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FEDERAL ENERGY
REGULATORY COMMISSION

Mark Salisbury

Temple Mountain Beef

877 N.H. Rt. 45

Temple, NH 03084

August 25, 2015

Ms. Kimberly D. Bose,
Secretary Federal Energy Regulatory Commission
888 First Street NE
Washington, DC 20426

ORIGINAL

Docket No. PF14-22-000

Dear Secretary Bose,

My name is Mark Salisbury and I live in Temple, New Hampshire. I own and operate a grass fed beef cattle farm that has been in my family since 1941. This is my family's home and place of business. My property abuts the land where the proposed compressor station is to be built in New Ipswich, NH.

I have received documentation from the New Hampshire Department of Environmental Health Services stating that there will be 50+ chemical emissions from the compressor station as noted in the attached document (Southwest Pennsylvania and Compressor Stations Environmental Health Impact Project – Summary on Compressor Stations and Health Impacts – February 24, 2015).

My cattle will be grazing within 500 feet of this proposed site and I have concerns that I would like to bring to your attention:
What will the emissions do to my cattle?
What kind of chemicals will be released - not just in the air, but in the soil as well?
What will these emissions do to my cattle?
How will they affect the people that eat the beef and the people that live around here?

In the other attached document please find the results from research into these questions. This report (Impacts of Gas Drilling on Human and Animal Health) details the known effects of the emissions and pollution from compressor stations on both people and livestock. In other words – my family and my livelihood!

20150831-0052 FERC PDF (Unofficial) 08/31/2015

My customers have already stated that if this proposal goes through, they will no longer buy my cattle or my hay. If this happens, I will suffer complete financial ruin, being as this farm and my cattle are my only source of income.

This will be largest compressor station on the pipeline. With all the noise and the emissions coming from the compressor station, this will have an extreme negative effect on the children that attend the elementary school across the street as well as my cows.

The school is downwind of the proposed compressor station and will be directly in line with the exhaust plume from the general running of the station and the expelled gases during "blow downs.
Also, the school gets it water supply from a reservoir that is fed by a stream originating on the site of the proposed compressor. As the construction site is intended to be placed on a brownfield site, heavily polluted with lead, the disturbance of the topsoil involved in the construction phase, will leach lead directly into this stream and consequently into the school's water supply. It should be noted that the same reservoir is also the water supply for the nearby town of Greenville.

The prospect of an industrial size compressor in our quite, agricultural surroundings, running 24/7 is appalling. This will totally destroy the peace we have come to regard as the natural state of our small community.

So – to summarize- we are faced with noise, chemical emissions, a threat to the water supply of our farm, the school, and the next town all for the profit of a remote, huge corporation with a known record of poor maintenance to its pipelines and compressors. In addition to all this it would seem most likely I would lose both my cattle and farm and the land would be ruined for all future agricultural use.

Can you imagine living next to a compressor station that is running 24/7?

All I ask is that you please take the time to read the attached documents. I know they are not an exciting read, but there is a lot of relevant information there about what can and will happen to the surrounding area if this pipeline is approved.

Thank you for your time and consideration.

Sincerely,

Mark Salisbury

20150831-0052 FERC PDF (Unofficial) 08/31/2015

SWPA-EHP
SOUTHWEST PENNSYLVANIA ENVIRONMENTAL HEALTH PROJECT
www.environmentalhealthproject.org

Summary on Compressor Stations and Health Impacts
February 24, 2015

Compressor station emissions

Compressor station emissions fall into two categories: construction emissions and operational emissions. Within operational emissions there are three types that warrant individual attention – blowdowns, fugitives and accidents. This document provides perspective on the aptness of the method of estimation (in tons per year) and need for further detail about the VOC and PM estimated emissions to better consider health risk.

Compressor construction and operational phases are generally projected to produce emissions below the NAAQS standards. They are presented in *tons per year*. This measure of emissions is used for NAAQS purposes which determines the air quality designation over a region and over long periods of time. The problem posed by estimating tons of contaminants emitted per year is that over the course of a year emissions will vary, often greatly. As phases of construction and operation change so will emissions content and concentrations. For a resident living near a compressor station, the concern is not simply PM2.5 emissions over the course of a year, but is PM2.5 emissions during the peak construction time when it's at its most intense.

Even during normal operations compressor stations have been shown not to emit uniformly ("blowdown" and accident events will be discussed separately).[1] The measurement *tons per year*, while common in the industry and common in the environmental field where regional air quality is at issue, is not an appropriate measure to determine individuals' health risks which increase during episodes of high exposures.

Table 4 shows the day to day and morning to evening variability in emissions at one compressor station near Hickory, Pennsylvania. It comes from a Pennsylvania Department of Environmental Protection. We present this case to show documentation of fluctuations not captured by averages.[2] Note how much relevant emissions information is lost when relying on averages, even of just three days. When extending this logic across a year, there is little doubt that there will be times of high levels of contaminants released and these high levels can increase health risks to residents. It is also notable that the EPA inhalation reference concentration (RfC) for ethylbenzene is 1 mg/m3 (equivalent to 1,000 ug/m3).[3] Some of the reported emissions exceed this standard of health safety.

4198 Washington Road Suite 5, McMurray, PA 15317
Office: 724.260.5504 Cell: 724.249.7501

Table 1. Variation in ambient air measurements of five VOCs near a compressor station reported in ug/m^3 *[4]

Chemical	May 18		May 19		May 20		3 day average
	morning	evening	morning	evening	morning	evening	
Ethyl-benzene	No detect	No detect	964	2,015	10,553	27,088	6,770
n-Butane	385	490	326	696	12,925	915	2,623
n-Hexane	No detect	536	832	11,502	33,607	No detect	7,746

*The PA DEP collected data on many more chemicals than those listed above; the authors of this paper have chosen these chemicals specifically to highlight variation in emissions.

Documented compressor emissions

It is important to know, with more specificity, what chemicals will be emitted by a compressor facility so that a targeted assessment can be made about its potential health impacts.

There is a small but growing body of literature on emissions from shale gas extraction, processing and transport activities. In its early stages of inquiry, the focus was predominantly on drill pad activity, but there are now some reports on natural gas compressor station emissions. Below are examples of chemicals that have been found at or near compressor stations during operations. These emissions reports – whether from public databases or from a private sector firm or organization – do not provide relevant background levels of the chemicals detected. Without a "control" location it is not possible to say with certainty that the chemicals found are the result of the compressor station, although these facilities are often the only industrial activity in the areas where they are found.

Emissions from two compressor stations (Stewart and Energy Corps), published by the Pennsylvania Department of Environmental Protection (DEP)[5] are:

MTBE
CO
iso-Butane
methyl mercaptan
n-Butane
n-hexane
n-octane
nitrogen dioxide
nitrous-acidstyrene
2-methyl butane
2 methyl pentane
3 methyl pentane
ethyl benzene
benzene
ethane
propane
methanol
napthlelene

20150831-0052 FERC PDF (Unofficial) 08/31/2015

The Texas Commission on Environmental Quality (TCEQ), as part of its Barnett Shale Formation Area Monitoring Projects found the following chemicals downwind from two monitored compressor stations[6]:

- Downwind of Devon Energy Company LP's Justin compressor station the TCEQ reports propane, isobutene, n-butane, ethane, cyclohexane, benzene, n-octane, toluene, m+p-xylene, n-hexane.
- Downwind of Targa North Texas LP's Bryan Compressor Station the TCEQ reports: ethane, propane, isobutene, n-butane, cyclohexane, n-octane, toluene, isopentane, n-pentane + isoprene, benzene.[7]

Officials in DISH, TX commissioned a study of compressor station emissions in its vicinity. Wolf Eagle Consultants performed whole air emissions sampling for VOCs, HAPs as well as Tentatively Identified Compounds (TICs). Chemicals identified as *exceeding* Texas's ESLs include:[8]

benzene	tettramethyl benzene
dimethyl disulfide	naphthalene 1,2,4-trimethyl benzene
methyl ethyl disulphide	m&p xylenes
ethyl-methylethyl disulfide	carbonyl sulfide
trimethyl benzene	carbon disulfide
diethyl benzene	methyl pyridine
methyl-methylethyl benzene	dimethyl pyridine

In 2011 and 2013, Earthworks, a non-profit organization, collected air samples within 0.33 miles of two compressor stations: Springhill compressor in Fayette County and the Cumberland/Henderson compressor station in Greene County, Pennsylvania.[9] Results from samples collected include:

1,1,2-Trichloro-1,2,2-trifluoroethane,
1,2-dichlorobenzene
2-butanone
benzene
carbon tetrachloride
chloromethane
dichlorodifluoromethane
ethylbenzene
methane
methylene chloride
tetrachloroethylene
toluene
trichloroethylene
trichlorofluoromethane

Anecdotally, we know that people living near compressor stations report episodic strong odors as well as visible plumes during venting or blowdowns. Residents often report symptoms that they associate with odors such as burning eyes and throat, skin irritation, and headaches. These are simply anecdotes but they are fairly consistently reported. It should be noted that residents in southwest Pennsylvania where these anecdotes were collected, often live near drill pads and in some instances processing plants along with compressor stations.[10]

Emissions pathways

In addition to the emissions produced during the normal operations of a compressor station there are several other ways that emissions might be dispersed from the site. These include fugitive releases, blowdowns, and accidents. Trucks play a significant role in the emissions profile during construction but are not common once the facility is complete and on line.

Fugitive emissions

Fugitive emissions are uncontrolled or under-controlled releases. They occur from equipment leaks and evaporative sources. It has been suggested that fugitive emissions will increase over time as machinery begins to wear.[11]

There does not appear to be a central publically available source of information of these emissions. There are, however, many opportunities for fugitive emissions to be released from a compressor station. We were able to locate only one study on natural gas compressor station fugitive emissions. In that study, conducted in the Fort Worth, TX area, researchers evaluated compressor station emissions from eight sites, focusing in part on fugitive emissions. A total of 2,126 fugitive emission points were identified in the four month field study of 8 compressor stations: 192 of the emission points were valves; 644 were connectors (including flanges, threaded unions, tees, plugs, caps and open-ended lines where the plug or cap was missing); and 1,290 were classified as Other Equipment. The Other category consists of all remaining components such as tank thief hatches, pneumatic valve controllers, instrumentation, regulators, gauges, and vents. 1,330 emission points were detected with an IR camera (i.e. high level emissions) and 796 emission points were detected by Method 21 screening (i.e. low level emissions). Pneumatic Valve Controllers were the most frequent emission sources encountered at well pads and compressor stations.[12]

Blowdowns

The largest single emission at a compressor station is the compressor blowdown.[13] They can be scheduled or accidental. As the natural gas rushes through the blowdown valve, a gas plume extends upward of 30 to 60 meters. The most forceful rush of air occurs at the very beginning, then the flow gradually slows down. The first 30 to 60 minutes of the blowdown are the most intense, but the entire blowdown may last up to three hours.[14] One blowdown vents 15 MCf gas to atmosphere on average. Isolation valves leak about 1.4 Mcf/hr on average through open blowdown vents.[15]

It is not possible to know what exactly would be emitted in a given natural gas compressor station blowdown as there is no data available. We know that it will include whatever is in the pipeline when the blowdown occurs. This would undoubtedly include the constituents of natural gas: methane, ethane, etc., and various additional constituents would be present during different episodes. We are especially concerned about the presence of radioactive material during a blowdown. Anecdotally, there are reports of odors and burning eyes, headaches and coughing associated with the events.[16]

An exposure to blowdown concentrations of contaminants would have different health implications than a long-term lower level exposure (i.e. yearly average) to the same contaminants when the compressor is on line.

Accidents

In addition to planned emissions, fugitive emissions and blowdowns there is also the possibility of accidents at the compressor station. There are no central national or state inventories of compressor station accidents that we were able to locate. In their absence we turned to local news accounts of individual accidents (which are generally in the form of fires). Without knowing what precisely is in the pipeline nor what else (if anything) may be housed on the site, it is not possible to estimate emissions from a fire at the compressor station. The possibility, however, is very real. A gas compressor station exploded near Godley, TX. That fire destroyed the compressor station where it started and also the one next to it. The fire burned for several hours.[17] In a compressor station fire in Madison County, TX volunteer firefighters from four towns were dispatched to the site. First responders blocked roads near the site and evacuated three homes.[18] In Corpus Christi, TX a fire broke out at a compressor station which then spread to nearby brush before being extinguished.[19]

The possibility of fire or other accidents raises the concern over whether the localities surrounding a compressor station have the resources available to contain a fire or explosion adequately and whether first responders and hospitals are able to care for injured workers or others nearby or whether an evacuation plan could be implemented. In Wheeler County, TX four contractors were performing maintenance activities near a compressor station when a flash fire occurred. The workers were brought to a nearby hospital. Two were treated and released; the other two were transferred to a burn unit in Lubbock.[20] In Carbon County, UT an explosion and fire damaged a natural gas compressor station and other buildings on the site injuring two workers and engulfing the facility in flame. Firefighters from every city in the county responded to the emergency. Injured workers had to be evacuated by medical helicopters.[21]

Overall, there is little information on the division of responsibility between the company operating the facility and the locality. This should be clarified.

The question of radioactivity

A 2008 publication of the International Association of Oil & Gas Producers has laid out the discussion on radioactive material in the natural gas extraction and production process.

> During the production process, naturally occurring radioactive material (NORM) flows with the oil, gas and water mixture and accumulates in scale, sludge and scrapings. It can also form a thin film on the interior surfaces of gas processing equipment and vessels. The level of NORM accumulation can vary substantially from one facility to another depending on geological formation, operational and other factors.
>
> [R]adionuclides such as Lead-210 and Polonium-210 can ... be found in pipelines scrapings as well as sludge accumulating in tank bottoms, gas/oil separators, dehydration vessels, liquid natural gas (LNG) storage tanks and in waste pits as well as in crude oil pipeline scrapings.[22]

The gas which flows through the pipeline likely carries gaseous radon with it, and as radon decays within the pipeline, the solid daughter elements, polonium and lead, accumulate along the interior of the pipes. There is a concern that the gas transiting, and being compressed and regulated, will have radioactivity levels which will put at risk not only the workers at these stations and along the pipeline, but potentially also to the residents.[23] Radon, a gas, has a short half-life (3.8 days) but its progeny are lead and polonium, and these are toxic and have relatively long half-lives of 22.6 years and 138 days respectively.[24] There is no data that we can turn to in order to assess the risk of radioactive exposures in our community.

Health risks from relevant air contaminants

Averages, peaks and health events

As stated previously, one of our primary concerns is the poor fit of a *tons per year* measurement to the assessment of risk to the public's health near a compressor station. Furthermore, the National Ambient Air Quality Standards (NAAQS) used as a benchmark for air quality were not created to assess the air quality and safety in a small geographic area with fluctuating emissions. NAAQS effectively address regional air quality concerns. But these standards do not adequately assess risk to human health for residents living in close proximity to polluting sources such as unconventional natural gas development (UNGD) sites, where emissions can be highly variable.

