners who have leased don’t even live on their lands, so they’re not going to get the direct air and health impacts. So, the noise, the traffic, the air emissions, the groundwater contamination, will have a disproportionate impact on low-income folks in a county like [ours],* said a leader of a science-based environmental justice organization in North Carolina. Low-income residents were also described as more likely to be renters affected by increasing rents or housing demand or overburdened public services (e.g., emergency and health care). Several people also mentioned that poorer residents are less likely to feel they have a choice about signing a lease because they need the income, are less likely to have the education, knowledge, or legal resources to negotiate a beneficial lease, and are less able to take proactive steps to protect their environment and health (e.g., lack financial resources for independent baseline or long-term water quality monitoring, to afford health care if they are exposed to pollution, or to move away during active drilling). An advocate for rural communities in North Carolina said, *“When you talk about public health issues, what we have to talk about is the coercion of people in poverty who have no other options, who are looking for some level of financial stability.”*

In addition, some interviewees expressed concern that **rural residents** have no alternative source of drinking water if their wells are contaminated. As noted above, there were also concerns about impacts on agriculture, tourism, and wildlife, which may be primary sources of income for rural populations. Interviewees believed that damage to these economic sectors might have disproportionate impacts on the economic status and, indirectly, health of rural populations.

Overall, there was widespread recognition that changes in the environment, community and economy would affect different people differently, whether because of their exposures (workers and near neighbors), lack of resources to avoid or minimize risks (low-income, renter, and rural residents), or physical vulnerabilities (pregnant women, children, older adults, and those with preexisting conditions).

RESEARCH NEEDS

The responses summarized above emphasize the major uncertainties and gaps in knowledge related to the health effects of UNGD. Most interviewees acknowledged that **additional research would help inform better decision-making about UNGD**. However, a neutral public health representative from Ohio suggested that the divided nature of the discourse in communities meant that people who oppose UNGD will call for additional health research and people who support it will not. When discussing the types of research needed, interviewees focused on the lack of available information about the potential health effects of UNGD, with nearly two-thirds of the interviews expressing a desire for additional research on health effects. Their comments ranged from wanting to characterize the available information to identifying specific chemicals for which they would like more information on associated health effects. A leader of a science-based environmental justice organization in North Carolina said, *“There are far more questions than there are answers for the health effects. What we have is a sampling of the health effects. We don’t have anything like surveys as to how common those health effects are. We don’t have good exposure data.”* Specific health outcomes that were mentioned as needing further study in relation to shale gas extraction included endocrine disruption, developmental disorders, cancer, respiratory disorders (COPD, asthma), birth defects and miscarriage, among others.

Baseline Study of Water and Air Quality

Interviews also directly connected environmental quality to community health, focusing on the need for communities to have baseline measures of air and water quality prior to the onset of UNGD, thereby enabling a more nuanced understanding of how industry may impact the environment over time. Of particular interest across all positions and all three states, but noted with more frequency in New York and North Carolina, were the **baseline environmental studies of water quality** (in groundwater, surface water and wells) and **air quality**, with over a third of interviews calling for such study. A neutral resident in North Carolina stated, *“There’s a whole lot of baseline data that North Carolina should have, county by county, before it begins this process, so we’ll know...if and when fracking occurs...we will know if the picture has changed. Now like I said, you’ve had this issue in other places and you can’t resolve it because they didn’t have the data to start with.”* Participants raised a set of logistical issues related to baseline monitoring, including which parameters to test, where to test and how to cover costs, among other factors.

Environmental Monitoring

Participants also identified a need for **environmental studies** to inform health-protective decisions, particularly focused on the impacts of active UNGD on water quality and air quality. An environmental group member and landowner in Ohio said, *“Whether it’s air or water, water and air—those are the top two.”* A New York landowner who was supportive of shale gas extraction noted that air quality was not just a trucking issue and recommended air quality monitoring around compressor stations. Both these interviewees recognized that environmental sampling would be costly, and that public funds were not currently budgeted for it. They also both identified a need for a central and accessible repository for any sampling data.

