Madison County, New York

Department of Health

Comments to the Federal Energy Regulatory Committee

Concerning Docket No. CP14-497-000, Dominion Transmission, Inc.

Submitted by
Madison County Department of Health
Madison County, New York

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Executive Summary

The following comments are addressed to the Federal Energy Regulatory Commission in response to the permit application (Docket No. CP14-497-000) filed June 2, 2014, by Dominion Transmission, Inc. of Richmond, Virginia. The Madison County Department of Health has concerns that impacts to public health have not been adequately addressed in this permit, specifically in regard to the Sheds compressor station in Madison County. The National Environmental Policy Act requires that FERC take into account potential environmental impacts and that FERC address public concerns in its permit review. The Madison County Department of Health's concerns are based in part on the report from the United States Environmental Protection Agency (USEPA) Inspector General that documents a lack of emissions data from oil and gas facilities which, in turn, casts doubt on the accuracy of projected air quality impacts. This brings into question the appropriateness of using the National Ambient Air Quality Standards to establish health safety risk near the Sheds compressor station. There are also documented correlations between health impacts and residential proximity to unconventional natural gas development facilities, including compressor stations.

Section II of these comments reviews what is known from the literature about compressor station emissions. Information specific to compressors is very limited. The types of chemicals that have been identified include VOCs, carbonyls and aldehydes, HAPs, aromatics and particulate matter. In particular, there is a lack of information on the intensity, frequency and duration of emission peaks that occur during blowdowns and large venting episodes that are a normal part of compressor operations. Blowdowns, on average, release 15 Mcf of gas into the atmosphere. Fugitive emissions and accidents are also of concern. One study from Fort Worth, Texas reported 2,126 fugitive emission points from a set of compressor stations. Radioactive chemicals are present in natural gas pipelines and can be released into the atmosphere, though little is yet known about exposure profiles for communities near compressor stations.

Section III reviews known health risks from known chemicals emitted, while acknowledging that there are data gaps in both chemicals emitted and potential health effects. Health risks from VOCs in the short term include eye and respiratory tract irritation, headaches, dizziness, visual disorders, fatigue, loss of coordination, allergic skin reaction, nausea, and memory impairment. Effects from long-term exposure include loss of coordination and damage to the liver, kidney, and central nervous system as well as elevated risk of cancer. Health effects from particulate matter 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. Diesel emissions from truck traffic (primarily during construction of the compressor) 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. Chemical exposure to vulnerable populations is a particular concern. The problem of chemical mixtures and how these might affect health needs further research.

Health effects associated with compressor stations are summarized in section IV. This set of research relies primarily on self-reported data from public health surveys. The symptoms identified are associated with health impacts on respiratory, neurological and cardiovascular body systems. These health effects correlate with the impacts associated with many of the chemicals emitted from compressor stations.

Madison County residents have reported numerous concerns to FERC and to the MCDOH (Section V). Primary concerns are for health safety and food/crop safety. Concerns about the safety record of compressors and pipelines, impact on community character and home values, emergency response preparedness, air quality and other environmental impacts were also raised.

Recommendations for framing and scoping public health issues (Section VI) includes information on relevant health data sources. Methods for assessing environmental health determinants include baseline data collection on air emissions, soil, and water quality.

Data gaps and other challenges to the implementation of a public health analysis are identified in section VII. These are: a lack of previous health studies that address compressor stations; limited data on chemical constituents of compressor air emissions including intensity, frequency and duration; the problem of poorly identified chemical mixtures and potential health effects; unidentified related emissions from metering stations and pipelines; the lack of data on potential radioactive chemical emissions; inadequate assessment of the effect of local weather patterns on dispersal of air pollutants (air dispersion modeling); and very limited information on the exposure pathway of air pollutants entering soil and food crops, and the potential for human health impacts.

Recommendations are also provided in the event that the permit is granted, as follows:

- Perform a baseline health study to establish population health status before the compressor station is built.
- Require best practices to ensure that effective emissions control measures are kept up to date.
- Establish an alert system for blowdowns or other large emissions and/or noise events.
- Put Emergency Plans in place.
- Institute a monitoring strategy at the Sheds compressor station and surrounding locations.
- Institute a health registry.

