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Original article

# Maryland is not for Shale: Scientific and public anxieties of predicting health impacts of fracking

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ABSTRACT

In 2011, Maryland established the Marcellus Shale Safe Drilling Initiative to determine whether and how gas production in the state could be accomplished without causing unacceptable risks to public health, safety, natural resources, and the environment. This initiative required a statewide health impact assessment of unconventional natural gas development and production via hydraulic fracturing (i.e., fracking). Increasing number of studies have shown that fracking has significant potential to impact health and non-health outcomes. However, because of its rapid development, there is a lack of substantive research related to the public health effects of fracking. I discuss my firsthand experiences as a medical anthropologist and public health researcher on a multi-disciplinary research team tasked with conducting Maryland's first health impact assessment to determine the potential public health impacts associated with fracking. I focus on how fracking, as a relatively new economically viable source of energy and an emergent focus of study, brings about public and scientific anxieties, and how these anxieties shape subsequent environmental and health policy decision making processes. I reflect on the potential role of social scientists in matters of scientific knowledge production and resulting policy decisions and the broader implications of such engagement for public social science.

## 1. Introduction

Like many places around the world, Maryland is grappling with the prospect of large scale natural gas development and production via hydraulic fracturing (or fracking). In 2011, former governor Martin O'Malley issued an executive order establishing the Marcellus Shale Safe Drilling Initiative to assist state policymakers and regulators in determining whether and how gas production from the Marcellus Shale formations in Maryland can be accomplished without unacceptable risks to the environment and the populace (O'Malley and McDonough, 2011). This initiative required research assessing the impacts associated with drilling in the Marcellus Shale in Maryland on the environment and natural resources, the economy, and public safety and health. A state-wide public health impact assessment of fracking (the Maryland Study), the first of its kind, was commissioned by the state and conducted by a team of interdisciplinary researchers, composed of environmental and occupational health, environmental justice, and social science experts, with input from residents and a variety of other stakeholders. This assessment warned that fracking had the potential to impact public health. However, a final report issued by various government agencies concluded that fracking, with adequate regulation and monitoring, posed minimal risks to the environment and human health. Despite this government report, fracking was banned in Maryland in 2017.

I served as a co-investigator on the Maryland Study based on my capacity as a public health researcher with methodological expertise in conducting health impact assessments. In this role, I experienced firsthand the myriad challenges researchers encounter as they engage in controversial research matters related to extraction and energy. In this article, I critically reflect on public and scientific anxieties brought about by fracking, both as a new economically viable source of energy and an emergent focus of scholarship. As a social scientist, I am interested in exploring how these anxieties shape subsequent environmental and health policy decision making processes. In doing so, I consider the broader implications of the role of social science in matters of knowledge production and resulting policy decisions on contested and politically divided matters such as fracking.

This article has two main parts. In the first half of the article, I explore the multiple anxieties—of known and unknown health risks, property rights, the role of experts, and scientific evidence and legitimacy—which permeated the research and policy making process related to fracking. Here, I use the notion of "anxiety" to describe feelings, actions, discourses of unease and concern about a process—fracking—shrouded in uncertainty. Public anxieties over fracking have been well-documented in the press and scientific scholarship, much of it encompassing concerns over environmental degradation including

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water contamination, air pollution, and prolonged noise exposure (Adgate et al., 2014; Boudet et al., 2014; Clarke et al., 2015; Macnaghten, 2017). Growing concerns over potential short and long-term health risks and issues of land ownership have been also receiving increasing attention in the research and public realms (Clough and Bell, 2016; Hays and Shonkoff, 2016; Johnston et al., 2016; Ryder and Hall, 2017; Watterson and Dinan, 2018).

Yet, scientific anxieties—the uncertainties and concerns among scientists and researchers themselves—have been largely overlooked in the literature on fracking. Recent work has investigated contexts within which moral or normative claims of scientists become rendered as scientific discourse and the influence that this has on social scientists' engagement with extraction research (Evensen, 2015; Edwards, 2018). However, very few studies have engaged with scientists as they undertake research or have documented the research process itself as it unfolds. Introspective studies—ones that reflect on the direct experience of scientists themselves who are engaged in research of controversial issues—can be useful in understanding how research processes unfold, scientific norms are constructed, and researchers engage with emerging challenges. During the Maryland Study, for instance, researchers' community engagement efforts to understand "local" concerns and questions, along with a lack of existing public health data on the health outcomes of fracking, generated anxieties among scientists as they sought to generate evidence to predict future health impacts from fracking. Anxieties also surfaced when researchers presented evidence to indicate that there were several potential serious threats to public health should fracking move forward and the final report presented to policy makers by government agencies concluded that minimal risks would be involved.