Geology was also identified by participants in all three states as needing further study, so that decision makers could have a better understanding of the potential for chemicals to migrate. In Ohio and North Carolina, seismic activity in particular was identified as an area needing further research, both in terms of how often it was occurring and also it how it might affect existing materials in the subsurface. A participant who is a newspaper editor in Ohio said, *“I think somebody needs to do a better job at tracking these earthquakes, quite frankly,”* while a member of an Ohio environmental group said, *“We have earthquakes and what’s that going to break loose? We’ve got lots of old wells and old coal mines in the area.”*

Human Health Studies

In addition to environmental study (baseline and ongoing monitoring), interviews called for **broader study of human health** including approaches as diverse as epidemiology studies, health impact assessment, and compilation of case studies. A fifth of the interviews called for epidemiologic or other health studies, with at least one noting that the magnitude of unknowns makes such study even more critical. *“There’s so many chemicals, there’s so many avenues of contamination. You know, water, air, land, food...we don’t have any idea...so we need long-term epidemiological studies,”* said a public health representative from North Carolina. At the same time, interviewees highlighted the inherent challenges of epidemiologic studies, with one environmental advocate from North Carolina saying *“I don’t know a lot about public health monitoring, but I suspect we’re going to have a very hard time drawing direct lines on this.”* A representative of a science-based non-profit [participant’s choice of language] in New York noted, *“Epidemiology takes time and money and it’s a complex issue...the issue of causal inference...complex chemicals and exposure pathways...we’ve seen how difficult it can be to prove this kind of thing; tobacco was an example.”* On a related note, the uncertainties regarding how long a particular well might be operational were flagged by one interviewee as affecting our ability to estimate health effects.

Health impact assessment (HIA) was mentioned in five interviews (including four from New York, where there had been an intensive public debate about commissioning an HIA on UNGD) as a useful tool for evaluating health effects. Notably, HIA was mentioned by people representing all positions (i.e., neutral, opposed, supportive). One respondent, a program director of a regional environmental group in New York, stated *“We have been pushing for comprehensive health impact assessment (HIA), because there’s a lot of unanswered questions about health impacts and there hasn’t been nearly enough peer-reviewed studies happening...the process of HIA, as recognized by the CDC or WHO...is a process for gaining information and also finding out where the gaps are.”* Underscoring the desire for transparency and access to data expressed by several participants, another New York respondent (a business owner) called for any HIA to be *“open to the public.”*

A neutral Cooperative Extension educator from New York suggested a need for **meta-analysis of existing studies** related to air or water contamination and health, saying *“I think it’s more research but*

it's also someone pulling it together and saying 'You know there's been twelve studies and here's the metadata from that...'" Another North Carolina interviewee made a similar point, saying *"There are a lot of studies that have been done...when I see them...I have wondered, is someone else also looking at this so that you can get a bigger body of knowledge than one study?"* On a related note, a multidisciplinary, science-based non-profit [participant's choice of language] focused on energy issues and based in New York emphasized the issue of responsibility for providing information on community health impacts, saying *"There have never been any reports that look at human health in communities where drilling has been taking place, say for the past five years...right now it's the citizen's responsibility to provide that kind of information when it should be either the extractive industry itself or the government."* This interviewee also identified the need for a *"health registry for tracking symptoms and conditions...something like SEER"* to move data on current cases from the realm of anecdotal and into a tool that could be used in health studies.

Interviewees from all three states highlighted the **value of case studies from areas with active shale gas extraction** (such as Colorado, Pennsylvania and Texas) in terms of informing other communities about potential health impacts. One environmental advocate from North Carolina said, *"If we want to prepare the public health infrastructure...we should be looking at other communities around the country that have real boom-bust cycles."* Another North Carolinian, a supportive landowner, echoed these sentiments, saying, *"If there were studies done nationally at some of these areas...at boom towns...obviously for short term there is incredible uptick of wealth, but it quickly goes in the other direction. I think it would be fascinating to know...nationally, what are some of those issues and how you can avoid some of that."* Similarly, a supportive community development specialist in Ohio wondered, *"What's going to happen when the boom is over? Are we going to be left with a lot of slum and blight?...We can look at the communities who have gone through it and are currently still going through it...and see what is happening in their area...I think the research would need to be ongoing, even after [the industrial operation is] over to come to any type of conclusion."*