Generally, it has been shown that:

1. Current protocols used for assessing compliance with ambient air standards do not adequately determine the intensity, frequency or durations of the actual

human exposures to the mixtures of toxic materials released regularly at UNGD sites, including compressor stations.

2. The typically used periodic 24-hour average measures can underestimate actual exposures by an order of magnitude.
3. Reference standards are set in a form that inaccurately determines health risk because they do not fully consider the potential synergistic combinations of toxic air emissions.[25]

Thus estimates of yearly totals of contaminants released by a compressor station do not allow for an assessment of the physiological impact of those emissions on individuals.

NAAQS reflects what, over a region, over time, is deemed safe population-wide. This is very different than what is safe within for instance 1200 feet of this compressor station. As already stated, averaging over a year can wash out important higher spikes in emissions (thus exposures) that may occur at various points throughout the year. These high spikes can put residents at risk for illnesses caused by air toxics.

Toxicity and characterization of exposures

Toxicity of a chemical to the human body is determined by the concentration of the agent at the receptor where it acts. This concentration is determined by the intensity and duration of the exposure. All other physiological sequelae follow from the interaction between agent and receptor. Once a receptor is activated, a health event might be produced immediately or in as little as one to two hours.[26 27] In some instances, where there is a high concentration of an agent, a single significant exposure can cause injury or illness. This is the case in the instance of an air contaminant induced asthma event. On the other hand, after an initial exposure, future exposures might compound the impact of the first one, in time, producing a health effect. Repeated exposures will increase, for instance, the risk for ischemic heart disease.[28]

Peak exposures

Researchers have demonstrated the wisdom of looking at peak exposures as compared to averages over longer periods of time. Darrow et al (2011) write that sometimes peak exposures better capture relevant biological processes. This is the case for health effects that are triggered by, short-term, high doses. They write, "Temporal metrics that reflect peak pollution levels (e.g., 1-hour maximum) may be the most biologically relevant if the health effect is triggered by a high, short-term dose rather than a steady dose throughout the day. Peak concentrations ... are frequently associated with episodic, local emission events, resulting in spatially heterogeneous concentrations...."[29]

Delfino et al (2002) posited that maxima of hourly data, not 24-hour averages, better captured the risks to asthmatic children, stating, "it is expected that biologic responses may intensify with high peak excursions that overwhelm lung defense mechanisms."

Additionally, they suggest that "[o]ne-hour peaks may be more influenced by local point sources near the monitoring station that are not representative of regional exposures...."[30]

Because episodic high exposures are not typically documented and analyzed by researchers and public agencies, natural gas compressor stations emissions are rarely correlated with health effects in nearby residents. However, examination of published air emission measurements shows the very real potential for harm from industry emissions.[31] Reports of acute onset of respiratory, neurologic, dermal, vascular, abdominal, and gastrointestinal sequelae near natural gas facilities contrast with research that suggests there is limited risk posed by unconventional natural gas development.

Health Effects from exposures to VOCs

VOCs, present at compressor station construction and operation, are a varied group of compounds which can range from having no known health effects to being highly toxic. Short-term exposure can cause eye and respiratory tract irritation, headaches, dizziness, visual disorders, fatigue, loss of coordination, allergic skin reaction, nausea, and memory impairment. Long-term effects include loss of coordination and damage to the liver, kidney, and central nervous system. Some VOCs, such as benzene, formaldehyde, and styrene, are known or suspected carcinogens.[32] The case for elevated risk of cancer from UNGD VOC exposure has been made by McKenzie et al (2012) and others.[33]

The inhalation of the VOC, benzene, produces a number of risks including

> [acute (short-term)] drowsiness, dizziness, headaches, as well as eye, skin, and respiratory tract irritation, and, at high levels, unconsciousness. Chronic (long-term) inhalation exposure has caused various disorders in the blood, including reduced numbers of red blood cells and aplastic anemia, in occupational settings. Reproductive effects have been reported for women exposed by inhalation to high levels, and adverse effects on the developing fetus have been observed in animal tests. Increased incidence of leukemia (cancer of the tissues that form white blood cells) have been observed in humans occupationally exposed to benzene. EPA has classified benzene as known human carcinogen for all routes of exposure.[34]

Benzene, which is documented at compressor stations by the States of Pennsylvania and Texas, carries its own risk, including risk for cancer.[35] [36] There is growing evidence that benzene is associated with childhood leukemia. Benzene affects the blood-forming system at low levels of occupational exposures, and there is no evidence of a threshold. It has been argued in the literature that "[t]here is probably no safe level of exposure to benzene, and all exposures constitute some risk in a linear, if not supralinear, and additive fashion.[37]

20150831-0052 FERC PDF (Unofficial) 08/31/2015

Another substance that is detected near compressor stations is methylene chloride.

According to the EPA:

> The acute (short-term) effects of methylene chloride inhalation in humans consist mainly of nervous system effects including decreased visual, auditory, and motor functions, but these effects are reversible once exposure ceases. The effects of chronic (long-term) exposure to methylene chloride suggest that the central nervous system (CNS) is a potential target in humans and animals. Human data are inconclusive regarding methylene chloride and cancer. Animal studies have shown increases in liver and lung cancer and benign mammary gland tumors following the inhalation of methylene chloride.[38]

The VOC formaldehyde is also considered a Hazardous Air Pollutant (HAP) by the US EPA (EPA).[39] It is one of the emissions chemicals that the natural gas development industry is required to report, for instance to the PA DEP. According to these reports, compressor stations are the highest UNGD source for formaldehyde.[40] For the year 2012, emissions of formaldehyde from compressor stations in Pennsylvania ranged from 0.0 TPY to 22.5 TPY. [41]

A recent study of air emissions in the Barnett shale region of Texas found concentrations of formaldehyde at sites with large compressor stations.[42] Some of these concentrations were greater than the Texas Commission on Environmental Quality's health protective levels (page 62). Formaldehyde was one of 101 chemicals found in association with methane in this study. The research showed that aromatics in particular were associated with compressor stations.

Air exposures to formaldehyde target the lungs and mucous membranes and in the short-term can cause asthma-like symptoms, coughing, wheezing, and shortness of breath. The EPA classifies it as a probable human carcinogen.[43] The World Health Organization classifies it as carcinogenic to humans.[44] It has also been associated with childhood asthma.[45] The California Office of Environmental Health Hazard assessment (OEHHA) has "identified formaldehyde as a Toxic Air Contaminant and gives it an inhalation Reference Exposure Level (REL) of 55 ug/m^3 for acute exposures and 9 ug/m^3 for both 8-hour and chronic exposures.[46] The acute REL is 74 ppb based on irritation of asthmatics.[47] It has also been linked with adverse pregnancy outcomes and reproductive and developmental toxicity.[48]

More recent investigations on formaldehyde near compressor stations are focused on the chemical reaction between methane and sunlight.[49] While it is well known that stationary compressor station engines emit formaldehyde, it is less well known that formaldehyde may also be formed at these sites through this chemical reaction. While the research is ongoing, it suggests that health hazards associated with formaldehyde

may be greater than previously thought. Because reported health symptoms near compressor stations, such as respiratory impacts and shortness of breath, can be caused by exposure to formaldehyde, targeted monitoring of this chemical at these sites would be recommended.

Effects from exposure to particulate matter

In addition to the VOC exposure presented above, PM2.5 also poses a significant health concern and interacts with the airborne VOCs increasing their impact. In fact, at a compressor station PM2.5 may pose the greatest threat to the health of nearby residents. Fine particles are expected to reach a total of 1.136 tons for 2015 and 2016.

The size of particles determines the depth of inhalation into the lung; the smaller the particles are, the more readily they reach the deep lung. Particulate matter (PM10, PM2.5 and ultrafine PM), in conjunction with other emissions, are at the core of concern over potential effects of UNGD.

High particulate concentrations are of grave concern because they absorb airborne chemicals in their midst. The more water soluble the chemical, the more likely it is to be absorbed onto a particle. Larger sized particles are trapped in the nose and moist upper respiratory tract thereby blocking or minimizing their absorption into the blood stream. The smaller PM2.5 however, is more readily brought into the deep lung with airborne chemicals and from there into the blood stream. As the particulates reach the deep lung alveoli the chemicals on their surface are released at higher concentrations than they would in the absence of particles. The combination of particles and chemicals serves, in effect, to increase in the dose of the chemical. The consequences are much greater than additivity would indicate; and the physiological response is intensified. Once in the body, the actions between particles and chemicals are synergistic, enhancing or altering the effects of chemicals in sometimes known and often unknown ways.[50]

Reported clinical actions resulting from PM2.5 inhalation affect both the respiratory and cardiovascular systems. Inhalation of PM2.5 can cause decreased lung function, aggravate asthma symptoms, cause nonfatal heart attacks and high blood pressure.[51] Research reviewing health effects from highway traffic, which, like UNGD, has especially high particulates, concludes, "[s]hort-term exposure to fine particulate pollution exacerbates existing pulmonary and cardiovascular disease and long-term repeated exposures increases the risk of cardiovascular disease and death."[52] PM2.5, it has been suggested, "appears to be a risk factor for cardiovascular disease via mechanisms that likely include pulmonary and systemic inflammation, accelerated atherosclerosis and altered cardiac autonomic function. Uptake of particles or particle constituents in the blood can affect the autonomic control of the heart and circulatory system."[53]

Ultrafine particles (<0.1) get less attention in the literature than PM2.5 but is found to have high toxic potency.[54] These particles readily deposit in the airways and centriacinar region of the lung.[55] Research suggests increases in ultrafine particles pose additional risk to asthmatic patients.[56] Ultrafine particles are generally produced by combustion processes. They, along with the larger PM2.5, are found in diesel exhaust.

Diesel is prevalent during the construction phase of compressor station site. High levels of diesel exhaust from construction machinery as well as trucks increase the level of respirable particles. Health consequences of diesel exposure have been widely studied and include immediate and long term health effects. Diesel emissions can irritate the eyes, nose, throat and lungs, and can cause coughs, headaches, lightheadedness and nausea. Short-term exposure to diesel exhaust also causes inflammation in the lungs, which may aggravate chronic respiratory symptoms and increase the frequency or intensity of asthma attacks. Long-term exposure can cause increased risk of lung cancer.[57]

PM2.5 acute effects

There is an abundance of research on the health effects of short term PM2.5 exposure. Mills et al demonstrate that one to two hours of a diesel exhaust exposure, which occurs during the construction phase of development, includes reduced brachial artery diameter and exacerbation of exercise-induced ST-segment depression in people with pre-existing coronary artery disease; ischemic and thrombotic effects in men with coronary heart disease;[58] and is associated with acute endothelial response and vasoconstriction of a conductance artery.[59] Fan He et al. suggest that health effects can occur within 6 hours of elevated PM2.5 exposures, the strongest effects occurring between 3 and 6 hours. Such an acute effect of PM2.5 may contribute to acute increase in the risk of cardiac disease, or trigger the onset of acute cardiac events, such as arrhythmia and sudden cardiac death.[60]

Numerous epidemiological studies have demonstrated a consistent link between particulate matter and increased cardiopulmonary morbidity and mortality (Brook et al. 2004; Mann et al. 2002; Pope et al. 2002; Samet et al. 2009; Schwartz 1999).[61] Previous studies have suggested that PM2.5 exposure is significantly associated with increased heart rate and decreased heart rate variability (HRV; Gold et al., 2000; He et al. 2010; Liao et al. 1999; Luttmann-Gibson et al. 2006; Magari et al. 2001; Park et al. 2005).

In addition to short term exposures and associated effects, there is evidence of health impacts from long-term exposures.[62] An HIA reviewing data from a number of European cities found that nearly 17,000 premature deaths from all causes, including cardiopulmonary deaths and lung-cancer deaths, could be prevented annually if long-term exposure to PM2.5 levels were reduced. Equivalently, this reduction would increase life expectancy at age 30 by a range between one month and more than two years in the study cities. A Canadian national cohort study found positive and

statistically significant associations between non-accidental mortality and estimates of PM2.5, the strongest association being with ischemic heart disease. Associations in this study were with concentrations of PM2.5 as low as only a few micrograms per cubic meter.[63] Research has also shown that there is an association between PM2.5 and hospitalization for COPD in elderly people.[64]

There is also a considerable literature on the health effects specifically from diesel emission that include PM2.5 along with chemical components. Mills et al conclude that even dilute diesel emissions can induce risk and point to ischemic and thrombotic mechanisms for the adverse cardiovascular events associated with diesel exposure.[65]

After an extensive review the EPA concluded that

> long-term inhalation exposure is likely to pose a lung cancer risk to humans. Estimation of cancer potency from available epidemiology studies was not attempted.... A noncancer chronic human health hazard is inferred from rodent studies showing dose-dependent inflammation and histopathology in rats. Short-term exposures were noted to cause irritation and inflammatory symptoms of a transient nature these being highly variable across an exposed population. The assessment also indicates that there is emerging evidence fro the exacerbation of existing allergies and asthma symptoms.[66]

Children, pregnant women and air contaminants

Children and pregnant women are especially sensitive to pollution. Many studies confirm a range of adverse effects of air pollution on children's lung function and respiratory symptoms, especially for asthmatics. Recent studies have found statistically significant associations between the prevalence of childhood asthma or wheezing and living very close to high volume vehicle roadways.[67] Other research aimed specifically at children's PM2.5 exposure has found that PM2.5 and several of its components have important effects on hospital admissions for respiratory disease, especially pneumonia. The authors count among the sources for this exposure diesel exhaust, motor vehicle emissions, and fuel combustion processes.[68]

Health effects have been found in pregnant women from high particulate highway pollution. Such particle pollution "may provoke oxidative stress and inflammation, cause endocrine disruption, and impair oxygen transport across the placenta, all of which can potentially lead to or may be implicated in some low birth weight ... and preterm births." The consequences do not stop with low birth weight and preterm births because these conditions can negatively affect health throughout childhood and into adulthood.[69]

Mixtures and sequential exposures

Mixtures of pollutants are a critically important topic in addressing the public health implications of UNGD broadly and compressor stations in this case. While this report has focused primarily on three pollutants (VOCs, formaldehyde as one example, and PM2.5), in fact, a very large number of chemicals are released together. Medical reference values are not able to take the complex nature of the shale environment, its multiple emissions and interactions into full consideration.[70] Although the shale gas industry is not unique in emitting multiple pollutants simultaneously, this industry is unique in doing so as close as 500 feet from residences.