Finally, in the latter half of the article, I contextualize fracking as a site of social scientific inquiry by reflecting on the implications and impact of social scientific engagement with emergent forms of extraction and energy. Tracing these multiple interconnected sites of anxiety invariably necessitates reflections on my own and, therefore, social scientists' role in the politics of knowledge production and resulting policy decisions. I explore how social scientists' sense-making relate to the social construction of knowledge about fracking, where knowledge and expertise is inescapably incomplete, deeply contested, and based on emerging, and therefore, uncertain evidence. Social scientists have long effectively engaged in public health and environmental debates through interdisciplinary engagements of the politics of knowledge production as both full participatory actors and reflective outsiders (Sovacool, 2014; Rosen, 2015). Yet, inherent aspects of this research—issues of reflexivity, positionality, and the politics of observation and involvement—remain largely under-examined. I seek to contribute to the literature by considering the implications of social scientists' roles and engagements in contemporary controversies of a moral and scientific nature such as fracking for public social science (Calhoun, 2004).

## 2. Background

Fracking has become a catchall term for unconventional natural gas development and production, the horizontal drilling of a rock layer and the subsequent injection of pressurized mixture of water, sand, and other chemicals to release gas and oil (Evensen et al., 2014; Stoutenborough et al., 2016). I use the term fracking to indicate both a technique and process used to extract previously inaccessible natural gas and oil reserves found deep underground in shale formations. Fracking has been hailed by some as bringing about American energy independence, recharging the economy, and providing relief to millions by way of falling prices at the gas pump (Mullaney, 2012). Oil and natural gas development have rapidly expanded throughout North America, Europe, Asia, and Australia because of fracking, and as a result, the United States has become a net exporter of natural gas (Boersma et al., 2015; US Energy Information Administration, 2017).

Western Maryland, along with Pennsylvania, Ohio, and West Virginia, sits atop one of the largest shale formations in the United States—Marcellus Shale—which is abundant in gas resources. Fracking has been underway along the Marcellus Shale in the Northern Appalachian region, in states like West Virginia and Pennsylvania, for only about a decade (Jacquet et al., 2018); it has had a longer history of development in the Western United States in states like Colorado and Texas. Currently, the areas where most fracking activities occur include the Great Plains region that extends from Canada to Texas and the Marcellus Shale which spans from New York and Ohio to Western Maryland and Virginia. Despite its more recent development, Marcellus Shale is currently the largest producing shale gas basin in the United States, accounting for almost 40% of US shale gas production (US Energy Information Administration, 2015).

Fracking remains highly controversial due to its potential economic, environmental, and health impacts, much of which have not been adequately researched. For instance, the process of extracting gas from shale formations is complex and often includes several inter-related phases. Critical aspects of fracking include the negotiation of mineral rights with owners of land, tree removal and clearing land for well pads, construction of roads and other types of infrastructure including pipelines and compressor stations, shipment and management of extracted gas as well as water and wastewater, and the movement of transient workers and populations into established communities. These stages of production and development have the potential to have significant economic, environmental, health, and social impacts on communities where fracking is implemented (Colborn et al., 2011; Ferrar et al., 2013; Jackson et al., 2014; Jacquet, 2014; McKenzie et al., 2012; Maryland Institute for Applied Environmental Health, 2014; Ladd, 2018).

Although there are some individuals and communities who welcome potential economic growth brought about by fracking, uncertainties about environmental and health risks have contributed to tension, anxiety, and stress among many who face rapid growth of energy development, especially those living in impoverished rural regions (Ladd, 2014; Sangaramoorthy et al., 2016; Theodori, 2018). For instance, research has indicated that fracking can result in varied economic impacts with some, like landowners who sign leases with energy companies, benefitting more than others (Collins and Nkansah, 2013; Ryder and Hall, 2017). Social impacts such as fluctuating patterns of community interaction, diminishing social cohesion, increase in crime, and escalation of indirect and direct health impacts have also been observed (Adgate et al., 2014; Evensen and Stedman, 2018; Stedman et al., 2012; Powers et al., 2015; Willow, 2014).

Researchers as well as the public situate fracking as both an emergent social and technological phenomenon as well as an extension of established extractive processes, which only serves to intensify contemporary debates related to the risks, benefits, and uncertainties of fracking. Although the various phases of fracking bring about new concerns regarding environmental, health, and social risks and uncertainty, they also build on previous community anxieties related to coal mining and oil and gas development. The rich literature on "boomtowns," for instance, has documented the cyclical nature of natural gas extraction industries (Brown et al., 1989; Freudenburg, 1981; Gilmore, 1976). A boom and bust economic cycle traditionally begins with intensified industrial activity at the start of energy development, when labor needs are high and large numbers of workers migrate to host communities. This rapid population influx places strains on public infrastructure and local communities' ability to provide public services; it also has severe adverse environmental and social impacts. When production evens out and eventually declines, sometimes abruptly, host communities often struggle with loss of jobs, increases in poverty rates, environmental degradation, poor health outcomes, and strained community relations during what is known as a "bust" phase. However, characteristics of the fracking process such as the use of large volumes of water along with unknown additives and proppants, the extensive infrastructure necessary to produce, process, and distribute natural gas from underground shale formations, and the

uncertainties related to regulatory frameworks and long-term environmental and health impacts, mark it as potentially different from previous energy development cycles (Jacquet, 2014; Stedman et al., 2012).