Site-Based or Operational Issues

Research needs were also described in the context of the **interactions among potential exposures resulting from shale gas extraction operations**, underscoring that at least some participants viewed the community as a system of interacting elements, many of which can contribute to community health. For instance, participants in all states, roles and positions noted a need for research on chemicals in hydraulic fracturing fluids (not only identification of which chemicals are being used but also potential health effects of those chemicals and how they may interact with other chemicals already on site). A member of a New York environmental group said, *"This is a big industrial activity...[it] doesn't just happen at a factory or at one particular spot. There's a lot of moving parts here. What happens when all these moving parts start moving together?...One of the things I think is most lacking is the cumulative impact, the...impact of what happens if we allow for drilling under different development scenarios. What happens when there are X number of trucks trips and X number of compressor stations and X number of fracking rigs all working at the same time in the same vicinity?"* Others indicated a desire to see research on how the chemicals used in UNGD interact with naturally-occurring or other chemicals that are already in the ground, with an environmental group member in Ohio saying, *"What is the synergistic effect of the toxic brew? I'm not sure how scientists and researchers can do a big research project without knowing the full extent of the chemicals. We could only ever know part of the story, even on health effects."*

In addition to hydraulic fracturing fluids, a number of other compounds used or released in UNGD operations were identified as needing further study with respect to their impacts on health. These included radioactive materials in flow-back water, methane, silica, VOCs and particulate matter, among others. Some also called for greater study of potential health impacts on wildlife and livestock in areas where shale gas extraction is already occurring, as noted earlier.

Technology was also identified as an important area for further research and also an area where participants wanted more information about existing technologies and practices. A New York landowner who was supportive of UNGD wanted to see research on methods of extraction, expressing a desire for *“research on better ways to extract...maybe less invasive, don’t use as much water.”* Similarly, a newspaper editor in Ohio noted that, *“Maybe methods could be perfected because industry, when they are pushed to come up with an alternative, industry becomes pretty effective at coming up with a different way to do business.”* Along these lines, several Ohio participants, ranging from opposed NGOs to supportive Chamber of Commerce members, also wanted to see research into wastewater treatment options, with more information available on where injected materials end up and alternatives to injection wells. In North Carolina, a Cooperative Extension Director wanted to know more about the impacts of injecting wastes, asking, *“When you start shooting stuff back in the ground, what are you going to do? Are you going to cause more of those earthquakes?”* Participants were also interested in learning about innovative, new technologies that could reduce negative impacts (such as water-conserving techniques).

Other Research Needs

About a fifth of interviews mentioned research needs related to **economic impacts to communities**, with some interviewees calling for cost-benefit analyses and better characterization of infrastructure costs. Some questioned how economic benefits were distributed in areas with shale gas resources and how sustainable the associated jobs would be, with a business owner from New York asking, *“Are these gas jobs sustainable or are they just a shot in the dark that makes a few people rich and the rest of us poor?”* A similar sentiment was expressed by an environmental advocate and landowner from Ohio, who asked: *“Property values will bump up, but in the long run, will it be good for the county? The jury’s still out.”*

Several interviews called for **legislative and policy research**, ranging from research on financing mechanisms to the extent of local government authority and eminent domain. These interviews raised questions about what regulatory frameworks would best protect human health and whether the federal government approaches were protective enough.

Similar to the health concerns identified, three interviews (two in North Carolina and one in New York) identified *research needs* related to **environmental justice** and **vulnerable populations**. Specifically, these participants wanted to know which communities were being most negatively impacted by UNGD and what the anticipated impacts would be. A Cooperative Extension educator in New York said, *“One of the concerns that I’ve heard about specifically is the health effects on youth and particularly not school-aged, but young children...young children and infants so there is a lower age range. So, it would be interesting as this moves forward, are there issues with more vulnerable populations where maybe some things won’t affect most populations, but if you’re in this age range or have a compromised immune system? I would find that helpful.”*