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I. Introduction

On June 2, 2014, Dominion Transmission, Inc. (DTI), of Richmond, Virginia filed an application with the Federal Energy Regulatory Commission (FERC), pursuant to Section 7(c) of the Natural Gas Act, to "construct, install, own, operate and maintain certain compression facilities that comprise the New Market Project located in Chemung, Herkimer, Madison, Montgomery, Schenectady, and Tompkins Counties, New York." One new compressor station, known as the Sheds compressor station, would be located in Madison County. The Madison County Department of Health (MCDOH) submits the following comments to FERC in regard to public health concerns relating to the Sheds compressor station and associated infrastructure. These comments are submitted for the FERC Scoping Process which opened for comments on September 18, 2014. The National Environmental Policy Act (NEPA) requires that FERC take into account potential environmental impacts in its permit review. NEPA also requires FERC to discover and address public concerns, which in this case focus on risks to public health.[1]

While the Madison County Department of Health understands that FERC has determined that the New Market Project (of which the Sheds compressor station is included) would follow an Environmental Assessment (EA) review process, instead of FERC's more comprehensive Environmental Impact Statement process, there remain many unanswered questions pertaining to the impacts on public health from the installation and operation of the Sheds compressor station along with concerns that the application of the EA process may fail to consider such health impacts in its review of the Sheds compressor station.

A recent report from the United States Environmental Protection Agency (USEPA) Inspector General states that there is inadequate information available on direct measurement emissions from oil and gas production activities.[2] The report finds that incomplete datasets lead to underestimates of air quality impacts from these sources. The report further notes that "Limited data could affect decision-making impacting human health and the environment." Health effects such as cancer risk, birth outcomes, skin rashes and respiratory problems have been correlated to production activities in peer-reviewed literature.[3] These findings, in addition to our review of the current literature on compressor emissions and potential health impacts frames the MCDOH concern that there is an underestimation of risk by DTI.

Currently available literature suggests that emissions produced during the construction and operation of the proposed Sheds Compressor station will have

the potential to put nearby residents at risk for health effects (see sections II, III, IV below). The MCDOH believes that a more comprehensive public health analysis is needed because:

1. There is incomplete information on the content of compressor emissions
2. Important aspects of the air emissions are not explicitly addressed in the DTI application (DTI permit application Section 9) such as episodic periods of very high emissions, including but not limited to blowdowns, which can adversely affect human health
3. Standards by which estimated emissions are evaluated (DTI permit application p.9-11) for health risk were not intended to be health protective at an individual or neighborhood level
4. Madison County residents have documented concerns about health risks

Table 1 shows the types and distribution of land parcels surrounding the proposed compressor station within a three mile radius. Local residents and the MCDOH are concerned that health impacts may be experienced by individuals in the vicinity of the station (sections IV and V).

Table 1. Land parcel distribution within three miles of proposed Sheds compressor station*

Parcel Category	1/2 Mile Radius	1 Mile Radius	3 Mile Radius
Agricultural Land	**5**	**9**	**60**
Residential Year Round	17*	30	207
Seasonal	2	3	21
Vacant Rural Residential Land	4	22	161
State/County Owned Forest	0	1	53
Private Forest	**0**	**0**	**1**
Utility Land	**1**	**1**	**1**
Cemeteries	**0**	**0**	**3**
Miscellaneous	**0**	**0**	**4****
Notes:			
* Closest Residential Structure Approx. 1,150 feet			
** Reputed Amish School Approx. 6,700 feet			

*Data courtesy of Madison County Real Property. Adapted by the Madison County Department of Health, Environmental Division. August 2014

The MCDOH recommends that if the more comprehensive EIS process is considered for this project it should take into account the following public health analysis component:

1. Data collection of baseline prevalence of relevant diseases including asthma, cancer, COPD, birth outcomes, as well as data on vulnerable populations in Madison County
2. Identification of impact pathways, susceptibility analysis, and cumulative impact factors
3. Consideration of local concerns in the assessment of health and environmental impacts