### 2.1. Western Maryland

Fracking operations in Maryland were slated to occur in Allegany and Garrett counties, the westernmost counties in the state, when the Maryland Study was commissioned. Both are positioned in the Ridge-and-Valley Country of the Appalachian Mountains, bordered to the north by the Mason-Dixon Line along with Pennsylvania and to the south by the Potomac River and West Virginia. Both counties have large acres of parks, lakes, and publicly accessible forestland. Garrett County is home to the state's only sub-arctic wetlands and is the only county in the state to produce natural gas.

Although this region is nestled in the foothills of the Appalachian Mountains, Western Maryland has been overlooked in the literature on Appalachia. The limited scholarship on Western Maryland has noted that Allegany and Garrett counties are more economically and culturally aligned with neighboring regions in West Virginia and Pennsylvania than to the rest of the state of Maryland (Hanna, 1995). Coal mining and oil and gas development have long influenced regional settlement patterns and still have considerable environmental, economic, and social impacts on the area (Bell and York, 2010). Much of the region is in economic and population decline after being major coal, oil, and gas production centers in the past century (Thorne et al., 2004). County residents are older, more racially homogenous, and experience higher rates of poverty, poorer health outcomes, and reduced access to health care compared to Marylanders overall (Maryland Institute for Applied Environmental Health, 2014; Sangaramoorthy et al., 2016).

### 2.2. The social science of fracking

Despite a long history of focus on extraction and energy, engagement with fracking is relatively new in the social sciences, spurred by the growing research in the natural and physical sciences on unconventional energy resources (Neville et al., 2017). Social scientists studying fracking have attended to a wide variety of issues including those of governance and policy, especially as they relate to environmental and human health protection in the absence of new regulatory frameworks (Balsiger and VanDeveer, 2012; Florini and Sovacool, 2011). Others have focused on emergent technologies and nascent approaches to extraction in relation to diminishing availability of other sources of energy such as conventional fossil fuels (Ladd, 2017). The social scientific scholarship on energy markets is also growing, capturing emerging debates over energy security and the complex and uneven economic implications brought about by large scale fracking (Bazilian et al., 2011; McGowan, 2014; Short et al., 2015).

Further, social scientific theoretical and methodological engagements with civil society responses to fracking have proliferated, especially on issues related to activism and community mobilization, social and environmental trauma experienced by communities undergoing fracking, and the shifting understandings of the social and ecological contexts in which such extractive and energy developments are embedded (Cartwright, 2013; Perry, 2012; Sangaramoorthy et al., 2016; Wylie, 2018). There is also growing interest in what some scholars have termed "energopolitics"—the intimate relations between energy processes and infrastructures and the politics of life (Boyer, 2014). This literature has sought to understand the interconnections between the logics of energy development, relations between states and transnational corporate entities, emergent science and technologies, shifting understandings of energy, and transformations in ecology, subjectivity, and social relations (Appel et al., 2015; Rogers, 2015a, 2015b; Strauss et al., 2013).

Yet, social scientists have remained distant from critically engaging with issues of reflexivity and positionality in their work even when serving in various roles such as industry consultants, community advocates, and state-funded researchers. With few exceptions, questions related to social scientific engagements in such projects have remained overlooked in the literature (Burton, 1998; Downing et al., 2002; Edwards, 2018; Filer, 1999; Hyndman, 2001; Kirsch, 2002, 2014; McNamara, 1987). Kirsch, in writing about anthropology and advocacy and his own political and legal activism in response to the environmental impact of the Ok Tedi copper and gold mine on the communities in Papua New Guinea, asserts data collected by researchers "has multiple and overlapping claims on it, including the interests of sponsoring organizations which may require that a portion of the research results be publicly archived, of universities and departments which expect that this information will be published in scholarly venues, and of community members themselves, who may regard this information as a form of investment –which may entail certain kinds of reciprocal obligations – in the researcher" (2002: 176). He argues that this latter claim requires anthropologists (as well as all researchers) to reexamine their relationships to the individuals and communities with whom they work – that the transaction of knowledge as data between communities and researchers is based on forms of reciprocity and commitments which necessitate critical engagements in the form of activism and advocacy rather than a rather than a "scholarly, neutral stance" (Kirsch, 2002: 193).