Chemicals that reach the body interfere with metabolism and the uptake and release of other chemicals, be they vitally important biochemical produced and needed by the body or other environmental chemicals with potentially toxic effects. Some chemicals attack the same or similar target sites creating an additive effect. This is the case with chemicals of similar structure such as many in the class of VOCs. Some mixtures like PM and VOC act synergistically to increase the toxicity of the chemicals. Other chemicals released environmentally are rapidly absorbed and slowly excreted. These slowly excreted chemicals will interfere with subsequent actions of chemicals because the body has not yet cleared the effects from the earlier exposure.

Noise

Excessive noise has been associated with an array of psychological and physical effects. A review article on noise exposure and health risk published in *Noise and Health* claims that the evidence for a causal relationship between community or transportation noise and cardiovascular risk has risen in recent years. In sum, the author finds limited evidence for a causal relationship between noise and biochemical effects; limited or sufficient evidence for hypertension; and sufficient evidence for ischemic heart disease.[71]

According to a World Health Organization assessment of research, excessive noise can also increase risk of cognitive impairment in children, sleep disturbance, tinnitus, and high levels of annoyance.[72] Researchers have found associations between elevated sound levels – including community sounds levels – and hearing loss, reduced performance and aggressive behavior.[73] Additionally some attention is being paid to the health effects of vibration exposure which is connected with but distinct from noise itself.[74]

Noise exposures are associated with construction activities and during blowdown episodes. As with air exposures, the periods of extreme exposures (in this case noise exposures) can cause different and sometimes more serious effects than low-level exposures.

Summary

In sum, we know that a number of different chemicals as well as PM2.5 are present during the construction phase of compressor stations and they are present in close

proximity to compressor stations that are on line. Some, although not all, have documented health effects on vulnerable populations and on the population at large. What we do not know is the precise mix and concentration of chemicals that will be released into the air. Without that information it is not possible to assess the compressor station's full impact on area residents.

Reported health effects specific to compressor stations

There is a growing body of research on emissions and health impacts from UNGD generally, though few studies specifically address health impacts from compressor stations. This is partly due to the fact that many compressors are sited in proximity to other UNGD sites such as well pads, impoundments, condensate tanks and processing stations. As the infrastructure for transporting natural gas continues to expand, more pipelines, metering stations and compressor stations will be sited away from other UNGD facilities.

Recent research that has been conducted near compressor stations in different parts of the country shows consistencies in the types of symptoms experienced by those living near these sites. These symptoms are associated with health impacts on respiratory, neurological and cardiovascular body systems. It should be noted that in each of the studies cited here health survey forms were filled out by residents and, as such, the findings are self-reported. To date there have been no epidemiological studies performed to identify health impacts from compressor stations.

A peer-reviewed article, *Investigating Links Between Shale Gas Development And Health Impacts Through A Community Survey Project In Pennsylvania* (2014) is one of the few publications that explicitly addresses health impacts from compressors.[75] The report states:

> In the Pennsylvania study, distance to industrial sites correlated with the prevalence of health symptoms. For example, when a gas well, compressor station, and/or impoundment pit were 1500-4000 feet away, 27 percent of participants reported throat irritation; this increased to 63 percent at 501-1500 feet and to 74 percent at less than 500 feet. At the farther distance, 37 percent reported sinus problems; this increased to 53 percent at the middle distance and 70 percent at the shortest distance. Severe headaches were reported by 30 percent of respondents at the farther distance, but by about 60 percent at the middle and short distances.[76] P.62

Age groups also responded differently in terms of health symptoms:

> Among the youngest respondents (1.5-16 years of age), for example, those within 1500 feet experienced higher rates of throat irritation (57% vs. 69%) and severe headaches (52% vs. 69%). It is also notable that the youngest group had the highest occurrence of frequent nosebleeds (perhaps reflective of the more

sensitive mucosal membranes in the young), as well as experiencing conditions not typically associated with children, such as severe headaches, joint and lumbar pain, and forgetfulness.

Among 20- to 40-year-olds, those living within 1500 feet of a facility reported higher rates of nearly all symptoms; for example, 44 percent complained of frequent nosebleeds, compared to 29 percent of the entire age group. The same pattern existed among 41- to 55-year-olds with regard to several symptoms (e.g., throat and nasal irritation and increased fatigue), although with smaller differences and greater variability than in the other age groups.

The subset of participants in the oldest group (56- to 79-year-olds) living within 1500 feet of facilities had much higher rates of several symptoms, including throat irritation (67% vs. 47 %), sinus problems (72% vs. 56%), eye burning (83% vs. 56%), shortness of breath (78% vs. 64%), and skin rashes (50% vs. 33%).

In sum, while these data do not prove that living closer to oil and gas facilities causes health problems, they do suggest a strong association since symptoms are more prevalent in those living closer to facilities than those living further away. Symptoms such as headaches, nausea, and pounding of the heart are known to be the first indications of excessive exposure to air pollutants such as VOCs [36], while the higher level of nosebleeds in the youngest age group is also consistent with patterns identified in health survey projects in other states [9, 10]." P.64

Earthworks, a non-profit organization, conducted the Pennsylvania study referred to above, (Gas Patch Roulette 2012) in which they surveyed residents about health symptoms and conducted air and water tests near residences in Pennsylvania and New York[77]. In their report, specific mention is given of a residence 800 feet from a compressor station. Health symptoms experienced by the residents (parents and children) were extreme tiredness, severe headaches, runny noses, sore throats and muscle aches, as well as dizziness and vomiting by one individual.

Earthworks also conducted a health survey in Dish, Texas in 2009.[78] The health symptoms reported to be associated with compressors were: burning eyes, nausea, headaches, running nose, sore throat, asthma, sinus problems and bronchitis. Odors experienced by residents near compressor stations were described as: sulfur smell, odorized natural gas, burnt wire, strong chemical-like smell and ether.

Wilma Subra[79], an environmental chemist and consultant who is on the Earthworks Board of Directors, has compiled information on health symptoms experienced near compressor stations based on her research with communities concerned about health impacts from UNGD[80]. Subra has served as Vice-Chair of the Environmental Protection Agency National Advisory Council for Environmental Policy and Technology (NACEPT),

and recently completed a five year term on the National Advisory Committee of the U.S. Representative to the Commission for Environmental Cooperation and a six year term on the EPA National Environmental Justice Advisory Council (NEJAC) where she served as a member of the Cumulative Risk and Impacts Working Group of the NEJAC Council. While her research on health impacts associated with compressor stations is reported back to communities, most of the data shown here have not been published in peer-reviewed journals (she is an author on the above-mentioned peer-reviewed article on Pennsylvania data).

Subra has reported the following health impacts in association with compressor stations:

Table 2. Most Prevalent Medical Conditions In Individuals Living In Close Proximity to *Compressor Stations and Metering Stations*

Medical Conditions:	% of Individuals (71)
Respiratory Impacts	58
Throat Irritation	55
Weakness and Fatigue	55
Nasal Irritation	55
Muscle Aches & Pains	52
Vision Impairment	48
Sleep Disturbances	45
Sinus Problems	42
Allergies	42
Eye Irritation	42
Joint Pain	39
Breathing Difficulties	39
Severe Headaches	39
Swollen & Painful Joints	32
Frequent irritation	32

The full list of health impacts "Reported by Community Members Living 50 feet to 2 miles from Compressor Stations and Gas Metering Stations Along Gas Transmission Pipelines" is available at the Luzerne County Citizens for Clean Air website[81]. It is notable that Subra reports that 61% of health impacts are associated with the chemicals present in the air that were in excess of short and long term effects screening levels.

Subra further reports that the following units at compressor stations and gas metering stations release emissions into the air:

Compressor Engines

Compressor Blowdowns

20150831-0052 FERC PDF (Unofficial) 08/31/2015

Condensate Tanks
Storage Tanks
Truck Loading Racks
Glycol Dehydration Units
Amine Units
Separators
Fugitive Emission Sources

She reports that 90% of individuals surveyed reported experiencing odor events from these facilities. Based on her analysis, the following health symptoms are associated with the chemicals detected in the air at compressor stations:

Allergies
Persistent Cough
Shortness of Breath
Frequent Nose Bleeds
Sleep Disturbances
Joint Pain
Difficulty in Concentrating
Nervous System Impacts
Forgetfulness
Sores and Ulcers in Mouth
Thyroid Problems

Subra reports that both the construction and production phases of compressor stations can cause acute and chronic impacts. In the construction phase impacts come from diesel truck emissions and from dust particles. In the production phase impacts are derived from constant emissions, venting, blowdowns, accidents/malfunctions and from the effects of noise, light and stress. She considers respiratory health impacts of particular concern, and vulnerable groups such as pregnant women, children, the elderly and sensitive individuals to be at greatest risk. Acute and chronic health impacts that Subra has documented are listed below.

Acute Health Impacts Experienced by Individuals Living and Working near Compressor Stations

Tense and nervous
Joint and muscle aches and pains
Vision Impairment
Personality changes
Depression, Anxiety
Irritability
Confusion
Drowsiness
Weakness
Irregular Heartbeat
Irritates skin, eyes, nose, throat and lungs
Respiratory impacts
Sinus problems
Allergic reactions
Headaches
Dizziness, Light headedness
Nausea, Vomiting
Skin rashes
Fatigue
Weakness

Chronic Health Impacts Experienced by Individuals Living and Working near Compressor Stations

- Damage to Liver and Kidneys
- Damage to Lungs
- Damage to Cardiovascular System
- Damage to Developing Fetus
- Reproductive Damage
- Mutagenic Impacts
- Developmental Malformations
- Damage to Nervous System
- Brain Impacts
- Leukemia
- Aplastic Anemia
- Changes in Blood Cells
- Impacts to Blood Clotting Ability

Radioactive elements: a long-term health threat

The possibility of exposure to radiation from natural gas pipelines and compressor stations is also a concern, especially for long-term health effects. The New York public health group, Concerned Health Professionals of New York, describes the problem in their report, Compendium Of Scientific, Medical, And Media Findings Demonstrating Risks And Harms Of Fracking (Unconventional Gas And Oil Extraction) (July 10, 2014): "Unsafe levels of radon and its decay products in natural gas produced from the Marcellus Shale, known to have particularly high radon content, may also contaminate *pipelines and compressor stations, as well as pose risks to end-users when allowed to* travel into homes."(P.5). Health impacts from exposure to radioactive materials in compressor station emissions have not been documented, but the risk of exposure to these carcinogens are a serious public health concern.

20150831-0052 FERC PDF (Unofficial) 08/31/2015

[1] Southwestern Pennsylvania Marcellus Shale Short-Term Ambient Air Sampling Report. Pennsylvania Department of Environmental Protection. November 2010.
[2] Southwestern Pennsylvania Marcellus Shale Short-Term Ambient Air Sampling Report. Pennsylvania Department of Environmental Protection. November 2010.
[3] http://www.atsdr.cdc.gov/ToxProfiles/tp110.pdf. Page 216.
[4] Ibid., Appendix A, p.31.
[5] "Emission Inventory." Pennsylvania Department of Environmental Protection. http://www.dep.state.pa.us/dep/deputate/airwaste/aq/emission/emission_inventory.htm 2010.
[6] Texas Commission on Environmental Quality Barnett Shale Formation Area Monitoring Projects. Doc number BS0912-FR http://www.tceq.state.tx.us/assets/public/implementation/barnett_shale/2010.01.27-BarnettShaleMonitoringReport.pdf.
[7] Ibid.
[8] Wolf Eagle Environmental. Town of DISH, Texas Ambient Air Monitoring Analysis Final Report. September 15, 2009.
[9] Steinzor N, Subra W, Sumi L. Investigating Links between Shale Gas Development and Health Impacts through a Community Survey Project in Pennsylvania New Solutions 2013; 23(1): 55-84.
[10] Southwest Pennsylvania Environmental Health Project internal review of intake materials, August 2014.
[11] Eastern Research Group, Inc. and Sage Environmental Consulting, LP. City of Fort Worth natural gas air quality study: final report. 2011. Available at: http://www.edf.org/sites/ default/files/9235_Barnett_Shale_Report.pdf. July 13, 2011.
[12] Ibid.
[13] Natural Gas Industry Methane Emission Factor Improvement Study Final Report Cooperative Agreement No. XA-83376101. Prepared by: Matthew R. Harrison Katherine E. Galloway Al Hendler Theresa M. Shires
[14]http://www.transcanada.com/docs/Our_Responsibility/Blowdown_Notification_Factsheet.pdf
[15]http://www.transcanada.com/docs/Our_Responsibility/Blowdown_Notification_Factsheet.pdf
[16] Personal communication with staff at SWPA-EHP.
[17] http://www.cleburnetimesreview.com/godley/x489007782/Compressor-station-blows-up.
[18] http://www.madisonvillemeteor.com/news/article_bb02293e-656e-11e2-b466-0019bb2963f4.html
[19] http://www.caller.com/news/natural-gas-explosion-in-jim-wells-county-shoots
[20] http://www.newschannel10.com/story/24605246/four-people-injured-in-workplace-accident
[21] http://www.sunad.com/index.php?tier=1&article_id=26535

[22] Guidelines for the management of naturally occurring radioactive material (NORM) in the oil & gas industry. International Association of Oil & Gas Producers, Report No. 412, September 2008. http://www.ogp.org.uk/pubs/412.pdf

[23] ATSDR. http://www.atsdr.cdc.gov/csem/csem.asp?csem=8&po=5.

[24] Dyrszka L. Potential Health Impacts Proposed Minisink Compressor Station. October 9, 2012. Unpublished affidavit.

[25] Brown D, Weinberger B, Lewis C, Bonaparte H. Understanding exposure from natural gas drilling puts current air standards to the test. Reviews in Environmental Health 2014; DOI 10.1515/reveh-2014-0002.

[26] Brook RD, Rajagopalan S, et al. Particulate matter air pollution and cardiovascular disease: An update to the scientific statement from the American Heart Association. Circulation. 2010; 121(21):2331–2378.

[27] Wellenius GA, Burger MR, Coull BA, Schwartz J, Sus HH, Koutrakis P, Schlaug G, Gold DR, Mittleman MA. *Ambient Air Pollution and the Risk of Acute Ischemic Stroke.* Archives of Internal Medicine 2012; 172(3):229-34.

[28] Pope CA, Muhlestein JB, May HT, Renlund DG, Anderson JL, Horne BD. Ischemic heart disease events triggered by short-term exposure to fine particulate air population. Circulation. 2006; 114: 2443-2448.

[29] Darrow LA, Klein M, Sarnat JA, Mulholland, Strickland MJ, Sarnat SE, Russell A, Tolbert PE. The use of alternative pollutant metrics in time-series studies of ambient air pollution and respiratory emergency department visits. Journal of Exposure Science and Environmental Epidemiology. 2011; 21(1): 10–19.