The Research Process

In the course of the discussion on research needs, over a fifth of interviews addressed issues related to **how research is conducted** and **who funds it**. Roughly a quarter of the interviews raised the issue of **providing public access to research data**. In this context, two key barriers to research were noted, and distrust of industry underpinned both: 1) lack of transparency with respect to existing data and 2) active efforts to conceal data from impacted communities and decision makers. A neutral representative of an outreach and education program in North Carolina said, *“Industry’s taking tests; you know that industry has an idea of what’s down there...they’ve done their own seismic stuff...we don’t have access to any of that. And they’re not going to give us access to any of that.”* Another North Carolina concerned resident with a scientific background [participant’s choice of language] asked, *“Who’s going to do the studies? The gas company doesn’t want to do them; they’re the ones with all the money. They don’t want to do them.”* This person also raised the issue of the Pennsylvania gag rule, asking, *“Why did they even feel that was necessary, to have a gag rule on physicians?...How are you going to collect data if that sort of stuff is going on?”* Along these lines, there were conflicting opinions on whether industry should sponsor the necessary health research. Some interviewees recognized that although industry may have the resources to conduct research, it may not be motivated to do so. An opposed environmental group member from Ohio said, *“The industry needs to pay for it, you know? They ought to be volunteering to pay for it if what they are doing is so safe.”* This respondent was also concerned that industry wouldn’t release results if they were “bad.” Another participant, a retired environmental scientist from New York, also highlighted this dilemma, noting *“It’s ironic...because studies should be paid for by those who have a financial stake, right? But how do you do that in a way...I still think it doesn’t really work”* for industry to fund the research. This participant suggested that industry could provide funding for research and work with an oversight committee or another mechanism that managed potential conflicts of interest

Other participants thought government should be supporting the needed health research, with a Cooperative Extension educator in New York saying that it would be *“very beneficial...[if the] federal government saw this as a major issue and pulled together a stronger set of research funds for people to go after.”* Yet another, a member of an environmental group in Ohio, said, *“What I really want to know...is why government is not funding the research that’s needed?”*

Finally, an elected official in North Carolina wondered whether local emergency responders would be adequately informed on risks associated with sites, saying *“There needs to be a lot more research on...what could happen in the event of a spill...what effects could that have on...first responders in our community? What are we going to need to do to better prepare our health care professionals?”*

COMMUNICATING INFORMATION ABOUT POTENTIAL HEALTH EFFECTS

We asked interviewees about how they obtained information on health effects and which sources of information they believed to be most credible. We also sought to understand how interviewees thought new information could be communicated most effectively to community audiences. We coded the responses to this question into eight information source ‘types.’ A ninth (“peer-reviewed”) might generally be thought of as a subset of university-based sources, but since it highlights a specific process for reviewing and disseminating (and since government or other sources of information can go through peer review), when ‘peer review’ was mentioned, we coded it as a separate response. University-based sources and media were the most commonly identified information sources, in general and when data were analyzed by state and by position of interview towards UNGD (Table 3). Government agencies and the Internet were also mentioned in more than two-thirds of the interviews.

Other sources included the oil and gas industry, environmental groups, stories and experiences of real people, and community meetings/forums/seminars. Some state-by-state variations suggest the impact of an active industry presence on both information dissemination and community demand for information. Specifically, the oil and gas industry and community meetings were mentioned more often as sources in Ohio than in the other states, perhaps because the industry is active there, meaning there is an ongoing industry presence as well as more resident/community organizing around the issue of UNGD. New York and North Carolina interviews tended to identify stories and experiences of real life people as sources, roughly twice as frequently as Ohio interviews. This dynamic underscores the belief of interviewees in states without active UNGD that they can learn from those who have experienced or are experiencing UNGD and also suggests that information dissemination needs to be context-sensitive and context-specific.