I suggest that social scientists have a further obligation to critically reflect on the research process itself in all its contours, including the complex interactions which unfold in the course of scientific inquiry. Kontopodis et al., 2011, in their special issue on emerging biomedical practices, argue that science "cannot be investigated as a readymade object of inquiry" and that it is part of the daily struggle for "authority against competing interests" (2011: 609). It is through this reflexive engagement that I come to illustrate that the fields of public health and environmental science and local community perspectives and experiences are operating across different analytical levels, scales, and rationalities, competing with each other about the logics and materiality of evidence and the production of knowledge about fracking.

Scientific knowledge, especially related to the potential environmental and health effects of fracking remains unclear, evolving, and contested. Add to that the growing public outcries over the potential environmental degradation and social impacts of fracking and policymakers' interests in economic development and energy independence, the various engagements around fracking are enacted and continuously being reorganized by multiple stakeholders through different practices at various scales. I explore these interstitial spaces of engagement where knowledge around fracking is continuously framed and performed by various actors at different scales. By doing so, I am also considering the usefulness of social science as a critical mode of inquiry in such engagements.

### 2.3. Health impact assessments

Although several definitions of the health impact assessment (HIA) methodology exist, certain elements are considered fundamental to the process (National Research Council, 2011). HIA is often used as a tool for examining health impacts of a proposed project, plan, or policy. It relies on a variety of data and analytic methods including stakeholder input to determine potential public health risks and recommend ways of addressing those concerns (Birley, 2011; Cole and Fielding, 2007; Institute of Medicine, 2014; National Research Council, 2011). Typically, an HIA is conducted using a series of sequential steps: 1) screening to determine if a problem warrants the use of HIA; 2) scoping to understand the extent and reach of the problem and to determine the direction of the research; 3) assessing "baseline" conditions of the affected population, and how the proposed action would alter those conditions; 4) recommending ways to address potential risks; 5) reporting the findings of the assessment; and 6) monitoring and

evaluating the implementation of the recommendations (National Research Council, 2011). The Maryland Study began with an extensive scoping process, followed by a description of risks and potential public health responses to fracking using a baseline assessment of population health, an impact assessment of potential public health impacts of fracking, and possible adaptive and public health mitigation strategies.[1]

In the next section, I present how anxieties surfaced in each step of the HIA process using focus group and public meeting transcripts from the scoping process and field notes from the entire research and policy making process. I write about such anxieties chronologically in order to highlight the specific points during the research process where they became highly problematized. However, anxieties pervaded the research process and were not limited to particular methodological approaches. Because I was part of the assessment team, I also switch to the narrative voice of "we," "our," and "us" in the next section to indicate my active participation in these discussions.

## 3. The contours of anxiety over fracking

### 3.1. The scoping process and the emergence of competing priorities

The assessment team first determined that a HIA was the most appropriate method to use for the assessment based on the memorandum of understanding from the State and our expertise in conducting similar research studies. We then began the assessment with a scoping process to determine the overall aims and objectives of the HIA, which hazards and impacts to evaluate, and the types of research strategies and methods to use for analysis. To ensure that all relevant issues are addressed and to increase the utility of HIA findings to decision-makers, experts urge that a wide range of stakeholders be consulted during this research phase (Witter et al., 2013). Our scoping process sought input from a variety of stakeholders including community residents through two public meetings, a review of over 100 public comments submitted to the state in 2013, two focus groups in West Virginia where fracking had already been developed, and observational data of fracking operations in West Virginia. Using these data, along with our own review of the scientific literature and careful consideration of the state mandate, we finalized a list of specific study topics.

The two public meetings were held in Western Maryland in September and October 2013 to discuss community concerns with fracking. Both meetings were open to the public and were advertised widely through press releases, radio and newspaper announcements, email blasts, and word of mouth. The first meeting was attended by 29 local residents and various stakeholders while the second drew 27 attendees. The meeting allowed residents and stakeholders to express their concerns related to the project. If some did not feel comfortable openly sharing their thoughts, they had the opportunity to submit note cards with their concerns.

In the meetings, economic impacts—potential short and long-term benefits to the region—were discussed. Some residents and stakeholders expressed that they welcomed the potential economic growth brought about by fracking. For instance, a resident told us, "Jobs impact the area…we have a need for more income from revenue that drilling will generate." A written comment underscored the potential benefits to the area's agricultural industries, "The farms in this area really need an infrastructure boost. They need a production boost. The farmers themselves are going to assess their own risk and say is this process going to contaminate my well. The farmers that I talk to feel that the benefits far outweigh the risks. They are going to build infrastructure from the money from their mineral rights into their farm."