[30] Delfino R, Zeiger RS, Seltzer JM, Street DH, McLaren CE. Association of asthma symptoms with peak particulate air pollution and effect modification by anti-inflammatory medication use. Environmental Health Perspectives. 2002; 110(10):A607-A617.

[31] Southwest Pennsylvania Environmental Health Project. EHP's Latest Findings Regarding Health Data. http://www.environmentalhealthproject.org/wp-content/uploads/2013/09/6.13.13-general.pdf. See also, Earthworks. Subra W. Results of Health survey of current and former DISH/Clark, Texas Residents. http://www.earthworksaction.org/library/detail/health_survey_results_of_current_and_former_dish_clark_texas_residents/#.UsG_EihCR0M.

[32] EPA. An introduction to indoor air quality: volatile organic compounds. http://www.epa.gov/iaq/voc.html#Health_Effects

[33] http://toxtown.nlm.nih.gov/text_version/chemicals.php?id=31

[34] http://www.epa.gov/ttn/atw/hlthef/benzene.html

[35] Marlyn T. Smith "Advances in understanding benzene health effects and susceptibility. Annual Review of Public Health. 2010; 31:133-48.

[36] http://www.epa.gov/teach/chem_summ/BENZ_summary.pdf

[37] Smith MT. Advances in understanding benzene health effects and susceptibility. Annual Review of Public Health. 2010; 31:133-48.

[38] http://www.epa.gov/ttn/atw/hlthef/methylen.html

[39] http://www.epa.gov/ttn/atw/orig189.html

20150831-0052 FERC PDF (Unofficial) 08/31/2015

[40] Pennsylvania Department of Environmental Protection. 2013. Air Emissions Inventory Data for the Unconventional Natural Gas Industry, http://www.dep.state.pa.us/dep/deputate/airwaste/aq/emission/marcellus/Nat%20Gas%20Emissions%202012%20-WellFarmStation20140324.xlsx. The Lathrop compressor station in Springville, Susquehanna County, PA emitted 22.5 TPY of formaldehyde. See page 78 of the data sheet.

[41] www.dep.state.pa.us/dep/deputate/airwaste/aq/emission/marcellus_inventory.html

[42] Rich A, Grover JP, Sattler ML. An exploratory study of air emissions associated with shale gas development and production in the Barnett Shale. Journal of the Air & Waste Management Association 2014; 64:1, 61-72DOI:10.1080/10962247.2013.832713

[43] www.epa.gov/ttn/atw/hlthef/formalde.html

[44] www.epa.gov/teach/chem_summ/Formaldehyde_summary.pdf

[45] Mcgwin G,J, Lienert J. and Kennedy, JI. Formaldehyde exposure and asthma in children: a systematic review. Environmental Health Perspectives. 2009; 118, 313-317.

[46] http://oehha.ca.gov/air/allrels.html

[47] http://oehha.ca.gov/air/toxic_contaminants/pdf_zip/formaldehyde-final.pdf

[48] Duong A, Steinmaus C, McHale CM, Vaughan CP, Zhang L. Reproductive and developmental toxicity of formaldehyde: a systematic review. Mutation Research. 2011; 728(3):118-38. doi: 10.1016/j.mrrev.2011.07.003.

[49] Personal communication, David Carpenter. August 20, 2014. Research article under review.

[50] Amdur MO. The response of guinea pigs to inhalation of formaldehyde and formic acid alone and with a sodium chloride aerosol. International Journal of Air Pollution 1960; 3:201-20.

[51] http://www.epa.gov/pm/health.html

[52] Brugge D, Durant JL, Rioux C. Near-highway pollutants in motor vehicle exhaust: A review of epidemiologic evidence of cardiac and pulmonary health risks. Environmental Health. 2007; 6:23.

[53] Ibid.

[54] Geiser M, Rothen-Rutishauser B, Kapp N, Schurch S, Kreyling W, Schulz H, et al. Ultrafine particles cross cellular membranes by nonphagocytic mechanisms in lungs and in cultured cells. Environmental Health Perspectives 2005; 1131(11):1555. Frampton MW, Stewart JC, Oberdorster G, Morrow PE, Chalupa D, Pietropaoli AP, et al. Inhalation of ultrafine particles alters blood leukocyte expression of adhesion moleculites in humans. Environmental Health Perspectives 2006; 114(1): 51.

[55] Donalson K, Stone V, Clouter A, Renwick L, MacNee W. Ultrafine particles. Occupational & Environmental Medicine 2001; 58:211-216.

[56] Peters A, Wichmann HE, Tuch T, et al. Respiratory effects are associated with the number of ultrafine particles. American Journal of Respiratory Critical Care Medicine 1997; 155:1376-1383.

[57] Oehha.ca.gov/public_info/facts/dieselfacts.html. See also Zhang JJ. McCreanor JE, Cullinan P, et al. Health effects of real-world exposure to diesel exhaust in persons with asthma. Research Report. Health Effects Institute 2009; 138:5-109; McClellan RO Health effects of exposure to diesel exhaust particles. Annual Review of Pharmacology and

20150831-0052 FERC PDF (Unofficial) 08/31/2015

Toxicology 1987; 27(1):279-300; Ris C. US EPA health assessment for diesel engine exhaust: a review. Inhalation toxicology 2007; 19(S1):229-239.

[58] Mills NL, Tornqvist H, Gonzalez MC, Vinc E, Robinson SD, Soderberg S, et al. Ischemic and thrombotic effects of dilute diesel-exhaust inhalation in men with coronary heart disease. New England Journal of Medicine. 2007; 357(11):1075-1082.

[59] Paretz A, Sullivan JH, Leotta DF, Trenga CA, Sands FN, Allen J, et al. Diesel exhaust inhalation elicits acute vasoconstriction in vivo. Environmental Health Perspectives. 2008; 118(7):837-942.

[60] He F, Shaffer ML, Rodriguez-Colon S, Yanosky JD, Bixler E Cascio WE. et al, Journal of Exposure Science and Environmental Epidemiology 2011, 21. Acute effects of fine particulate air pollution on cardiac arrhythmia: the APACR study. Environmental Health Perspectives 2011; 119(7): 927-932

[61] Ibid.

[62] Boldo E, Medina S, LeTertre A, Hurley F, Mucke HG, Ballester F, et al. Apheis: Health impact assessment of long-term exposure to PM2.5 in 23 European cities. European Journal of Epidemiology 2006; 21:449-458

[63] Crouse DL, Peters PA, van Donkeiaar A, Goldberg MS, Villeneuve PJ, Brion O, et al. Risk of nonaccidental and cardiovascular mortality in relation to long-term exposure to low concentrations of fine particular matter: a Canadian national-level cohort study. Environmental Health Perspectives 2012; 120:708-714.

[64] Chen Y, Yang Q, Krewski D, Shi Y, Burnett RT, McGrail. Influence of relatively low level of particulate air pollution on hospitalization for COPD in elderly People. Inhalation Toxicology 2004; 16(1):21-25.

[65] Mills NL et al. 2007.

[66] US EPA. U.S. EPA health assessment for diesel engine exhaust: A review. Inhalation Toxicology 2007; 19(s1): 229-39.

[67] Li S, Williams G, Jalaludin B, Baker P. Panel studies of air pollution on children's lung function and respiratory symptoms: a literature review. Journal of Asthma 2012; 49(9):895-910.

[68] Ostro B, Roth L, Malig B, Marty M. The effects of fine particle components on respiratory hospital admissions in children. Environmental health perspectives 2009; 117(3).

[69] http://ehp.niehs.nih.gov/122-a110/

[70] For additional information see, for instance, EPA's Integrated Risk Information System database.

[71] Babisch W. Transportation noise and cardiovascular risk: Updated review and synthesis of epidemiological studies indicate that the evidence has increased. Noise & Health 2006; 8(30):1-29.

[72] World Health Organization. Burden of disease from environmental noise: Quantification of healthy life years lost in Europe. 2011.

[73] Moudon AV. Real noise from the urban environment: How ambient community noise affects health and what can be done about it. 2009. American Journal of Preventive Medicine 37(2):167-171.

20150831-0052 FERC PDF (Unofficial) 08/31/2015

[74] Alves-Pereira M and Branco NC. Vibroacoustic disease: the need fro a new attitude towards noise. 1999. Public Participation and Information Technologies. http://www.citidep.pt/papers/articles/alvesper.htm

[75] Steinzor, N W. Subra and L Sumi. Investigating Links between Shale Gas Development and Health Impacts Through a Community Survey Project in Pennsylvania. New Solutions: A Journal Of Environmental And Occupational Health Policy Vol 23:55-83. 2013. http://baywood.metapress.com/openurl.asp?genre=article&id=doi:10.2190/NS.23.1.e Accessed 8.8.2014.

[76] Steinzor, N W. Subra and L Sumi. Investigating Links between Shale Gas Development and Health Impacts Through a Community Survey Project in Pennsylvania. New Solutions: A Journal Of Environmental And Occupational Health Policy Vol 23:55-83. 2013. http://baywood.metapress.com/openurl.asp?genre=article&id=doi:10.2190/NS.23.1.e Accessed 8.8.2014.

[77] Earthworks, Gas Patch Roulette, October 2012, http://www.earthworksaction.org/library/detail/gas_patch_roulette_full_report#.Uc3MAm11CVo, and "Investigating Links between Shale Gas Development and Health Impacts through a Community Survey Project in Pennsylvania," 2013, New Solutions 23 (1), 55-84, Nadia Steinzor, Wilma Subra, and Lisa Sumi.

[78] Wilma Subra, "Results of Health Survey of Current and Former DISH/Clark, Texas Residents" December 2009. Earthworks' Oil and Gas Accountability Project, http://www.earthworksaction.org/files/publications/DishTXHealthSurvey_FINAL_hi.pdf

[79] Wilma Subra, President, Subra Company P. O. Box 9813 New Iberia, La 70562.

[80] Summary tables posted at http://lu zernecountycleanair.com/health-affects/ . Accessed July 29, 2014.

[81] Ibid.

20150831-0052 FERC PDF (Unofficial) 08/31/2015

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Scientific Solutions

IMPACTS OF GAS DRILLING ON HUMAN AND ANIMAL HEALTH

MICHELLE BAMBERGER
ROBERT E. OSWALD

ABSTRACT

Environmental concerns surrounding drilling for gas are intense due to expansion of shale gas drilling operations. Controversy surrounding the impact of drilling on air and water quality has pitted industry and leaseholders against individuals and groups concerned with environmental protection and public health. Because animals often are exposed continually to air, soil, and groundwater and have more frequent reproductive cycles, animals can be used as sentinels to monitor impacts to human health. This study involved interviews with animal owners who live near gas drilling operations. The findings illustrate which aspects of the drilling process may lead to health problems and suggest modifications that would lessen but not eliminate impacts. Complete evidence regarding health impacts of gas drilling cannot be obtained due to incomplete testing and disclosure of chemicals, and nondisclosure agreements. Without rigorous scientific studies, the gas drilling boom sweeping the world will remain an uncontrolled health experiment on an enormous scale.

Keywords: hydraulic fracturing, shale gas drilling, veterinary medicine, environmental toxicology

> At what point does preliminary evidence of harm become definitive evidence of harm? When someone says, "We were not aware of the dangers of these chemicals back then," whom do they mean by *we*?
>
> —Sandra Steingraber, *Living Downstream* (Da Capo Press, 2010)

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20150831-0052 FERC PDF (Unofficial) 08/31/2015

Communities living near hydrocarbon gas drilling operations have become de facto laboratories for the study of environmental toxicology. The close proximity of these operations to small communities has created a variety of potential hazards to humans, companion animals, livestock and wildlife. These hazards have become amplified over the last 20 years, due in part to the large-scale development of shale gas drilling (horizontal drilling with high-volume hydraulic fracturing), encouraged by the support of increased drilling and exploration by U.S. government agencies [1]. Yet this large-scale industrialization of populated areas is moving forward without benefit of carefully controlled studies of its impact on public health. As part of an effort to obtain public health data, we believe that particular attention must be paid to companion animals, livestock, and wildlife, as they may serve as sentinels for human exposures, with shorter lifetimes and more opportunity for data collection from necropsies.

All phases of hydrocarbon gas production involve complex mixtures of chemical substances. For example, in hydraulic fracturing fluids, chemical substances other than water make up approximately 0.5 to 1 percent of the total volume; however, the very large volumes used require correspondingly large volumes of a variety of compounds. These substances range from the relatively benign to the highly toxic. Some of these are reported to the public and others are not, but the quantities and proportions used are largely considered trade secrets. In addition to these added chemicals, naturally occurring toxicants such as heavy metals, volatile organics, and radioactive compounds are mobilized during gas extraction and return to the surface with the gas/chemical mix (wastewater); of the 5.5 million gallons of water, on average, used to hydraulically fracture a shale gas well one time [2], less than 30 percent to more than 70 percent may remain underground [3]. Hydraulic fracturing takes place over 2 to 5 days and may be repeated multiple times on the same well over the course of the potential 25- to 40-year lifetime of a well [4]. Many of these chemicals are toxic and have known adverse health effects, which may be apparent only in the long term. A discussion of these compounds and their health effects is beyond the scope of this article; however, Colborn et al. [5] have analyzed this topic in depth.

The large-scale use of chemicals with significant toxicity has given rise to a great deal of public concern, and an important aspect of the debate concerns the level of proof required to associate an environmental change with activities associated with gas drilling. Environmental groups typically invoke the precautionary principle [6]. That is, if an action is suspected of causing harm to the environment, then in the absence of a scientific consensus, the burden of proof falls on the individual or organization taking the action. The oil and gas industry has typically rejected this analysis and has approached the issue in a manner similar to the tobacco industry that for many years rejected the link between smoking and cancer. That is, if one cannot prove beyond a shadow of doubt that an environmental impact is due to drilling, then a link is rejected. This approach

20150831-0052 FERC PDF (Unofficial) 08/31/2015

by the tobacco companies had a devastating and long-lasting effect on public health from which we have still not recovered [7], and we believe that a similar approach to the impacts of gas drilling may have equally negative consequences.

Although reports of petroleum hydrocarbon exposure in humans [8-14], primates [15], and several other species, including ruminants [16-26], horses [27], wildlife [28], and a dog [29], have been cited in the literature, there are few reports on exposure of animals to gas operations, and to our knowledge, no case reports on exposure of humans to hydrocarbon gas operations [30]. Adler et al. [31] observed aspiration pneumonia in sheep following exposure to gas condensate. In another study, Waldner et al. [32] found no association between the productivity of cattle and exposure to a sour gas pipeline leak; while in a longer-term study [33] in cattle, the same group reported associations between sour-gas flaring and increased risk of stillbirth across three of the four years studied, as well as increased risk of calf mortality in one of the years studied. In a study of habitat selection, Sawyer et al. [34] found that mule deer tended to move away from areas of gas development, and in a recent report [35] from the same author, the deer population dropped by 45 percent in one year, and the survival rate decreased.