The remaining sections of these comments provide background information on four areas of public health concern for MCDOH (sections II – V), information on current data gaps (section VI), recommendations (section VII), and a summary of critical questions (section VIII):

Section II – Compressor station emissions - There are known emissions from compressor stations, as well as unidentified emissions. Frequency, intensity and duration of emissions at the proposed compressor station are not documented, yet these factors will determine the impact on nearby residents' health.
Section III – Health risks from relevant air contaminants - The full array of possible health effects is not known, but there are known health effects from some of the chemicals emitted. A review of some known chemical effects on health is provided.
Section IV – Reported health effects specific to compressors - Some health effects have been documented in the vicinity of other compressor stations and associated pipelines and metering stations. A review of available research is provided.
Section V - Concerns of Madison County residents – A review of comments submitted to FERC ad MCDOH is provided.
Section VI - Recommendations for framing and scoping the public health issues for the Sheds compressor station.
Section VII – Data gaps and other challenges to the implementation of a public health analysis are identified.
Section VIII – Recommendations and mitigation (if permit granted) - MCDOH suggests several recommendations for mitigation specific to the Sheds compressor station.
Section IX - A summary of questions for FERC to address in assessing risks to public health.

II. **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. DTI provides a set of emissions projections for both the construction and overall operational phases of the Sheds compressor station (Resource Report 9 of DTI's Application). This section of our comments reviews those projections and 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. Discussion of the health risks produced by compressor station emissions will be presented in Sections III and IV.

Construction emissions

DTI reports the dust and other air contaminant emissions projections in its Abbreviated Application for a Certificate of Public Convenience and Necessity[4]. The Application states that of the six sites in the New Market Project, only three – the new compressor stations at Horseheads and Sheds, and adding combustion equipment to the existing Brookman Corners site – are large enough to require pre-construction permits. The other three are small and exempt from the Air State Facility Permit that the larger projects require.[5]

Fugitive Dust Emissions from Construction Activities[6]

Construction-related fugitive dust emission projections are required for the three larger facilities mentioned above. It is not clear whether the totals provided in the Application are for all six sites or just the three that require pre-permitting. The estimates are based on the extent and duration of active surface disturbance and are provided in tons per year (tpy).[7]

Table 2. Fugitive Dust Emissions (tpy) for multiple New Market locations

	2015	2016
PM	2.90	21.44
PM 10	2.90	21.44
PM 2.5	0.29	2.14

These aggregated estimates tell us nothing specific about the construction phase of the Sheds compressor site. Because construction dust exposures at homes nearby would increase residents' risks for respiratory and cardiac illness, we believe a set of estimates specific to Sheds is needed to adequately evaluate health risk.

Total construction emissions for Sheds project

Total emissions estimates for construction-related engines are provided specifically for the Sheds project. These construction emissions are, in part, the result of diesel powered vehicles and equipment.

Table 3. Sheds non-road and on-road construction engine emissions (tpy)[8]

	2015	2016
CO	2.12	3.45
NOx	3.76	4.70
SO2	0.01	0.02
VOC	0.37	0.60
PM10	0.27	0.39
PM2.5	0.27	0.38
CO2	959.44	1288.86
CH4	0.05	0.06
N2O	0.02	0.02
CO2e	966.80	1297.69

When thinking about exposures in the vicinity of the Sheds construction site, it is important to note the particulate matter (PM) numbers. Table 3 includes only the PM10 and PM2.5 emissions from construction engines. For a total estimate, those numbers would need to be added to the PM10 and PM2.5 dust emissions (Table 2). Additionally, the estimates in tons per year raise concerns that will be addressed in conjunction with the operational emissions below.