But these discussions also underscored community anxiety over potential environmental and social impacts of fracking. Concerns over water quality was of paramount concern to residents and stakeholders and included issues related to water acquisition, chemicals used during hydraulic fracturing, and wastewater. Issues related to air quality were highlighted, including diesel truck traffic and exhaust. Residents and stakeholders also expressed worry over the synergistic effects of climate change, weather, and fracking on population change, reemerging health conditions, and healthcare capacity. They conveyed their concerns about specific health risks potentially stemming from fracking operations, "Hundreds of trucks traveling back and forth, truckloads of toxic chemicals, gasses and chemicals released accidentally or at 'approved' levels during the fracking, drilling process – all leading to gastrointestinal problems, skin problems, breathing problems, cardiovascular events."

Further, they raised concerns about our ability to get an accurate depiction of the baseline health status of Western Maryland due to a lack of secondary data, especially among vulnerable populations—farmers, children, women of a childbearing age, elderly, immune-suppressed individuals, and individuals living in poverty and without health insurance, "I know we had talked about some of the pockets of the community that don't actually have insurance or access to doctors because of finances. We looked at some of the smaller communities that are here…there are folks that aren't identified in these types of studies who actually may be more impacted from these types of activities. I wanted to see if we could keep on the track of bringing that to the forefront." They also discussed the importance of understanding non-direct impacts of fracking such as social disruption, mental health and stress, increased crime, noise, and traffic, and destruction of roadways, "Don't overlook the peace of living in Garrett County that would be disrupted and destroyed if fracking invaded our rural legacy through traffic and emissions, noise, air and water pollution." Another key concern raised by residents and stakeholders was the ability of the healthcare system to handle acute health issues related to fracking, including its ability to manage care for transient laborers working in high-risk occupational positions and protect emergency responders.

In addition, residents and stakeholders urged us to gather the perspectives of neighboring Appalachian communities where fracking was already underway to better understand potential public health impacts.[2] Finally, residents and stakeholders stressed the importance of transparency of the overall study process, "I just want to make a plea for the process to be as transparent as possible. We heard a comment about New York and how nobody really knows what happened with their study. This is such a wonderful opportunity and this is a great start. You've created a dialogue with people out here and you're going to continue it. We know it is going to be hard to do this in this amount of time with the available funds, so try to communicate what's happened, even if it's not perfect."

After each of these public meetings, we conducted a thematic analysis of recorded transcriptions and detailed field notes taken from the meetings to determine which community concerns to focus on during the HIA. Ten themes emerged related to community concerns over fracking: water quality, baseline health assessment, secondary impacts, economic impacts, climate change/weather, air quality, populations of concern, occupational issues, healthcare infrastructure, and benefits (Maryland Institute for Applied Environmental Health, 2013; Maryland Institute for Applied Environmental Health, 2014). These themes served as the basis for identifying the hazards that were ultimately reviewed in

[1] Please see Boyle et al. (2016), Maryland Institute of Applied Environmental Health (2013), Maryland Institute of Applied Environmental Health (2014) and Sangaramoorthy et al. (2016) for further details of the health impact assessment methodology used in the Maryland Study.

[2] Based on this recommendation, we later conducted two focus groups among Doddridge County, West Virginia residents and participant observation in fracked areas in November 2013 to gain insight into how individuals living in neighboring communities where fracking is underway were being impacted, the results of which have been published elsewhere (Sangaramoorthy et al., 2016).

the Maryland Study.

Issues of credibility and relevance of an HIA to the decision-making process depend on systematic evaluations of a full range of potential risks and benefits (especially community concerns) rather than on issues solely predetermined by investigators' research interests or regulatory obligations (National Research Council, 2011; Parry and Stevens, 2001). However, keeping a balance between the goals of the assessment and community priorities proved challenging in practice during the scoping phase. For instance, community concerns in Western Maryland as described above reflected a strong desire for us to examine climate change issues and their potential associations with fracking. Primarily, residents and stakeholders expressed concern about the interrelated effects of climate change, natural disasters, seasonal weather changes, and community public health. For instance, a resident asked, "Will you be taking into consideration the effects of climate change in the coming decades on Western Maryland? It may affect some of the health effects."

In our written assessment, we rightfully acknowledged that fugitive methane emissions, which can occur throughout the fracking production and distribution process, can considerably contribute to climate change and threaten public health (Maryland Institute for Applied Environmental Health, 2014). But we chose not to examine this issue for a variety of reasons. Adequately assessing these impacts would have required specific types of scientific evidence to support eventual conclusions (where few exist), climate simulation computations, and major assumptions about what policy alternatives are politically realistic. We determined that exploring this issue fell outside not only our expertise and available resources, but also the scope of our charge by the State which was to focus on health impacts primarily restricted to the local areas where fracking was set to take place (Maryland Institute for Applied Environmental Health, 2014).