Just as epidemiologic studies linked smoking to human health impacts, such studies could be used to assess the health impacts of gas drilling operations on human beings. Studies in laboratory animals have also been a powerful tool for linking components of tobacco smoke to cancer, not only because controlled studies can be done but also because breeding cycles are short and the age at which cancer develops is within a range accessible to laboratory studies. Though such controlled animal studies of the effects of gas drilling are not feasible, animals can nevertheless serve as sentinels for human health impacts. Animals, particularly livestock, remain in a confined area and, in some cases, are continually exposed to an environmental threat. Further, effects on reproduction can be more readily assessed in a herd of cattle than in a human population, simply due to the higher rates of reproduction.

For the past year, we have been documenting cases of animal and owner health problems with potential links to gas drilling. Many cases are currently in litigation. To protect individuals' privacy and due to ongoing legal action, the discussion will not include personal identifying information. We summarize the results of our investigation, provide several case studies, and conclude with recommendations for minimizing or preventing similar problems in the future. This study is not an epidemiologic analysis of the health effects of gas drilling, which could proceed to some extent without knowledge of the details of the complex mixtures of toxicants involved. It is also not a study of the health impacts of specific chemical exposures related to gas drilling, since the necessary information cannot be obtained due to the lack of testing, lack of full disclosure of the International Union of Pure and Applied Chemistry (IUPAC) names and Chemical Abstracts Service (CAS) numbers of the chemicals used, and the

20150831-0052 FERC PDF (Unofficial) 08/31/2015

industry's use of nondisclosure agreements. Nevertheless, the value of this study is twofold. First, clear health risks are present in gas drilling operations. These cannot be eliminated but can be decreased by commonsense reforms. Second, our study illustrates not only several possible links between gas drilling and negative health effects, but also the difficulties associated with conducting careful studies of such a link. Again, simple commonsense policy reforms could facilitate the collection of data that would lead to a careful assessment of the health consequences of gas drilling on both humans and animals.

SUMMARY OF THE EFFECTS OF GAS DRILLING ON PRODUCTION AND COMPANION ANIMALS AND ANIMAL OWNERS

To describe how exposures may occur, and to report health effects, we conducted interviews with animal owners in six states (Colorado, Louisiana, New York, Ohio, Pennsylvania, Texas) affected by gas drilling. In all but one case, we spoke directly with animal owners. The exception was a case that had previously been documented by the state environmental regulatory agency [36]. When possible, we interviewed the owners' veterinarians. Where available, we have obtained the results of water, soil, and air testing as well as the results of laboratory tests on affected animals and their owners. Documentation was obtained from the animal owners, the veterinarians (with permission of the owners), drilling company representatives, state regulatory agencies, and a Freedom of Information Act (FOIA) request from the Pennsylvania Department of Agriculture. Cases were identified by requesting referrals from environmental groups and individuals actively involved in influencing shale gas policy and studying its effects. For each case, a standard series of questions was asked, including the exact location of each owner's property; details on wells in the area (subsequently verified by crosschecking with state records and, using software developed for this project, mapping the wells relative to the owner's property); details of seismic testing and well flaring; location of wastewater impoundments; results of water, soil, and air testing; details of animal husbandry and medical records preceding, during and following drilling, depending upon the individual case; a list of animals (species, breed, age, sex, use (e.g., livestock)), sorted into those healthy and those unhealthy; health history for all animals; observations of wildlife in the area; and health histories of the humans living in the household. As each case is different, the standard form was used as a starting point, with additional information invariably supplied by individuals being interviewed.

More than one-third of the cases involved conventional wells (shallow or deep vertical wells), with the remainder comprising horizontal wells subjected to high-volume hydraulic fracturing. Because of the scale of the horizontal well drilling operations, such wells were more commonly associated with animal health problems. However, conventional wells have also had problems

20150831-0052 FERC PDF (Unofficial) 08/31/2015

associated with faulty well casings and failure of blowout preventers; in our study, wastewater dumping and leakage, failure of a blowout preventer, and affected well water involving conventional gas wells were associated with both animal and human health problems.

By the standards of a controlled experiment, this is an imperfect study, as one variable could not be changed while holding all others constant. It also is not a systematic study that will provide the percentage of farms with problems associated with gas drilling, but the design is such that the study can illustrate what can happen in areas experiencing extensive gas drilling. It is also possible to observe temporal correlations between events such as well flaring and air quality, or hydraulic fracturing and water quality leading to toxicity. In two cases, spatial differences (cows in a single herd, with some allowed access to a creek or pond and others not allowed access) could be used to compare outcomes.

Table 1 summarizes the types of wells involved and the sources of exposure, and Table 2 describes the details of each individual case. In some cases, exposure was due to accidents or negligence, but at other times, it was a consequence of normal operations. Direct exposure to hydraulic fracturing fluid occurred in two cases: in one, a worker shut down a chemical blender during the fracturing

Table 1. Number of Cases, by Type of Gas Well and Source of Exposure[a]

Type of gas well	
Shallow vertical wells	4
Deep vertical wells	3
Horizontal high-volume hydraulically fractured wells	18
Source of exposure	
Hydraulic fracturing fluid spill from holding tank	2
Drilling fluids overran well pad during blow out	1
Storm water run-off from well pad to property	3
Wastewater impoundment leak	1
Wastewater impoundment allegedly compromised	1
Wastewater spread on road	2
Wastewater dumped on property	1
Wastewater dumped into creek	3
Wastewater impoundment not contained	3
Well/spring water	17
Pond/creek water	8
Pipeline leak	1
Compressor station malfunction	2
Flaring of well	3

[a]Total number of cases is 24; one case has two types of wells.

20150831-0052 FERC PDF (Unofficial) 08/31/2015

Table 2. Summary of Individual Cases

Case	Type of gas well[a]	Source	Animal	Health impact
1	SV	Wastewater dumped on property and into creek	White-tailed deer	Body condition
2	SV	Well/spring water	Bovine	Reproduction, milk production
3	SV	Well/spring water Pond/creek water Drilling fluids overran well pad during blowout	Bovine	Reproduction
4	SV	Well/spring water Pond/creek water Wastewater impoundment allegedly compromised	Bovine Fish	Reproduction, growth Sudden death
5	DV	Well/spring water Pond/creek water	Equine Canine Human	Neurological Urological, gastrointestinal, dermatological Upper respiratory, burning of eyes, headache, gastrointestinal, dermatological
6	DV	Pond/creek water	Bovine	Reproduction
7	DV, HHV	Well/spring water	Canine Poultry Human	Reproduction, dermatological Sudden death, musculoskeletal, dermatological Upper respiratory, burning of eyes, neurological, gastrointestinal, headache
8	HHV	Well/spring water Pond/creek water Wastewater impoundment not contained Wastewater dumped into creek	Song birds Human	Sudden death Neurological, immunological
9	HHV	Pond/creek water Storm water runoff from well pad	Fish	Sudden death

20150831-0052 FERC PDF (Unofficial) 08/31/2015

Table 2. (Cont'd.)

Case	Type of gas well[a]	Source	Animal	Health impact
10	HHV	Well/spring water Wastewater impoundment not contained	Ovine Canine Human	Reproduction Sudden death Gastrointestinal, neurological, upper respiratory, burning of eyes, dermatological, vascular, sensory, headache
11	HHV	Wastewater impoundment leak	Bovine	Reproduction
12	HHV	Storm water runoff from well pad	Canine Human	Neurological Gastrointestinal, headache, dermatological
13	HHV	Well/spring water Pond/creek water Pipeline leak	Equine	Neurological, gastrointestinal, musculoskeletal, upper respiratory
			Canine	Urological, gastrointestinal, musculoskeletal, neurological
			Amphibian	Sudden death
			Human	Upper respiratory, burning of eyes, bone marrow
14	HHV	Well/spring water Wastewater spread on road Wastewater impoundment not contained	Canine Human	Reproduction Neurological
15	HHV	Well/spring water	Canine	Gastrointestinal, dermatological
			Feline	Dermatological
			Human	Gastrointestinal, upper respiratory, burning of eyes, vascular, headache

20150831-0052 FERC PDF (Unofficial) 08/31/2015

Table 2. (Cont'd.)

Case	Type of gas well[a]	Source	Animal	Health impact
16	HHV	Well/spring water	Llama	Reproduction, upper respiratory
			Human	Endocrine, upper respiratory, burning of eyes, vascular, dermatological, sensory
17	HHV	Well/spring water Flaring of well	Canine Feline	Urological Gastrointestinal, dermatological
			Human	Upper respiratory, burning of eyes, urological, dermatological, headache
18	HHV	Well/spring water	Ovine Poultry	Sudden death Sudden death
		Storm water runoff from well pad Flaring of well	Human	Vascular, gastrointestinal, headache
19	HHV	Well/spring water Hydraulic fracturing fluid spill from tank Wastewater dumped into creek	Equine Ovine Human	Reproduction Reproduction Neurological
20	HHV	Compressor station malfunction Flaring of well	Canine	Upper respiratory
			Human	Upper respiratory, burning of eyes
21	HHV	Well/spring water	Bovine	Neurological, reproduction
		Pond/creek water	Equine Poultry	Neurological Sudden death
		Compressor station malfunction	Human	Vascular, immunological
22	HHV	Well/spring water	Ovine Fish Human	Neurological Dermatological Dermatological, gastrointestinal

20150831-0052 FERC PDF (Unofficial) 08/31/2015

Table 2. (Cont'd.)

Case	Type of gas well[a]	Source	Animal	Health impact
23	HHV	Well/spring water Wastewater spread on road	Equine Canine Human	Neurological Reproduction, gastrointestinal Reproduction, upper respiratory, burning of eyes, vascular, sensory, headache
24	HHV	Hydraulic fracturing fluid spill from tank	Bovine	Gastrointestinal, neurological, respiratory, sudden death

[a]SV = shallow vertical well, DV = deep vertical well, HHV = horizontal high-volume hydraulically fractured well.

process, allowing the release of fracturing fluids into an adjacent cow pasture, killing 17 cows in one hour; the other was a result of a defective valve on a fracturing fluid tank, which caused hundreds of barrels of hydraulic fracturing fluid to leak into a pasture where goats were exposed and suffered from reproductive problems over the following two years. Exposure to drilling chemicals occurred during a blowout when liquids ran into a pasture and pond where bred cows were grazing; most of the cows later produced stillborn calves with congenital defects. Exposure to wastewater occurred through leakage or improper fencing of impoundments, alleged compromise of a liner in an impoundment to drain fluid, direct application of the wastewater to roads, and dumping of the wastewater on creeks and land. The most common exposure by far was to affected water wells and/or springs; the next most common exposure was to affected ponds or creeks. Finally, exposures also were associated with compressor station malfunction, pipeline leaks, and well flaring. In addition to humans, the animals affected were: cows, horses, goats, llamas, chickens, dogs, cats, and koi. Other than photographing and recording the presence of dead and dying wildlife (deer, songbirds, fish, salamanders, and frogs) in the vicinity of affected pastures, creeks and ponds, the effect on wildlife has not been well documented.

Because production animals were exposed to the environment for longer periods and in greater numbers than companion animals, and because most of the farms we documented raised beef cattle, cows were represented to a greater extent than other animals. Exposures through well water, ponds, springs, dumping of

20150831-0052 FERC PDF (Unofficial) 08/31/2015

wastewater into creeks, and spills or leakage of wastewater from impoundments were believed by farmers to result in deaths over time periods typically ranging from one to three days, with cows going down and unable to rise despite symptomatic treatment. The most commonly reported symptoms were associated with reproduction. Cattle that have been exposed to wastewater (flowback and/or produced water) or affected well or pond water may have trouble breeding. When bred cows were likewise exposed, farmers reported an increased incidence of stillborn calves with and without congenital abnormalities (cleft palate, white and blue eyes). In each case, farmers reported that in previous years stillborn calves were rare (fewer than one per year). In most cases where diagnostics were pursued, no final diagnosis was made; in other cases, acute liver or kidney failure was most commonly found. Of the seven cattle farms studied in the most detail, 50 percent of the herd, on average, was affected by death and failure of survivors to breed. In one case, exposure to drilling wastewater led to a quarantine of beef cattle and significant uncompensated economic loss to the farmers.

The most dramatic case was the death of 17 cows within one hour from direct exposure to hydraulic fracturing fluid. The final necropsy report listed the most likely cause of death as respiratory failure with circulatory collapse. The hydraulic fracturing fluid contained, among other toxicants, petroleum hydrocarbons and quaternary ammonium compounds (tetramethylammonium and hexamethylenetetramine). Although petroleum hydrocarbons were reported to be found in the small intestine, lesions in the lung, trachea, liver and kidneys suggested exposure to other toxicants as well, and quaternary ammonium compounds have been described as producing similar lesions [37].

Two cases involving beef cattle farms inadvertently provided control and experimental groups. In one case, a creek into which wastewater was allegedly dumped was the source of water for 60 head, with the remaining 36 head in the herd kept in other pastures without access to the creek. Of the 60 head that were exposed to the creek water, 21 died and 16 failed to produce calves the following spring. Of the 36 that were not exposed, no health problems were observed, and only one cow failed to breed. At another farm, 140 head were exposed when the liner of a wastewater impoundment was allegedly slit, as reported by the farmer, and the fluid drained into the pasture and the pond used as a source of water for the cows. Of those 140 head exposed to the wastewater, approximately 70 died and there was a high incidence of stillborn and stunted calves. The remainder of the herd (60 head) was held in another pasture and did not have access to the wastewater; they showed no health or growth problems. These cases approach the design of a controlled experiment, and strongly implicate wastewater exposure in the death, failure to breed, and reduced growth rate of cattle.

Companion animals were defined as those animals that were kept as pets, and included horses, dogs, cats, llamas, goats, and koi. Companion animal exposures typically occurred when animals ingested affected water from a well,

20150831-0052 FERC PDF (Unofficial) 08/31/2015

spring, creek or pond. Reproductive problems (irregular cycles, failure to breed, abortions, and stillbirths) and neurological problems (seizures, incoordination, ataxia) were the most commonly reported. Other commonly reported symptoms included those of gastrointestinal (vomiting, diarrhea) and dermatological (hair and feather loss, rashes) origin.

In the majority of cases, owners of animals were exposed upon using their well or spring water for drinking, cooking, showering and bathing. Upper respiratory symptoms (including burning of the nose and throat) and burning of the eyes were the most commonly reported. Headaches and symptoms associated with the gastrointestinal (vomiting, diarrhea), dermatological (rashes), and vascular (nosebleeds) systems were commonly reported.