<u>Operational emissions</u>

DTI presents a summary of its estimated operational emissions for the Sheds Compressor Station.[9] The Sheds combustion turbine will be fired exclusively with natural gas.[10] The operational emissions estimates are:

NOx	24.4 tpy	SO2	0.7 tpy
CO	6.6 tpy	Formaldehyde	0.1 tpy
PM10/PM2.5	6.4 tpy	Other HAPs	0.1 tpy
VOCs	2.9 tpy	Total HAPs	0.3 tpy

Perspective on emissions projected by DTI

The Sheds construction and operational phases are 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 determine 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).[11] 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.[12] 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).[13] Some of the reported emissions exceed this standard of health safety.

Table 4. Variation in ambient air measurements of five VOCs near a compressor station reported in ug/m^3 *[14]

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.

Without knowing the characteristics of peak exposures expected from the Sheds project, an accurate estimate of health risk cannot be made. Discussion of those health risks is found in Sections IV and V of this report.

Documented compressor emissions

It is important to know, with more specificity, what chemicals will be emitted by the proposed Sheds 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)[15] are:

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

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[16]:

- 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.[17]

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: [18]

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.[19] Results from samples collected include:

1,1,2-Trichloro-1,2,2-trifluoroethane,	ethylbenzene
1,2-dichlorobenzene	methane
2-butanone	methylene chloride
benzene	tetrachloroethylene
carbon tetrachloride	toluene
chloromethane	trichloroethylene
dichlorodifluoromethane	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.[20]

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. DTI includes fugitive emissions in its estimate of VOC emissions. Other categories of fugitive pollutants such as PM likely would increase if they were included in emissions projections. It has been suggested that fugitive emissions will increase over time as machinery begins to wear.[21]

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.[22]

Blowdowns

The largest single emission at a compressor station is the compressor blowdown.[23] 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.[24] One blowdown vents 15 MCf gas to atmosphere on average. Isolation valves leak about 1.4 Mcf/hr on average through open blowdown vents.[25]

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

[see Radioactivity section]. Anecdotally, there are reports of odors and burning eyes, headaches and coughing associated with the events.[26]

In addition to uncertainty about *what* would be emitted and therefore what nearby residents would be exposed to, there is no special mention of *how much* is emitted under different circumstances in the DTI Application. There is attention paid to these episodic events in terms of noise disturbance, but not in terms of air contamination and subsequent exposure to individuals nearby. Because DTI does not address blowdown emissions separately, we cannot know at this point if blowdown emissions are included in the annual TPY emissions projections. This should be clarified. Whether they are or are not, their potency, when they are underway, is not known although the emission is extreme.

In Section III we show why averaging over a year such extreme emission events will underestimate the risks posed by them. 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.[27] 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.[28] In Corpus Christi, TX a fire broke out at a compressor station which then spread to nearby brush before being extinguished.[29]

The possibility of fire or other accidents raises the concern over whether the localities surrounding the proposed Sheds 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.[30] 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.[31]

This is of particular concern for Madison County where the ambulatory squads and first response units are operated with volunteers and it has become increasingly difficult for communities in Madison County to keep these emergency medical services fully staffed and trained in advanced medical techniques and response activities.

Overall, there is little information on the division of responsibility between the company operating the facility and the locality. This should be clarified if the Sheds compressor station moves forward.

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.[32]

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.[33] 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.[34] There is no data that we can turn to in order to assess the risk of radioactive exposures in our community.

III. Health risks from relevant air contaminants

Averages, peaks and health events

As stated in the Operational Emissions section, 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 the proposed Sheds compressor station. Furthermore, the National Ambient Air Quality Standards (NAAQS) used by DTI 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.[35]

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

About the construction emissions, DTI says:

> Operations associated with Project facilities will not exceed any NAAQS. At the Sheds Compressor Station, modeling results indicate that all resultant pollutant concentrations (baseline concentration plus impact of the new compressor station) would be less than approximately 55 percent of any NAAQS. However, because of the relatively large margin between modeled concentrations and NAAQS limits, it is unlikely that any NAAQS would be exceeded from the cumulative impacts in the Project area.