Aside from climate change, all other community concerns were examined in the study including air and water quality, noise pollution, earthquakes, social determinants of health, healthcare infrastructure, cumulative exposures and risk, and occupational impacts. Members of our assessment team, as well as external reviewers who were commissioned by the State to evaluate our study, often expressed "surprise" about how well the concerns of community members aligned with priorities such as primary and secondary community impacts and occupational impacts outlined in previous natural and physical scientific research conducted on fracking. Such exchanges between researchers highlight the continued challenges in aligning scientific and local knowledge within risk-based management approaches such as HIAs.

Participatory research, such as that promoted by the principles of HIA, fosters a relatively high degree of control over research by community members and stakeholders and is meant to equalize power within the research process, which can enrich both the quality and outcomes of such studies (National Research Council, 2011; Parry and Stevens, 2001; Witter et al., 2010, 2013). At the same time, such processes can be fraught with ethical and other related challenges to scientific norms. For instance, stakeholders expressed concerns about the relationship between climate change and fracking, but because such associations had yet to be supported by scientific literature and was outside the scope of our charge and current resources, it was not considered to be within the purview of our investigation. Such issues bring into focus potential tensions between lay and professional ways of knowing and values placed on particular forms of knowledge and knowledge production about fracking.

### 3.2. Baseline assessment: what is an appropriate baseline?

During the next phase of our assessment, we conducted a baseline assessment to describe the baseline health status of the affected population in order to evaluate impacts of potential fracking operations. Stakeholder input gathered from the scoping process favored the collection of primary, representative, individual health and exposure data. However, a lack of time and resources did not allow for this (Maryland Institute of Applied Environmental Health, 2013). Instead, we created the baseline health assessment using a variety of existing quantitative data from national, state, and local public health sources. We focused on mortality rates, prevalence of morbidity, percentages of the population engaging in risky health behaviors, and levels of healthcare access. Most of this existing data, however, had been collected at the level of the county, rather than at the neighborhood or census-tract level (Maryland Institute of Applied Environmental Health, 2014). This caused challenges for our team because local-level data (e.g., neighborhood or census-tract level data) is considered ideal by scientific norms especially in contexts which necessitate understanding health outcomes and disparities specific to local populations.

In addition, during the scoping phase, community members supported the comparison of health data for Western Maryland with data for neighboring counties of Pennsylvania and West Virginia, rather than to the rest of Maryland, for an overall health profile. Residents and stakeholders firmly believed that their health profile (as well as their social identities) were more closely related to these Appalachian communities than to the rest of Maryland. Such perceptions align with the limited scholarship which has noted that Western Maryland is more similar to the Northern Sub region of Appalachia than to the rest of the state of Maryland due to closely-aligned economic, geopolitical, and cultural histories (Hanna, 1995).

Often local health profiles are based on population health models that compare localities to each other within a specific state or local-level health data to state and national-level data. The creation of a "regional" health profile that included several counties spanning three states instead of standard county and state-level comparisons posed challenges and debates within our assessment team. We discussed at length whether and how to collect constitution of a valid "baseline" since such data were difficult to collect, measures proved inconsistent across states, and the process of demarcating regional contours could be perceived as highly subjective by other researchers. In the end, we made the decision to include comparisons of Western Maryland health data to those of other counties in Pennsylvania and West Virginia and to the state of Maryland, merging our need to consider stakeholder input as part of the HIA process and create a standard community health profile that reflected established scientific norms.

Baseline health data, or a profile of existing health conditions, is a necessary component in a HIA in order to trace the current health status of a population and to understand any potential needs that may arise with a project, policy, or plan (National Research Council, 2011; Parry and Stevens, 2001; Witter et al., 2013). Pre-existing health conditions or needs of a specific community can have an impact on the public health consequences of environmental change. Baseline data can include health status indicators as well as social, economic, and environmental health indicators; such data can also bring attention to health inequities among populations. HIA often aims to provide a context-specific analysis but as in our case, the types of data that stakeholders requested were not always available, were not available at the needed geographic scale, or were difficult to quantify. Such discussions amongst scientists (including me) and between scientists and community residents brought to the forefront various anxieties involved in the politics of knowledge production around the constitution of an appropriate "baseline"— as quantifiable object, social identity, and geospatial boundary — highlighting how different actors marshalled evidence oscillating between so-called subjective and objective stances in the process of assessing impacts, risk, and health.