CASES ILLUSTRATING THE EFFECTS OF GAS DRILLING ON PRODUCTION AND COMPANION ANIMALS AND THEIR OWNERS

Case 1

Two homes (A and B) are located within two miles of approximately 25 shale gas wells. The closest pad, drilling muds pit, and wastewater impoundment are within one mile of both homes; the impoundment is approximately 4.5 acres in area and is at a higher elevation than either home. Two compressor stations are located within one mile of both homes. The owners have a variety of companion and farm animals, and reported no unusual pet morbidity or mortality preceding drilling operations. Predrilling tests on water sources were not done for either home. Soon after drilling began, the owner of Home B noted that her well water had an odor and black sediment, and the owners of Home A observed a decreased quantity of their water sources (a well and a spring). Once the wastewater impoundment was constructed, the owners of Home A noted a dramatic decrease in quantity, as well as poor quality, of both the well and spring water. The spring served as the sole source of water for the owners' farm animals. Approximately nine months after drilling began, the owners of Home A began hauling water from a nearby creek, to supplement the spring water.

Since drilling operations began, both owners have observed wastewater being spread on the roads during all weather conditions, and noted that cats and dogs in their neighborhood licked their paws after walking on the road, and also drank from wastewater puddles; some of these animals became severely ill and died over a period of one to three days following these exposures. According to the owner of Home B, the wastewater impoundment was not initially fenced and animals had direct access to the wastewater. An accident involving the wastewater impoundment was noted by both owners; after filling, a truck carrying wastewater drove away from the impoundment site with an open valve, releasing approximately 20 gallons of wastewater onto the impoundment access

20150831-0052 FERC PDF (Unofficial) 08/31/2015

road and onto the road near the property of Home A. Most recently, both the drilling company and the state environmental regulatory agency were notified of a spill from the wastewater impoundment that flowed past temporary barriers and into a creek; based on soil erosion patterns, the owners of Homes A and B reported that this spill had been ongoing for months. Soon after this accident, a malfunction occurred in the wastewater impoundment aeration system, producing a raw sewage smell that persisted in the air around Homes A and B for days and sickened the families in both homes. When the owner of Home A complained, the drilling company offered to pay motel expenses for her and her family; this offer was declined because the owner refused to leave her animals.

Approximately a year after drilling began, an 18-year-old intact female American Quarter Horse in Home A had an acute onset of anorexia, malaise, rapid weight loss, and mild incoordination after testing normal on a physical examination a few weeks earlier. The horse was treated symptomatically with an antibiotic, steroid, and antihistamine. A few days later, the horse had become ataxic, and was treated for equine protozoal myeloencephalitis, although no diagnosis was made. The horse did not improve after three to four days and was treated again. Within a few days, the horse's neurological symptoms had progressed such that the horse was unable to rise. Blood and clinical chemistry parameters indicated acute liver failure due to toxicity. The veterinarian suspected heavy metal poisoning as a cause of the horse's sudden illness; this was not confirmed, as toxicology tests were not done. The horse was euthanized two weeks after onset due to poor prognosis and failure to respond. Similar neurologic signs were reported in another case in this study that involved two horses living adjacent to a deep, vertical gas well operation.

In addition, both homeowners were caring for animals that were bred at this time: the owner of Home B had a three-year-old intact female Boer goat that aborted two kids in the second trimester, and the owners of Home A had a five-year-old intact female Boxer that experienced dystocia with a fourth litter (after previously whelping three normal litters), producing one stillborn pup and one pup with cleft palate that died soon after birth. This same dog subsequently whelped a fifth litter of 15 pups in which seven pups were stillborn and eight pups died within 24 hours. All the pups were afflicted with congenital hypotrichosis; that is, they were born with the complete or partial absence of normal hair.

Soon after drilling and hydraulic fracturing began for the first well, a child living in Home B began showing signs of fatigue, severe abdominal pain, sore throat, and backache. Six months later, the child was hospitalized with confusion and delirium and was given morphine for abdominal pain. After the deaths of several animals as cited above, the child's physician suspected that the child's symptoms were of toxicological origin. A toxicology test revealed arsenic poisoning as the cause of the child's sickness. The family stopped using their well water despite test results indicating that the water was safe to drink, and the child gradually recovered after losing one year of school.

20150831-0052 FERC PDF (Unofficial) 08/31/2015

During high-volume hydraulic fracturing, substances that occur naturally in the shale, including arsenic, come to the surface in wastewater. In this case, the wastewater was stored in the impoundment, where aerators misted the chemicals into the air, increasing the chances of inhalation by animals and people; also, surface spillage of wastewater, as noted above, could have contaminated the ground water. Tests on well water from both Homes A and B, and the spring from Home A, did not show elevated levels of arsenic; however, it is possible that, given fluctuations in the water table and water quality, high levels of arsenic may have initiated symptoms in the child in Home B and then dropped to low levels before water testing was done more than one year later. Also, reported arsenic levels may be deceptively low because arsenic can be converted to arsine-a toxic gas that dissipates rapidly [38]. In people, both acute and chronic oral exposure to inorganic arsenic causes gastrointestinal effects as well as effects on the nervous system: short-term effects include headaches, weakness, and delirium, while long-term effects include peripheral neuropathy [39]. Acute exposure of people to arsine can produce many effects including abdominal pain and headaches [39]. Animals exposed acutely to inorganic arsenic may show many symptoms including staggering gait, extreme lethargy, and intense abdominal pain, while animals exposed over a longer period of time may manifest signs including anorexia, depression, and partial paralysis of the rear limbs [40]. Animal studies show that arsenic can also cause fetal malformations and fetal death [41].

As the family in Home B continued to be screened for toxicants, random urine tests on all family members were positive for phenol, a metabolite of benzene, with dramatic increases over a period of a few months. Based on occupational health studies [e.g., 42], the testing laboratory judged these results to be consistent with chronic exposure to 0.5 to 4.0 ppm benzene in the air. The most recent symptoms observed by families in both homes include extreme fatigue, headaches, nosebleeds, rashes, and sensory deficits (smell and hearing). The child in Home B also had difficulty breathing, and again had to be taken out of school. Doctors of the families in both homes warned them to leave their homes for at least 30 days or suffer more severe health consequences. The owner of Home B followed her doctor's advice, and moved her children out of her home, returning each day to care for her animals; the owners of Home A elected to remain at their home to care for their animals. After one month of being away, the phenol levels as well as the symptoms of the children in Home B decreased, while the owner of Home B, who returns to the home for a few hours each day, has increased phenol levels and worsening of symptoms. One of the owners in Home A, who works at home, has experienced worsening of symptoms.

This case illustrates the importance of considering both animal and human health. Animals live among us and are exposed to the same environmental influences; however, they tend to suffer more direct exposure and have shorter life and reproductive cycles. If it were not for the numerous deaths of animals

20150831-0052 FERC PDF (Unofficial) 08/31/2015

soon after shale gas operations began in this neighborhood, the child's doctor might not have ordered toxicology tests, as arsenic poisoning is not a common diagnosis.

Case 2

In this case, a beef cattle farmer had a herd of 96 cattle (Angus Limousine cross) that was divided among three pastures. The farm is located in an area of intensive gas drilling, with two active shallow vertical gas wells on the farmer's property and approximately 190 active gas wells within five miles of the property; of these, approximately 11 are shale gas wells and approximately 26 are deep vertical gas wells. In one pasture, 60 cows (a mixed herd, mostly 5- to 10-year-old bred cows) had access to a creek as a source of water. In a second pasture, 20 cows (bred yearlings) obtained water from hillside runoff, and in a third pasture, 14 feeder calves (8 to 14 months old) and two bulls had access to a pond. Over a three-month period, 21 head from the creek-side pasture died (17 adult bred cows and 4 calves). All the cattle were healthy before this episode. Despite symptomatic treatment, deaths occurred 1 to 3 days after the cows went down and were unable to rise. Basic diagnostics were done, but no cause of death was determined. On rendering, 16 of the 17 adults were found to have dead fetuses, nearly doubling this farmer's losses. Of the 39 cows on the creek-side pasture that survived, 16 failed to breed and several cows produced stillborn calves with white and blue eyes. The health of the cattle on the other two pastures was unaffected; on the second pasture, only one cow failed to breed. Historically, the health of the herd was good, the farmer reporting average losses of 1-2 cows a year in his herd of nearly 100 cattle.

This is an interesting case because it has a natural control group. That is, the cattle that were kept along the creek suffered severe problems while the cattle in pastures at a higher elevation and away from the creek experienced no morbidity or mortality. As discussed below, the contamination of the creek may have been caused by illegal dumping of wastewater. Fortunately, these cows were not taken to slaughter, as they died on the farm. However, they still may have entered our food chain as well as that of our pets: rendering plants produce feed for many non-ruminants including chickens, pigs, cats, dogs and horses, so it is possible that chickens, raised for egg production or meat, and pigs were fed the flesh from these cattle.

Case 3

This case concerns farmers that have raised beef cattle (Herford Simmental cross) for the past 21 years. Before drilling operations began the farmers lost one or two animals out of a closed herd of 33 (yearlings, heifers, mature cows, two bulls) every few years to illness or accident. There is one active shale gas well on the farmers' 530-acre property, and approximately six active shale gas wells within two miles of their property. A private well provides water for the family's

20150831-0052 FERC PDF (Unofficial) 08/31/2015

use; the water for the herd comes from a creek that originates from springs above and below the well pad, and spillover from a pond below the well pad. The gas wellhead is 300 feet from the farmers' house and 250 feet from their water well. The well pad is 75 feet from their barn at higher elevation, and slopes directly down to the door. A one-acre impoundment, used to collect wastewater from the high-volume hydraulic fracturing operations, and a 1/3-acre drilling muds pit, used to collect the chemicals and fluids brought to the surface during drilling operations, were both within 350 feet of the farmers' water well, and within 200 feet of the creek and the pond where the cattle drink.

Soon after hydraulic fracturing operations concluded, the farmers noticed that on the far bank of the wastewater impoundment, two dark spots could be seen adjacent to a 20-acre cow pasture. According to the farmers, these two spots were a concern as they grew in size from day to day; approximately one month after first observing these spots, the farmers found ankle-deep water in one-third of an acre of the pasture with the wet area extending another one-quarter of an acre into the pasture; the pasture grass in these areas appeared to be burned. Fearing their herd drank the wastewater, they voluntarily quarantined their farm and notified the state environmental regulatory agency.

According to the farmers, drilling company workers informed them that the liners of both the wastewater impoundment and the drilling muds pit had two-foot tears, and that the tear in the liner of the wastewater impoundment had caused the leak into the cow pasture. Except for the two bulls, the entire herd was exposed to the wastewater leakage.

Four notices of violations were issued to the drilling company by the state environmental regulatory agency: failure to notify the agency, improperly lined impoundment (pressure testing of liner revealed a failed patch), pollution of a spring and farm pond due to leakage of the impoundment, and mismanagement of residual waste (wastewater leaked from the impoundment onto the ground and surfaced in an adjacent pasture).

Testing of the wastewater in the impoundment indicated the presence of calcium, iron, magnesium, manganese, potassium, sodium, strontium, fluoride, chloride, sulfate, and bromide; there was no reported testing for any organic compounds. Strontium was of most concern: it can be toxic to both animals and people because it replaces calcium in bone, especially in the young, and because it may take years to be eliminated from the body [43]. The state environmental regulatory agency placed a quarantine on the herd such that mature cows would be held from slaughter for six months, yearlings would be held for nine months, calves exposed in utero would be held for eight months, and growing calves would be held for two years. Six of the exposed cows eventually went on to slaughter, and, according to the farmers, there was no testing before or after slaughter.

Pre-drilling tests were not done on any of the cattle's sources of water; post-drilling tests were done and revealed no significant findings. Soil tests done

20150831-0052 FERC PDF (Unofficial) 08/31/2015

on the cow pasture contaminated by the leaked wastewater revealed high levels of chloride, sulfate, sodium, and strontium when compared to background samples. The liners from both the wastewater impoundment and drilling-muds pit were removed, the affected soil removed, and areas remediated; sulfate concentrations remained at high levels in the cow pasture despite remediation.

During the spring of the first calving season following the leakage of wastewater into their cow pasture, the farmers lost two calves: one calf was aborted late-term, and the other calf lived for approximately seven days before dying [44]; both calves were exposed in utero to the wastewater. In the second calving season post-drilling, the farmers lost 11 out of 17 calves: seven were stillborn, three died a few months after birth and one was born alive but severely ill; the dams of all the calves had previously been exposed to the wastewater. The severely ill calf and a stillborn calf were sent for necropsy: the ill calf was diagnosed with *E. coli* septicemia, and the stillborn calf was diagnosed with goiter (diffuse thyroid hyperplasia); both calves were also diagnosed with low liver vitamin E and selenium.

This case illustrates several important points. First, the testing was not complete. According to the farmers, they were not informed of the chemicals used during either drilling or hydraulic fracturing operations. Testing of the water well and cattle's sources of water excluded organic compounds except for a pasture spring; the wastewater analysis also excluded organic compounds. No toxicology tests were done on live cattle, and the tests at necropsy omitted volatile organic compounds, endocrine disruptors, and many minerals present in the wastewater. The cattle's sources of water were tested only after the farmers lost many calves. Soil tests were not done in the area affected by the leakage of the drilling-muds pit. Second, the cattle were exposed to sulfate in the wastewater for at least one month and to elevated sulfate in the grass and soil [45, 46] for over a year. Studies show that increasing dietary sulfur decreases the bioavailability of selenium [47-50], and that Vitamin E and selenium deficiency is associated with reproductive failure in cattle [51, 52]. Third, the liner tear and subsequent leakage of drilling fluids onto the farmers' land were not considered a potential problem and not officially recorded as a violation by the state environmental regulatory agency. Due to gas drilling operations on their property, the farmers now have 26 head of cattle instead of 33, and have lost 40 to 50 acres of hayfields. These farmers received no compensation from the drilling company for the loss of their animals, damage to their land, or the treatment of the animal health problems they have encountered since gas drilling began.

DISCUSSION

The most striking finding of our investigations was the difficulty in obtaining definitive information on the link between hydrocarbon gas drilling and health effects. However, the results point to a number of ways policies can

20150831-0052 FERC PDF (Unofficial) 08/31/2015

be changed to facilitate better data collection and to avoid obvious risks to animal and human health.