When participants discussed the credibility of sources (Table 3), they generally indicated awareness of the potential for misinformation and bias around the issue of UNGD, with a neutral outreach/education professional from Ohio saying, *"You always have to consider the source, and you're always weighing the quality of the information that you are getting."* "University-based" sources of information, followed closely by "government agencies," were mentioned in around a third of the interviews as credible. One resident from North Carolina, who was neutral regarding UNGD, articulated why many find university-based information credible, saying *"People who have no way of profiting from whatever their information is...a lot of times are credible sources. That is they aren't paid by, hired by, work for, some way of profiting from a group that is pro-fracking or anti-fracking. You know not pro, not a part of a gas company or a part of a group that's maybe an extreme/extremist environmental group that's just opposed to it in general. University folk quite often are neutral in that regard, and I seem to put a lot of stock in those kinds of people and those kinds of reports that I've read."*

In terms of sources believed to be biased, "oil and gas industry" was mentioned the most frequently, in a third of interviews. A public health professional from Ohio, who opposed UNGD, stated, *"The big point I'm making, is from the beginning, they've [oil and gas] used deception. If your opening ground is deception, pretending you're from Canada when you're really from Dubai, I mean, that is so classic of everything they're doing."* However, some interviews found the industry to be a useful source of technological information, with an environmental group representative in North Carolina saying, *"We were able to find something, actually in the industry literature...in the petroleum geology literature, which turned out to be very powerful information to share with environmental health departments and let them understand just how much at risk wells were and how shallow our shales were and the potential implications of that. We found things in industry publications, so we have reviewed industry websites as well."* At least one interview (a neutral representative of an environmental group in New York) flagged persistent bias in discussions of UNGD, saying, *"We've found it to be really VERY difficult to find things that don't have a fairly conspicuous bias, including in the peer-reviewed literature."* In addition, interviewees recognized the potential for bias among media sources, with a neutral public health representative from Ohio saying, *"I want to go to the actual sources and not rely on the news media all that much because I think things get twisted."* Comparatively, more people mentioned university-based and government sources as credible than not credible. Media and environmental groups had about the same number who mentioned them as credible and not credible, and the oil and gas industry had more people who perceived it as not credible.

New York and North Carolina interviews tended to identify stories and experiences of real life people as sources roughly twice as frequently as Ohio interviews. This dynamic underscores the belief of interviewees in states without active UNGD that they can learn from those who have experienced or are experiencing UNGD.

The responses to questions about how interviewees would like to receive future information on potential health effects and risk reduction actions focused on media and internet and community meetings/forums/seminars, suggesting these as appropriate outreach approaches or communications channels for sharing research findings. Government agencies were mentioned by a quarter of interviews, followed closely by “stories and experiences of real people.”

Table 3: Sources of information by credibility and frequency of mention*

Source	Mention	Described as credible	Described as not credible
University-based	84% (36/43)	32.5% (14/43)	9% (4/43)
Media	79% (34/43)	16% (7/43)**	12% (5/43)**
Government	70% (30/43)	28% (12/43)	7% (3/43)
Internet	65% (28/43)	2% (1/43)***	2% (1/43)***
Oil & gas	58% (25/43)	9% (4/43)	32.5% (14/43)
Environmental	56% (24/43)	9% (4/43)	9% (4/43)
Stories	49% (21/43)	5% (2/43)	0% (0/43)
Community	46.5% (20/43)	2% (1/43)	5% (2/43)
Peer-reviewed	25.5% (11/43)	12% (5/43)	2% (1/43)

*This table was created from free response questions, meaning some participants mentioned sources and addressed their relative credibility, some mentioned sources without addressing credibility and some did neither.

**In addition to these numbers, two interviewees mentioned media as sometimes credible and sometimes not credible.

***In addition to these numbers, one interviewee mentioned internet as sometimes credible and sometimes not credible.

OTHER THEMES

A variety of other themes arose in our interviews, each of which is briefly summarized below.