### 3.3. Impact assessment and the methodological challenges of evaluating environmental, social, and economic determinants of health

The last phase of our assessment included an impact assessment of potential public health impacts of fracking which included possible adaptive and public health mitigation strategies. To provide a thorough

overview of the impact of fracking associated hazards on public health, we developed a hazard ranking methodology to evaluate the overall public health concern for eight hazards associated with fracking in Maryland that were identified during the scoping process and literature review (Boyle et al., 2016). The hazard ranking methodology is akin to a scoring system which seemed like a reasonable choice for our study, given that a similar scale was used in one of the only other fracking HIAs conducted to date (Witter et al., 2010). This approach also enabled us to provide an assessment of potential public health risks despite limited data on health and environmental effects of fracking. As we have described elsewhere (Boyle et al., 2016), the hazard ranking included measures related to the presence of vulnerable populations, exposure, possible health effects, geographic extent, and effectiveness of a setback (i.e., distance between natural resources or buildings and fracking activity). Overall impact was determined by a color-coded ranking system (low, moderate, and high) that was generated based on the total for each hazard. Air quality, occupational health and the social determinants of health were ranked as "high" concern; water quality, noise, traffic and cumulative risk were ranked as "moderate" concern; and earthquake was ranked as "low" concern for their potential to negatively impact public health.

Several challenges arose during this assessment phase that created anxieties amongst our research team. First, we made a suggestion of 2000 foot setback although this was not empirically determined. This suggestion was based on traffic-related air pollution literature which was the closest data we could find (Boyle et al., 2016). However, we understood and explicitly stated that the spatial and temporal dimensions of fracking activities may be quite different from traffic from major roads, and additional measurements would be required to determine specific setbacks for fracking.

In addition, there were concerns in applying the hazard ranking criteria to such a broad range of impacts, especially those that did not pertain to natural environmental hazards such those categorized as social determinants of health and health care infrastructure (Boyle et al., 2016). For instance, the social determinants of health category included both public safety measures (e.g., industrial traffic and violent crime) and psychosocial and physical health outcomes (e.g., mental health, substance use, and sexually transmitted infections). Because this process of evaluating impacts is dependent on data collected from the baseline assessment, these categories consisted of only quantitative data, and did not capture the complex dynamics of public anxieties over fracking that was captured in the public meetings and focus groups (i.e., qualitative data) during our scoping phase related to concerns over social and environmental change.

Further, although the duration of and frequency of exposure, likelihood and magnitude of health effects, and geographic extent could be evaluated for each of these measures in a consistent manner, the definition of vulnerable populations varied across measures. Psychosocial and physical health outcomes could disproportionately impact vulnerable populations such as those with pre-existing conditions or substance abuse issues, but public safety issues could affect all subpopulations evenly. Furthermore, setback regulations may not have any impact on psychosocial and physical health outcomes as well as public safety issues such as crime.

Likewise, healthcare infrastructure, the use of a community's health care facilities and services, cannot easily be assessed according to our hazard ranking criteria. Exposure in this scenario was established as population influx, particularly migrant workers engaged in high-risk occupations, which we then determined to lead to increased demands on existing healthcare infrastructure. Healthcare infrastructure disproportionately impacts those who are more likely to use healthcare services such as the elderly, the disabled, those already in poor health, and children, although the entire community is potentially at risk. Similar to the social determinants of health, the effectiveness of a physical setback was not determined to mitigate issues related to healthcare infrastructure.

Our final report included an assessment of the potential significance of public health impacts related to fracking. Certain health impacts and environmental conditions (e.g., air quality) have established quantitative criteria that can provide justification for the significance in the impact assessment. However, very few rules or standards exist in the scientific literature or practice for hazardous agents or for social and economic determinants of health, and may not actually be adequate to meet the actual health needs of a place or population (National Research Council, 2011; Parry and Stevens, 2001; Witter et al., 2013). These challenges underscore that when there are multiple potential health effects that are being assessed, the process of evaluating different types of effects that are assessed using different types of measurements is often based on the social norms of research and researchers.

### 3.4. Findings, recommendations, and the ensuing politics of energy

In various presentations and in the final report released in August 2014, our study underscored that without adequate safeguards, drilling for natural gas using fracking operations could harm the health of residents, workers, and communities in Western Maryland. Our report, along with other commissioned reports on economic and environmental assessments, were used by state agencies to present a final assessment to policy makers in accordance with the executive order. In late 2014, these agencies concluded in their final report that with adequate regulation and monitoring, "the risks of Marcellus Shale development can be managed to an acceptable level" (Maryland Department of the Environment and Maryland Department of Natural Resources (MDE and MDNR, 2014: 2). Weeks before he left office, O'Malley, a Democrat, ultimately supported moving forward with fracking with regulations to mitigate against air and water pollution. However, in June 2015, the Maryland legislature passed a moratorium on fracking until October 2017. In April 2017, the new governor, Larry Hogan, only the second Republican governor to be elected in Maryland in nearly 50 years, signed into law a bill establishing a ban on fracking. Debates over natural gas production in Maryland continue despite this ban.