Practices for Providing Better Assessment of Health Impacts

Nondisclosure Agreements

Nondisclosure agreements between injured parties and corporations make it difficult to document incidents of contamination. Compensation in the form of cash, payment for all settlement expenses, an offer to buy the property and/or payment for medical expenses in exchange for a nondisclosure agreement prevents information on contamination episodes and health effects from being documented and analyzed. Nondisclosure agreements are common in all areas of business and are often essential to protect intellectual property. However, when documentation of health problems associated with gas operations is shielded from public scrutiny by a nondisclosure agreement, this is clearly a misuse of this important business tool and should be prohibited. Likewise the lack of prior testing of air and water, and of follow-up testing during drilling and after incidents of suspected contamination, impedes the analysis of health impacts. Even when testing is done, the results are being withheld from interested parties either by government agencies (e.g., by incomplete responses to FOIA requests) or by the industry. If the industry, government agencies, and the public truly want the facts, then appropriate testing must be done, and full disclosure of all data associated with both baseline and incidents of suspected contamination must be made. Without full disclosure of all facts, scientific studies cannot properly be done. Science should drive decisions on whether or not to use a practice such as shale gas drilling, and until scientific studies can proceed unimpeded, then an accurate assessment cannot be made.

Food Safety

A major problem is the lack of federal funding for food safety research. We documented cases where food-producing animals exposed to chemical contaminants have not been tested before slaughter and where farms in areas testing positive for air and/or water contamination are still producing dairy and meat products for human consumption without testing of the animals or the products. Some of these chemicals could appear in milk and meat products made from these animals. In Case 3, a quarantine was instituted after cattle were exposed to wastewater. However, basic knowledge, such as hold times for animals exposed to chemical contaminants as a result of gas operations, is lacking, and research in this area is desperately needed to maintain an adequate level of food safety in our country [53]. Without this information, contaminants in the water, soil and air from gas drilling operations could taint meat products made from these animals, thus compromising the safety of the food supply.

20150831-0052 FERC PDF (Unofficial) 08/31/2015

Routes of Exposure

The major route of exposure in the cases documented here is through water contamination. This is perhaps the most obvious problem (seen in all three case studies), but other routes of exposure are of serious concern. Soil contamination can be significant in situations such as that described in Case 3. Although the cases we have documented thus far include only a handful of exposures through affected air, the actual incidence of health effects may be underestimated due to a lack of air sampling. In Case 1, toxicological testing suggested high levels of ambient benzene due to a nearby impoundment pond, but air canister tests were not done at the time. Neither drilling companies nor state environmental regulatory agencies routinely offer air canister tests as a part of testing protocols, and due to the expense, many property owners are reluctant to pursue them on their own. Nevertheless, the effects of air pollution on cardiovascular and respiratory health have been well documented [54], and we believe that exposure to contaminated air may contribute significantly to the health problems of both people and animals living near gas drilling operations. In several cases where air monitoring was done, the results confirmed the presence of carcinogens commonly known to originate from gas industrial processes such as exploration, drilling, flaring, and compression. Thus, the Environmental Protection Agency (EPA) must include a study of air in its congressionally mandated hydraulic fracturing study [55] if it is to be complete.

Testing

The most important requirement for an assessment of the impact of gas drilling on animal and human health is complete testing of air and water prior to drilling and at regular intervals after drilling has commenced. This includes chemicals used in the drilling muds, fracturing fluid and wastewater (the latter contains heavy metals and radioactive compounds normally found in a particular shale [56]). Currently, the extent of testing (particularly for organic compounds) is frequently inadequate and limited by lack of information on what substances were used during the drilling process. In a number of the cases that we have studied, drinking water is clearly unsuitable for human and animal consumption, based not only on the smell and turbidity, but also on pathological reactions to drinking the water. Nevertheless, because of inadequate testing, the water is deemed fit for consumption and use, and neither bottled water nor the large plastic containers known as "water buffaloes" are typically provided for the affected individuals-and even less commonly for animals living on those farms. In Case 1, water was reluctantly provided for the humans (after considerable effort) but not to the animals living on the farm. Even when identified, the health effects of chemicals associated with the drilling process are unknown in many cases. No Maximum Contaminant Levels (MCLs) have been set by the EPA for many of the compounds used, and those that have been set are based on older data that does not

20150831-0052 FERC PDF (Unofficial) 08/31/2015

take into consideration effects at significantly lower concentrations (e.g., endocrine disruption [5]). Furthermore, the disclosure of all chemicals involved in the drilling and hydraulic fracturing processes is not required if a component can be justified as a "trade secret." In order to be complete, air, soil and all sources of potable water used for humans and animals in the vicinity of a well site (at least within 3,000 feet for soil and water tests [57], and five miles for air monitoring, based on dispersion modeling of emissions from compressor stations [58]) must be tested for all components that are involved in drilling and are likely to be found in wastewater, before any work on the site commences. Sampling must then be repeated at intervals following the commencement of drilling as well as upon suspicion of adverse effects. The following practices must be part of a testing protocol:

1. The sampling must be done by a disinterested third party with a clear chain of custody between sampling and testing. A certified independent laboratory must do the testing, and the results must be available to all interested parties.
2. All chemicals (with IUPAC names and CAS numbers) used in the hydraulic fracturing fluid at any concentration for each well must be disclosed to the property owners within a five-mile radius, testing laboratories, local governments, and state agencies. Material Safety Data Sheets (MSDSs) for each chemical and chemical mixture must accompany this disclosure. Following this procedure will allow prior testing to be targeted to specific chemicals to be used in the drilling process for a specific well, as well as providing valuable information to first responders and hospital personnel in the case of an accident.
3. Upon suspicion of adverse health effects, testing must include air, soil, wastewater, all sources of drinking water, and blood, urine and tissue samples from affected animals and humans. If methane is present in drinking water, isotopic analysis to determine the origin (thermogenic vs. biogenic) must be done.
4. As illustrated by several cases we documented, air canister tests are essential. This must be done as a baseline before drilling begins and during and after well flaring. It must also be done after a wastewater impoundment and a compressor station have been established.
5. Any fracturing fluid chemicals and chemicals released from the shale that are known or possible human carcinogens, are regulated under the Safe Drinking Water Act, or are listed as hazardous air pollutants under the Clean Air Act must have MCLs, which are set by the EPA. Many of the chemicals to which both people and animals are exposed as a result of high-volume hydraulic fracturing are not listed as primary contaminants, and thus have no enforceable MCL. More than half of the chemicals listed as toxic chemicals in a recently released U.S. House of Representatives report [59] have no MCL.

20150831-0052 FERC PDF (Unofficial) 08/31/2015

6. All testing expenses must be a part of the cost of doing business for gas drilling companies.

Testing before and during drilling operations is an important part of documenting health effects. If health effects are related to a chemical pre-existing in a pond or well, this would prevent a false association between drilling and water contamination. Alternatively, if a change in chemical composition is correlated to health changes, then a strong justification for compensation is provided. In numerous cases that we documented, compensation was not provided because adequate prior testing had not been done. By doing complete testing, at the proper times, a clear scientific justification can be made for providing or denying compensation. Beyond that, a better understanding of what practices lead to water contamination can be obtained. This will be a benefit to people living in the midst of shale gas drilling and will, in fact, benefit the industry by providing consistent and useful data to guide operations. The current practice of under-testing and denying any link between drilling and water, air, or soil contamination is beneficial to neither the public nor the industry.

Practices for Avoiding Animal and Human Exposure to Environmental Toxicants

As shale gas drilling expands across the northeastern United States, exposure of animals and humans to environmental toxicants can result from negligence, illegal actions, catastrophic accidents (at drilling pads or compressor stations), or normal operations. Negligence and illegal actions are difficult to prevent and may have contributed to the health problems we documented. Suspected illegal dumping of wastewater and the alleged compromise of the liner of a wastewater impoundment were most likely responsible for cattle deaths in two instances that we studied. Cases of alleged wrongdoing [60] illustrate the vulnerability of agricultural operations in the midst of large volumes of toxic waste. Dumping and other intentional violations are difficult to prevent or regulate given the large numbers of small companies involved in servicing drilling operations and the lack of willingness and funding on the part of state environmental regulatory agencies to investigate and fine the gas industry. The prevalence of small subcontractors increases the possibility that best practices will not be followed due to inadequate training and supervision.

Although accidents might be minimized with strict safety standards and careful inspection, regulatory agencies would require sufficient staff to monitor operations. This is obviously not the case in Pennsylvania, where 666 environmental health and safety violations have been reported in 2011 as of June [61]. With a staff of 37 inspectors [62] and 64,939 active wells (as of December, 2010), regulatory oversight is essentially impossible. The situation is even worse in New York State, where only 16 inspectors are currently on the staff of the Department of Environmental Conservation. Although the number of staff

20150831-0052 FERC PDF (Unofficial) 08/31/2015

positions required to police this industry adequately would necessarily be very large, hiring of new inspectors is essential if environmental and health damages are to be minimized. New York, Pennsylvania, and Iowa are the only active drilling states that have no severance tax for drilling operations. A severance tax could fund additional inspectors and help insure compliance with existing regulations, although this will require the political will to levy a tax sufficient to fund the required number of inspectors. Given the high probability that accidents will happen [63], increasing setbacks between homes, barns, schools, ponds, and streams would provide some additional security. The current regulation in Pennsylvania is a setback of 200 feet from water supply springs and wells, 100 feet from surface water bodies, and 200 feet from wetlands. The revised draft supplemental generic environmental impact statement in New York indicates a 500-foot setback from private water wells. Increasing these setbacks 5- to 10-fold would decrease but not eliminate the impacts of accidents such as the April 20, 2011 spill in Bradford County, PA [64]. Contamination of the air by compressor station blowouts and contamination of streams leave an imprint that cannot be easily mitigated by even the most stringent setbacks.

Normal practices can be modified to reduce but not eliminate exposure of humans and animals to toxicants associated with gas drilling. One of the important problems associated with shale gas drilling is the huge volume of wastewater generated. This wastewater, which includes flowback and produced water, contains at different times in the process the chemicals used in the hydraulic fracturing fluid as well as compounds and minerals extracted in the fluid flowing back with hydrocarbon gas. The materials extracted from underground can be equally or more toxic than the hydraulic fracturing fluid, and include radioactive material (e.g., radium-226, radon-222, and uranium-238), arsenic, lead, strontium, barium, benzene, chromium and 4-nitroquinoline-1-oxide [56]. However, despite the actual toxicity of this material, according to the EPA, "drilling fluids, produced waters, and other wastes associated with the exploration, development, or production of . . . natural gas" are considered "solid wastes which are not hazardous wastes" [65]. This allows the substances to be spread on roads as deicing solutions and as solutions to minimize dust and sets up a potentially lethal threat, particularly to companion animals, wildlife, and children. Typically these solutions contain high salt concentrations and attract dogs and cats, as was illustrated in Case 1. This hazard can be easily mitigated by not allowing wastewater to be spread or sprayed on roads.

Before wastewater is removed from a drilling site, it is often stored in large impoundments (sometimes serving multiple well pads) where the volume is decreased by evaporation. This increases the concentration of some toxic substances in the impoundment (salts, heavy metals) and also introduces other toxicants into the atmosphere (e.g., volatile organics such as benzene and toluene). In addition, impoundments are associated with a number of deaths of both cattle and wildlife [66]. These effects raise the question of whether

20150831-0052 FERC PDF (Unofficial) 08/31/2015

wastewater should be stored in open impoundments. Whereas this may be economically advantageous to the drilling company, the environmental and agricultural impacts are too great to allow this practice to continue. In Pennsylvania, some progress has been made in recycling increasing fractions of the wastewater. This decreases the total volume of wastewater but increases its toxicity due to the successive increase in the concentrations of total dissolved solids. The alternative is to store wastewater in metal containers at the drilling site before it is removed for disposal.

Finally, the disposal of wastewater presents significant environmental risks. Cases of alleged dumping of untreated wastewater in streams have been documented in the press (e.g., [60]). In the southwestern United States, wastewater is disposed of in injection wells; however, the prevalence of nonporous sandstones and shales in Pennsylvania and New York State largely precludes the use of disposal wells. An earthquake of magnitude 3.2 was associated with injection into a hydraulically fractured vertical well on February 3, 2001 near Avoca, New York [67], suggesting that seismic considerations may further limit the development of injection wells in New York State. Similar seismic occurrences in other parts of the country, most recently in Ohio [68], may mean that New York and Pennsylvania will have fewer options for disposal of wastewater due to shale gas drilling. In May 2011, a voluntary moratorium was placed on the acceptance of hydraulic fracturing wastewater at sewage treatment plants in Pennsylvania. These plants are not equipped to handle either the radioactive and toxic compounds or the high salt content of this waste, and the increased use of recycling has magnified the problem. Discharge of water treatment plants into the Monongahela River led to the contamination of drinking water in Pittsburgh in 2010 [63]. Sewage treatment plants clearly are not a viable option for disposal of wastewater, and despite the industry's progress in recycling, suitable injection wells are unlikely to be located to support the scale of drilling planned in Pennsylvania and possibly New York State.

CONCLUSION

Animals, especially livestock, are sensitive to the contaminants released into the environment by drilling and by its cumulative impacts. Documentation of cases in six states strongly implicates exposure to gas drilling operations in serious health effects on humans, companion animals, livestock, horses, and wildlife. Although the lack of complete testing of water, air, soil and animal tissues hampers thorough analysis of the connection between gas drilling and health, policy changes could assist in the collection of more complete data sets and also partially mitigate the risk to humans and animals. Without complete studies, given the many apparent adverse impacts on human and animal health, a ban on shale gas drilling is essential for the protection of public health. In states that nevertheless allow this process, the use of commonsense measures

20150831-0052 FERC PDF (Unofficial) 08/31/2015

to reduce the impact on human and animals must be required in addition to full disclosure and testing of air, water, soil, animals, and humans.