The **economic impacts** of UNGD were noted as a key component of community-level discussions about health. Some people related the economic development potential to improved health status and public health services in rural communities, making statements like the following by an advocate for rural communities in North Carolina, *“You would have people who don’t have jobs now having jobs and feeding their families. And you would have growth in communities that have no growth now. You would have the ability to pay for services you’re not able to pay for.”* Others emphasized the potential negative, long-term effects on community health of a boom-and-bust resource extraction pattern, highlighting the unequal distribution of economic benefits that can accrue to those who already have resources (such as larger landowners) while higher costs (such as increased housing costs) are imposed on low-income residents. For example, a North Carolina environmental advocate, who opposed UNGD, said, *“It’s not raising all boats, it’s raising a few boats way high.”* A supportive local government interviewee from

Ohio said, *“Landlords and property owners know that they can get more out of these oil and gas workers. So, our low-income tenants, once their leases are up, are not going to be able to afford the new rent so they’re not going to have anywhere to go. It’s a big concern and they’ve seen it in other communities.”* At the same time, interviewees were keenly aware of the economic struggles of many of the areas where UNGD could expand, and that the prospect of economic benefit was likely to overwhelm concerns about health, as a community member from Ohio noted, *“I think people have a whole lot on their mind, other than fracking. Like, how do I put food on the table?”* Comments about potential economic benefits came from all three states and from people supportive, neutral, and opposed to UNGD.

Trust and perceptions of credibility were intertwined with interviewees’ position on UNGD. Interviewees who supported UNGD often expressed trust of government and industry, while interviewees opposed to UNGD gave examples of what they perceived to be unethical industry efforts to subvert concerns about health and environmental protections. An opposed resident from Ohio noted, *“When these folks first started drilling and stuff, they fought tooth and nail through the courts and did everything they could to deny public knowledge, access to the ingredients, the chemicals they were using in their drilling process. Eventually I think they lost most of their law suits or injunctions. But right from the get-go that worried me.”* Similarly, universities, researchers and other groups who received industry funding were perceived by many to be biased and not credible, as noted by an opposed science-based environmental justice organization in North Carolina, who said *“I am very skeptical of any industry money being involved. In some states, even the Cooperative Extension program is compromised—especially in Pennsylvania—but I’m sure that’s true in other states too.”* The fact that distrust and credibility came through so strongly in conversations about health impacts suggests that the distrust of industry is a fundamental consideration to be taken into account in designing future research and outreach efforts. This suggests that transparency about sources of information, funding, conflicting information, and uncertainty will be essential to effective research and outreach.

As described earlier, **learning from the experiences of other geographic regions** was a pervasive theme throughout the interviews. At the same time, interviewees were keenly aware of economic, social, geographic, and political factors that could shape the experience of UNGD in their communities differently than elsewhere. UNGD is often talked about as a singular practice, which suggests that similar solutions (policies, technologies, outreach strategies) can be implemented in a variety of locations. However, the actual health impacts of UNGD on humans are likely to be mediated by all the factors noted above. Our interviewees’ nuanced understanding of the complexities and ways in which their community may be *different* cautions us to be open to differences in all these dimensions as we develop research, outreach, and policy and underscores the need for context-sensitive and context-specific information.

Many of the interviewees were aware that UNGD uses **new and rapidly evolving technology**, and this awareness affected perceptions and projections of health risks. Some noted that many reports of health problems related to UNGD occurred several years ago, and that the drilling practices and technologies had significantly improved since then, with a supportive Chamber of Commerce member in Ohio saying, *“We also understand that even within the last 3 to 5 years, the progress they’ve made in safety measures is unbelievable.”* Others noted that it was difficult to predict health impacts because technology is constantly evolving both in response to regulation and industry-led improvements. Some interviewees also expressed confidence that technologic innovation could forestall potential health impacts. As a neutral resident in North Carolina said, *“We put a man on the moon and brought him back safely. We can drill for gas and do it safely and do it right, if they want to do it right.”*

Many interviewees raised concerns related to **government agencies and politics in the context of UNGD**. Key issues had to do with the relationship between the industry and government, particularly lobbying, campaign contributions, and influencing regulations. Another concern was the capacity of government agencies to develop and implement sufficiently protective regulations. Some participants believed that such infrastructure was all that was needed to protect public health, while others noted the need to adequately fund enforcement as well.

Finally, several interviewees described UNGD as fundamentally an **issue of landowner rights** and introduced **leasing issues** as central to educating landowners to protect these rights. Others saw good leases as an effective tool for guarding against negative health and environmental impacts. Regardless, it is clear that the structure and content of lease agreements is of critical importance to community health, conflict, and economic benefit.