Although the intention of the HIA is to inform policy determinations, the findings within a HIA do not necessarily result in decisions that follow research recommendations. This is important because it underscores that public and scientific anxieties are also political anxieties. It brings to the forefront the inherent tension between scientific expertise and knowledge, community needs, and political interests. Some have argued that a precautionary principle—calls for caution in the face of scientific uncertainty—was not followed due to a shifting political landscape which favored fostering economic growth and achieving energy independence (Mooney, 2014). Others have maintained that a precautionary approach was employed since fracking would move forward only with highly restrictive public health and environmental safeguards in place (Maryland Department of the Environment and Maryland Department of Natural Resources (MDE and MDNR, 2014).

These debates over precautionary approaches highlight the inherent challenges in determining how governing bodies measure and value the potential of future risks and the kinds of knowledge and evidence needed to trigger regulatory action. In 2000, the European Union attempted to address these issues in a report that stated that in circumstances where scientific evidence is uncertain but where there is indication through scientific risk assessment that there is sufficient grounds for concern, then the precautionary principle is the appropriate risk management strategy to use (Commission of the European Communities, 2000). Yet in the context of a distinctly controversial activity such as fracking, highly structured approaches (i.e. risk assessments) for studying its effects and the subsequent implementation of regulations can rarely occur before the activity is underway (Lees, 2011; Patterson and McLean, 2017). Fracking represents a type of "post-normal science" where facts are uncertain, values are in dispute, stakes are high, and decisions are urgent (Funtowicz and Ravetz, 1993).

In such situations, evidence, values, and political judgments combine in complex ways to produce contradictory policy decisions and vague precautionary approaches that also contribute to anxieties experienced by the public and researchers. In the case of the Maryland Study, we were a group of interdisciplinary researchers drawn from the natural, physical, and social sciences tasked with making concrete predictions concerning social ecological-systems in cases such as fracking. This inevitably enhanced not only our awareness of risk as contextually and culturally bound, but also the limits and uncertainties that encumber scientific knowledge and the blurring of boundaries between science and politics. These types of considerations need further social scientific exploration.

## 4. Collaborative entanglements

My official role in this study was as a co-investigator. I was involved in all aspects of the project—facilitating public stakeholder meetings in Western Maryland, conducting observations of fracking sites and moderating focus groups with community members impacted by fracking in neighboring West Virginia, analyzing health data, writing reports and recommendations, and publishing findings. In this collaboration, I was a full participant involved in the research process itself. My role in the project was not one of a social scientist per se and I was not asked to be on the research team due to my content expertise in the social science of fracking. Therefore, I did not conduct separate studies of the project, the scientists involved, or community members.

However, as a medical anthropologist and public health researcher without content expertise in environmental health, my role was also one of an inherent participant observer, trying to understand and reflect on the specific factors related to an emergent form of energy extraction and the subsequent study of it. It was often necessary to consider how concepts of risk and exposure are constituted within interactions between human bodies and changing environmental landscapes, especially in a context where knowledge about fracking is still not considered “universal” yet these notions are (re)produced in familiar and new ways in places with long histories of extraction (Sangaramoorthy et al., 2016).

The method used, a HIA, is likewise an emergent tool in public health and public policy planning activities related to land use. There is substantial variation in the content of HIAs and the processes by which they are produced. HIAs represent one mode of operationalizing and institutionalizing calls for the democratization of science. Even though I am implicated in the development and use of our HIA, my social scientific skills allowed me to observe and reflect more broadly on the kinds of methods often employed in situations where knowledge and expertise are contested, and how such methodologies sometimes have unintended consequences. In particular, our HIA underscores the anticipatory dimensions of public health science which, in this case, are situated in predicting human health risks and benefits in the face of rapid environmental change. Our HIA is one of only a few to be conducted on oil and natural gas activities; this will have implications for activities related to energy extraction, particularly in places where such activities are deeply contested.

This project contributes several discussion points to the landscape of public social science. First, it demonstrates the ability of social science and social scientists to effectively engage contemporary social issues through interdisciplinary engagements of knowledge production as both full participatory actors and reflective outsiders. In considering the unparalleled urgency and reflexivity that accompany the politics of extraction, social scientists must attend to multi-scalar, multi-stakeholder, and interdisciplinary approaches in research and practice. These multiple entanglements can help us situate the structures and processes informing knowledge production around fracking within broad debates regarding transformations in the relations between science, society, and policy (Caduff, 1999; Franklin, 1995; Mitchell, 2011). It can also move us towards more engaged public discussions about risk and exposure studies, democracy and governance in science, scientific transparency and accountability, land use and rights, and social justice. Finally, such collaborations have the potential to shift our research focus to both scientists and research tools, which would enrich our understandings of the contested and continually shifting terrains of fracking.

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