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NOTES

1. U.S. Department of Energy, "Natural Gas," http://www.energy.gov/energysources/naturalgas.htm (accessed July 6, 2011).
2. Chesapeake Energy, "Water Use in Marcellus Deep Shale Gas Exploration," http://www.chk.com/Media/Educational-Library/Fact-Sheets/Marcellus/Marcellus_Water_Use_Fact_Sheet.pdf (accessed July 6, 2011).
3. U.S. Department of Energy Office of Fossil Energy and National Energy Technology Laboratory, "Modern Shale Gas Development in the United States: A Primer," http://www.netl.doe.gov/technologies/oil-gas/publications/EPreports/Shale_Gas_Primer_2009.pdf (accessed July 14, 2011).
4. K. Cohen, "Facts on the Hydraulic Fracturing Process," http://www.exxonmobilperspectives.com/2011/06/17/facts-hydraulic-fracturing-process/ (accessed November 28, 2011).
5. T. Colborn et al., "Natural Gas Operations from a Public Health Perspective," *Journal of Human and Ecological Risk Assessment: An International Journal* 17(5) (2011): 1039-1056, doi: 10.1080/10807039.2011.605662.
6. Science and Environmental Health Network, "Wingspread Conference on the Precautionary Principle," http://www.sehn.org/wing.html (accessed July 6, 2011).
7. S. A. Glantz et al., "Looking through a Keyhole at the Tobacco Industry. The Brown and Williamson Documents," *Journal of the American Veterinary Medical Association* 274(3) (1995): 219-24, doi: 10.1001/jama.274.3.219.
8. A. J. Crisp, A. K. Bhalla, and B. I. Hoffbrand, "Acute Tubular Necrosis after Exposure to Diesel Oil," *British Medical Journal* 2(6183) (1979): 177, doi: 10.1136/bmj.2.6183.177.
9. W. H. Dice et al., "Pulmonary Toxicity Following Gastrointestinal Ingestion of Kerosene," *Annals of Emergency Medicine* 11(3) (1982): 138-42, doi: S0196-0644(82)80239-4 [pii].
10. N. R. Eade, L. M. Taussig, and M. I. Marks, "Hydrocarbon Pneumonitis," *Pediatrics* 54(3) (1974): 351-7.
11. M. Lippmann and L. C. Chen, "Health Effects of Concentrated Ambient Air Particulate Matter (Caps) and Its Components," *Critical Reviews in Toxicology* 39(10) (2009): 865-913, doi: 10.3109/10408440903300080.
12. G. D. Ritchie et al., "Biological and Health Effects of Exposure to Kerosene-Based Jet Fuels and Performance Additives," *Journal of Toxicology and Environmental Health Part B* 6(4) (2003): 357-451, doi: 10.1080/10937400306473.
13. E. Truemper, S. Reyes de la Rocha, and S. D. Atkinson, "Clinical Characteristics, Pathophysiology, and Management of Hydrocarbon Ingestion: Case Report and

20150831-0052 FERC PDF (Unofficial) 08/31/2015

Review of the Literature," *Pediatric Emergency Care* 3(3) (1987): 187-93, doi: 10.1097/00006565-198709000-00015.

14. N. K. Weaver, "Gasoline Toxicology: Implications for Human Health," *Annals of the New York Academy of Sciences* 534(1) (1988): 441-451, doi: 10.1111/j.1749-6632.1988.tb30133.x.
15. J. Wolfsdorf and H. Kundig, "Kerosene Poisoning in Primates," *South African Medical Journal* 46(20) (1972): 619-21.
16. R. W. Coppock et al., "Toxicology of Oil Field Pollutants in Cattle: A Review," *Veterinary and Human Toxicology* 37(6) (1995): 569-76.
17. R. W. Coppock et al., "Toxicopathology of Oilfield Poisoning in Cattle: A Review," *Veterinary and Human Toxicology* 38(1) (1996): 36-42.
18. V. C. Edwards, R. W. Coppock, and L. L. Zinn, "Toxicoses Related to the Petroleum Industry," *Veterinary and Human Toxicology* 21(5) (1979): 328-337.
19. W. C. Edwards, "Toxicology of Oil Field Wastes. Hazards to Livestock Associated with the Petroleum Industry," *Veterinary Clinics of North America. Food Animal Practice* 5(2) (1989): 363-74.
20. W. C. Edwards and D. G. Gregory, "Livestock Poisoning from Oil Field Drilling Fluids, Muds and Additives," *Veterinary and Human Toxicology* 33(5) (1991): 502-4.
21. W. C. Edwards and L. L. Zinn, "Diagnosis of Petroleum Hydrocarbon Poisoning in Cattle," *Veterinary Medicine, Small Animal Clinician* 74(10) (1979): 1516-8.
22. E. A. Gibson and J. L. Linzell, "Diesel Oil Poisoning in Cattle," *Veterinary Record* 60(6) (1948): 60-61.
23. S. F. Ranger, "A Case of Diesel Oil Poisoning in a Ewe," *Veterinary Record* 99(25-26) (1976): 508-9.
24. L. D. Rowe, J. W. Dollahite, and B. J. Camp, "Toxicity of Two Crude Oils and of Kerosine to Cattle," *Journal of the American Veterinary Medical Association* 162(1) (1973): 61-6.
25. F. Toofanian, S. Aliakbari, and B. Ivoghli, "Acute Diesel Fuel Poisoning in Goats," *Tropical Animal Health and Production* 11(1) (1979): 98-101, doi: 10.1007/BF02237779.
26. J. K. Winkler and W. J. Gibbons, "Petroleum Poisoning in Cattle," *Modern Veterinary Practice* 54(12) (1973): 45-6.
27. A. A. Case and J. R. Coffman, "Waste Oil: Toxic for Horses," *Veterinary Clinics of North America* 3(2) (1973): 273-7.
28. F. A. Leighton, "Clinical, Gross, and Histological Findings in Herring Gulls and Atlantic Puffins That Ingested Prudhoe Bay Crude Oil," *Veterinary Pathology* 23(3) (1986): 254-63.
29. A. Chalifoux et al., "Intoxication par Ingestion d'Huile a Moteur Chez un Chien. Dystrophie des Hepatocytes et Cholostase Secondaire," *Canadian Veterinary Journal* 14(3) (1973): 68-70.
30. M. L. Finkel and A. Law, "The Rush to Drill for Natural Gas: A Public Health Cautionary Tale," *American Journal of Public Health* 101(5) (2011): 784-5, doi: AJPH.2010.300089 [pii] 10.2105/AJPH.2010.300089.
31. R. Adler et al., "Toxicosis in Sheep Following Ingestion of Natural Gas Condensate," *Veterinary Pathology* 29(1) (1992): 11-20, doi: 10.1177/030098589202900102.

20150831-0052 FERC PDF (Unofficial) 08/31/2015

32. C. L. Waldner, C. S. Ribble, and E. D. Janzen, "Evaluation of the Impact of a Natural Gas Leak from a Pipeline on Productivity of Beef Cattle," *Journal of the American Veterinary Medical Association* 212(1) (1998): 41-8.
33. C. L. Waldner et al., "Associations between Oil- and Gas-Well Sites, Processing Facilities, Flaring, and Beef Cattle Reproduction and Calf Mortality in Western Canada," *Preventive Veterinary Medicine* 50(1-2) (2001): 1-17, doi: S0167587701002148 [pii].
34. H. R. Sawyer et al., "Winter Habitat Selection of Mule Deer before and During Development of a Natural Gas Field," *Journal of Wildlife Management* 70(2) (2006): 396-403, doi: 10.2193/0022-541X(2006)70[396:WHSOMD]2.0.CO;2.
35. H. Sawyer and R. Nielson, Mule Deer Monitoring in the Pinedale Anticline Project Area: 2010 Annual Report, September 14, 2010 (prepared for Pinedale Anticline Planning Office).
36. Louisiana Department of Environmental Quality, "Case Ai No. 164544," 2010, http://edms.deq.louisiana.gov/app/doc/querydef.aspx (accessed July 14, 2011).
37. L. Adelson and I. Sunshine, "Fatal Poisoning Due to a Cationic Detergent of the Quaternary Ammonium Compound Type," *American Journal of Clinical Pathology* 22(7) (1952): 656-61.
38. C. N. Cheng and D. D. Focht, "Production of Arsine and Methylarsines in Soil and in Culture," *Applied and Environmental Microbiology* 38(3) (1979): 494-8.
39. Environmental Protection Agency, "Arsenic Compounds," http://www.epa.gov/ttnatw01/hlthef/arsenic.html (accessed July 9, 2011).
40. L. A. Selby et al., "Epidemiology and Toxicology of Arsenic Poisoning in Domestic Animals," *Environmental Health Perspectives* 19(1977): 183-189.
41. Agency for Toxic Substances & Disease Registry, "Toxfaqs for Arsenic," http://www.atsdr.cdc.gov/toxfaqs/TF.asp?id=19&tid=3 (accessed July 8, 2011).
42. O. Inoue et al., "Quantitative Relation of Urinary Phenol Levels to Breathzone Benzene Concentrations: A Factory Survey," *British Journal of Industrial Medicine* 43(10) (1986): 692-7.
43. Agency for Toxic Substances & Disease Registry, "Toxic Substances Portal – Strontium," http://www.atsdr.cdc.gov/phs/phs.asp?id=654&tid=120 (accessed July 26, 2011).
44. Commonwealth of Pennsylvania Department of Agriculture, Right-to-Know Law Request No. 111012, Veterinary Report Dated June 24, 2010: Memo to Dr. Anthony Labarbera from Dr. Amy Nestlerodt. Subject: Frac Water Holding Pond Still on Beef Farm in Tioga County (accessed October 20, 2011).
45. G. F. Fries, G. S. Marrow, and P. A. Snow, "Soil Ingestion by Dairy Cattle," *Journal of Dairy Science* 65(4) (1982): 611-8, doi: S0022-0302(82)82238-8 [pii] 10.3168/jds.S0022-0302(82)82238-8.
46. H. F. Mayland, G. E. Shewmaker, and R.C. Bull, "Soil Ingestion by Cattle Grazing Crested Wheatgrass," *Journal of Range Management* 30(4) (1977): 264-265.
47. H. F. Hintz and D. E. Hogue, "Effect of Selenium, Sulfur and Sulfur Amino Acids on Nutritional Muscular Dystrophy in the Lamb," *Journal of Nutrition* 82(1964): 495-8.
48. J. Ivancic, Jr. and W. P. Weiss, "Effect of Dietary Sulfur and Selenium Concentrations on Selenium Balance of Lactating Holstein Cows," *Journal of Dairy Science* 84(1) (2001): 225-32, doi: S0022-0302(01)74472-4 [pii] 10.3168/jds.S0022-0302(01)74472-4.

20150831-0052 FERC PDF (Unofficial) 08/31/2015

49. A. L. Pope et al., "The Effect of Sulphur on 75Se Absorption and Retention in Sheep," *Journal of Nutrition* 109(8) (1979): 1448-55.
50. J. W. Spears, "Trace Mineral Bioavailability in Ruminants," *Journal of Nutrition* 133(5 Suppl 1) (2003): 1506S-9S.
51. J. P. Orr and B. R. Blakley, "Investigation of the Selenium Status of Aborted Calves with Cardiac Failure and Myocardial Necrosis," *Journal of Veterinary Diagnostic Investigation* 9(2) (1997): 172-9, doi: 10.1177/104063879700900211.
52. L. J. Hutchinson, R. W. Scholz, and T. R. Drake, "Nutritional Myodegeneration in a Group of Chianina Heifers," *Journal of the American Veterinary Medical Association* 181(6) (1982): 581-4.
53. J. Riviere (Co-Founder and Co-Director, USDA Food Animal Residue Avoidance Databank), personal communication, July 25, 2010.
54. U.S. Environmental Protection Agency, Final Report: The National Morbidity, Mortality, and Air Pollution Study: Morbidity and Mortality from Air Pollution in the United States (Jonathan M. Samet, investigator), March 2005, http://cfpub1.epa.gov/ncer_abstracts/index.cfm/fuseaction/display.abstractDetail/abstract/2399/report/F (accessed July 11, 2011).
55. Environmental Protection Agency, "Draft Plan to Study the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources," http://water.epa.gov/type/groundwater/uic/class2/hydraulicfracturing/upload/HFStudyPlanDraft_SAB_020711.pdf (accessed July 11, 2011).
56. R. E. Bishop, "Chemical and Biological Risk Assessment for Natural Gas Extraction in New York," http://wellwatch.files.wordpress.com/2011/05/risk-assessment-natural-gas-extraction.pdf (accessed July 11, 2011).
57. S. G. Osborn et al., "Methane Contamination of Drinking Water Accompanying Gas-Well Drilling and Hydraulic Fracturing," Proceedings of the National Academy of Sciences USA 108(20) (2011): 8172-6, doi: 1100682108 [pii] 10.1073/pnas.1100682108.
58. Wolf Eagle Environmental, "Dispersion Modeling of Emissions from Natural Gas Compressor Stations," http://www.townofdish.com/objects/DISH_Report.pdf1.pdf (accessed July 23, 2011).
59. Minority Staff U.S. House of Representatives Committee on Energy and Commerce, "Chemicals Used in Hydraulic Fracturing," http://democrats.energycommerce.house.gov/sites/default/files/documents/Hydraulic%20Fracturing%20Report%204.18.11.pdf (accessed July 11, 2011).
60. Marcellus Drilling News, "Southwest Pa Waste Hauler Indicted for Illegally Dumping Marcellus Drilling Wastewater," http://marcellusdrilling.com/2011/03/southwest-pa-waste-hauler-indicted-for-illegally-dumping-marcell/ (accessed July 11, 2011).
61. Pennsylvania Department of Environmental Protection, "Year to Date Inspections/Violations (Including Marcellus) [2011]" http://www.dep.state.pa.us/dep/deputate/minres/oilgas/OGInspectionsViolations/2011/2011AllViolations.xls (accessed July 11, 2011).
62. J. Legenos (Information Specialist, Pennsylvania Department of Environmental Protection), personal communication, July 3, 2011.
63. United States Congress. Senate Committee on Environment and Public Works and its Subcommittee on Water and Wildlife. Natural Gas Drilling: Public Health and Environmental Impacts. April 12, 2011. 112th Congress, 1st session. Testimony of

20150831-0052 FERC PDF (Unofficial) 08/31/2015

Dr. Conrad Daniel Volz. http://cpw.senate.gov/public/index.cfm?FuseAction=Files.View&FileStore_id=57d1bfd4-9237-488e-999f-4e1e71f72e52 (accessed July 14, 2011).

64. Associated Press, "Gas Well Spews Polluted Water," *New York Times*, April 21, 2011, http://www.nytimes.com/2011/04/21/us/21frack.html?_r=1&scp=1&sq=bradford%20blowout%20%22april%2020%22%20gas%20chesapeak&st=cse (accessed July 20, 2011).
65. U.S. Environmental Protection Agency, Identification and Listing of Hazardous Waste. 40 C.F.R. §261.4(b)(5) (2002).
66. P. Ramirez, U.S. Fish & Wildlife Service, Region 6, Environmental Contaminants Program, Reserve Pit Management: Risks to Migratory Birds, September 2009, http://www.fws.gov/mountain-prairie/contaminants/documents/ReservePits.pdf (accessed July 14, 2011).
67. W. Y. Kim, The Lamont Cooperative Seismic Network and the National Seismic System: Earthquake Hazard Studies in the Northeastern United States, 2001, www.ldeo.columbia.edu/LCSN/.../LCSN_Tech_Report-98-01.pdf (accessed November 16, 2011).
68. Associated Press, "Disposal Halted at Well after New Quake in Ohio," *New York Times*, January 1, 2012, http://www.nytimes.com/2012/01/02/science/earth/youngstown-injection-well-stays-shut-after-earthquake.html?_r=1&ref=todayspaper (accessed January 2, 2112).

Direct reprint requests to:

Robert E. Oswald
Department of Molecular Medicine
Cornell University
Ithaca, NY 14853
e-mail: reo1@cornell.edu

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