OUTREACH AND EDUCATION

Most of the public information on UNGD that currently exists relates to the technologic process of hydraulic fracturing, and some addresses impacts on the environment and natural resources. Few materials relate directly to human health, and fewer still address the broad range of direct and indirect individual and community health issues discussed above. As part of this project and based on input from participants, the authors drafted educational material to “put people in the picture” of UNGD’s impacts. Future work is needed to create an interactive, online version of this material. Because our findings showed that different kinds of materials will be needed for different regions, interests, and audiences, development of these products should include the ability for local adaptation. Research on the health implications of UNGD is expanded rapidly; regular updating of educational materials over time as new research findings emerge will be important.

CONCLUSIONS

A better understanding of what kinds of health impacts are of greatest concern to community members is an essential foundation for developing a research agenda that will generate the information needed to address these key uncertainties, reduce conflict, and improve decision-making. Drawing on the experiences and knowledge of 48 informed residents in three states, representing varied roles in the community and positions on UNGD, we see a subset of health concerns and research needs that are consistently identified and also gain important insights into effective communication channels.

Overall, our findings emphasize the need for continued involvement of diverse community members, representing a range of professional roles and positions towards UNGD, in the design and conduct of research and dissemination of research-based educational materials related to the potential community health impacts of UNGD. This assessment lays the groundwork for such efforts by identifying communities’ current information needs, assembling existing resources to meet these needs, and synthesizing communities’ input into a national process of identifying research needs related to the health effects of UNGD.

A stated goal of the Community Outreach and Engagement Cores (COECs) of the NIEHS-supported Environmental Health Sciences Core Centers is to promote two-way communication between

communities and researchers about environmental health information needs and concerns. Given the current interest in promoting research about the health effects of UNGD, we have a time-sensitive opportunity to incorporate into the research agenda the substantive input of these community members from regions experiencing or likely to experience UNGD.

REFERENCES

- Brasier KJ, Filteau MR, Jacquet J, Stedman RC, Kelsey TW, Goetz SJ. 2011. Residents' perceptions of community and environmental impacts from development of natural gas in the Marcellus Shale: A comparison of Pennsylvania and New York cases. *J Rural Soc Sci.* 26(1):32
- Ferrar KJ, Kriesky J, Christen CL, Marshall LP, Malone SL, Sharma RK. 2013. Assessment and longitudinal analysis of health impacts and stressors perceived to result from unconventional shale gas development in the Marcellus Shale region. *Int J Occup Environ Health.* 19(2):104-12.
- Finkel ML, Law A. The rush to drill for natural gas: A public health cautionary tale. *Am J Public Health.* 2011;101(5):784-5.
- Goldstein BD, Kriesky J, Pavliakova B. 2012. Missing from the table: Role of the environmental public health community in governmental advisory commissions related to Marcellus Shale drilling. *Environ Health Perspect.* 120(4):483-6.
- Kriesky J, Goldstein BD, Zell K, Beach S. 2013. Differing opinions about natural gas drilling in two adjacent counties with different levels of drilling activity. *Energy Policy.* 58:228 – 36.
- Miles MB, Huberman AM, Saldaña J. 2013. *Qualitative data analysis: A methods sourcebook.* 3 ed: SAGE Publications.
- Rubin HJ, Rubin IS. 2012. *Qualitative interviewing: The art of hearing data.* 3 ed: Sage Publications.
- Schmidt CW. 2011. Blind rush? Shale gas boom proceeds amid human health questions. *Environ Health Perspect.* 119(8):a348
- United States Environmental Protection Agency (USEPA). Natural gas extraction - hydraulic fracturing [website]. [updated Feb 11, 2014; cited 2014 Feb 14]. Available from: <http://www2.epa.gov/hydraulicfracturing>
- Witter RZ, McKenzie L, Stinson KE, Scott K, Newsman LS, Adgate J. 2013. The use of health impact assessment for a community undergoing natural gas development. *Am J Public Health.* 103(6):1002-10.