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 (which is how close the nearest residence is). 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.[36] [37] 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.[38]

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…."[39]

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…."[40]

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.[41] 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.[42] The case for elevated risk of cancer from UNGD VOC exposure has been made by McKenzie et al (2012) and others.[43]

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.[44]

Benzene, which is documented at compressor stations by the States of Pennsylvania and Texas, carries its own risk, including risk for cancer.[45] [46] 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.[47]

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.[48]

The VOC formaldehyde is also considered a Hazardous Air Pollutant (HAP) by the US EPA (EPA).[49] 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.[50] For the year 2012, emissions of formaldehyde from compressor stations in Pennsylvania ranged from 0.0 TPY to 22.5 TPY. [51]

A recent study of air emissions in the Barnett shale region of Texas found concentrations of formaldehyde at sites with large compressor stations.[52] 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.[53] The World Health Organization classifies it as carcinogenic to humans.[54] It has also been associated with childhood asthma.[55] 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.[56] The acute REL is 74 ppb based on irritation of asthmatics.[57] It has also been linked with adverse pregnancy outcomes and reproductive and developmental toxicity.[58]

More recent investigations on formaldehyde near compressor stations are focused on the chemical reaction between methane and sunlight.[59] 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.

<u>Effects from exposure to particulate matter</u>

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.[60]

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.[61] 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."[62] 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."[63]

Ultrafine particles (<0.1) get less attention in the literature than PM2.5 but is found to have high toxic potency.[64] These particles readily deposit in the airways and centriacinar region of the lung.[65] Research suggests increases in ultrafine particles pose additional risk to asthmatic patients.[66] 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.[67]

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;[68] and is associated with acute endothelial response and vasoconstriction of a conductance artery.[69] 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.[70]

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).[71] 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.[72] 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.[73] Research has also shown that there is an association between PM2.5 and hospitalization for COPD in elderly people.[74]

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.[75] 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.[76]

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.[77] 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.[78] While those living near the proposed Sheds compressor station are not on what would be consider typical high volume vehicle roadways, during the construction phase of the project residents along the access roads will be exposed to heavy emissions. And even once the construction phase is completed and compressor station is up and running there are similarities in what Dominion projects it will emit and those emissions from high volume vehicle traffic.

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.[79]

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.[80] 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.[81]

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.[82] Researchers have found associations between elevated sound levels – including community sounds levels – and hearing loss, reduced performance and aggressive behavior.[83] Additionally some attention is being paid to the health effects of vibration exposure which is connected with but distinct from noise itself.[84]

Noise exposures are associated with construction activities and during blowdown episodes. Although noise estimates were provided by DTI, we believe the effects of these exposures as well as vibration exposures should be evaluated by outside experts in the field. 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, in the case of the proposed Sheds compressor station, 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. A thorough community health study could, however, reveal important risks specific to residents in Madison County, NY.

IV. 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.[85] 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. [86] 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[87]. 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.

Based on data from the Town Assessor's office (Table 1), 17 year-round residences are located within ½ mile (2,640 feet) of the proposed compressor station and 30 residences are within 1 mile (5,280 feet). The nearest residence is 1,150 feet from the site. Symptoms reported in the Pennsylvania study, primarily throat irritation, sinus problems and headaches could potentially be experienced by town residents within

these distances. Numerous additional symptoms are possible and would vary depending upon the age and overall health of individuals.

Earthworks also conducted a health survey in Dish, Texas in 2009.[88] 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[89], 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[90]. 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[91]. 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
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.

V. Concerns from residents

FERC is required by NEPA to address concerns reported by local residents in the permitting process. Engaging community members in this process can effectively inform decision-making that ultimately improves public safety.[92,93]

In the public comments submitted to FERC by residents and in comments submitted to the MCDOPH, concerns about health risk are a priority. In reviewing these comments we found that of the 15 individuals who submitted comments to FERC the top 10 concerns mentioned were:

Food safety (risks to crops/farms/gardens and consumers)	10
Health risks (including risks to children)	9
Home values (resale, insurance, mortgage)	9
Air pollution	8
Environment	8
Water pollution	7
Noise pollution	7
Safety record of compressors	7
Rural character of community disruption	7
Wildlife	7

Of the 21 comments written to the MCDOPH during and following two public information meetings the top ten concerns were[94]:

Health Risks (including risks to children)	19
Food safety (Risks to crops/farms/gardens and consumers)	16
Air pollution	15
Noise pollution	14
Safety record of compressors	11
Water pollution	11
Emergency response	9
Rural character of community disruption	7
Home values (resale, insurance, mortgage)	7
Pipeline safety	5

Health safety and food safety are the top concerns for these residents. While the risks to health from potential chemical exposure is documented (and summarized above in relation to compressors), less is known about the route of exposure from air emissions through soil and food pathways. There are reports of soil contamination from UNGD caused by spills, leaks and underground contamination[95,96]. For this industry, we found no documentation of soil and plant contamination from air pollutants, but the pathway for contamination through air is well documented.[97 ,98 ,99] Thus concerns about food safety related to air emissions should not be discounted.

There is evidence of loss of property values near UNGD sites, though not specifically addressing to compressor stations.[100,101] Risks to wildlife and local habitats from UNGD has been addressed in the literature by Kiviat (2013).[102] Concern about accidents,

emergency response, compressor safety records and pipeline safety are related issues that bear on public health. In fact, each of the concerns listed above is related, directly or indirectly to public health. From the broad scope of "environment" and "rural community character" to the specifics of safety records and emergency response, these issues impact the health and wellbeing of the local community. These concerns can best be addressed through a thorough assessment of health risks.

VI. Recommendations for framing and scoping the public health issues for the Sheds compressor station:

FERC should consider expanding the scope of its public health analysis on the Sheds compressor station to address the concerns raised in this report to ensure that public health is not endangered in Madison County. To protect public health it is necessary to know whether dangerous spikes in pollutants will ever occur at this compressor station, how often, and what the health effects would be for nearby residents in the short and the long term. The important impact of local weather conditions on exposure profiles also needs to be considered.

To adequately assess human health impacts public health professionals and analysts would need to know:

- The pathways of exposure (air, water, soil)
- The intensity of the exposure
- The frequency of the exposure
- The duration of the exposure
- Interaction of components of the chemical mixture
- Length of time living near the compressor station

Public health professionals understand that:

- Chemical toxicity in the human body can occur within minutes or hours of exposure.
- Repeated episodic exposures increase the damage.
- High exposures to chemicals increase the seriousness of the damage.
- Understanding the variability of exposure is essential.

The need for a public health perspective in the process of regulating UNGD including transportation infrastructure has been presented in peer-reviewed journals, at scientific conferences and in public comments to State officials. See the following references:

A. Wernham, "Health Impact Assessment for Shale Gas Extraction," www.healthimpactproject.org/resources/health-impactassessment-for-shale-gas-extraction (accessed July 30, 2014).

Adgate, JA, Goldstein, BA and Mckenzie, LM. Potential Public Health Hazards, Exposures and Health Effects from Unconventional Natural Gas Development Environmental Science and Technology. 2014. [103]

Adgate et al (2014) report that :
"… pollution from UNG development originates from (1) direct and fugitive emissions of methane and nonmethane hydrocarbons from the well and associated infrastructure (e.g., production tanks, valves, pipelines, and collection and processing facilities); (2) diesel engines that power equipment, trucks, and generators; (3) drilling muds, fracturing fluids, and flowback water; and (4) deliberate venting and flaring of gas and related petroleum products." (page D)[104]

They further state that:
"Pilot studies in Colorado's Piceance Basin, Pennsylvania's Marcellus, and Texas's Barnett Shale indicate that VOCs, including C2− C8 alkanes, aromatic hydrocarbons, methyl mercaptan, and carbon disulfide, are emitted during well completions as well as from compressors, condensate storage tanks and related infrastructure." (page E)[105]

The lack of environmental public health expertise on advisory panels at the state and federal levels has also been addressed by:

Goldstein, B., Kriesky, J., Pavliakova, B. "Missing from the Table: Role of the Environmental Public Health Community in Governmental Advisory Commissions Related to Marcellus Shale Drilling." Environmental Health Perspectives. Vol 120(4)483-486, 2012. [106]

<u>Baseline health data and environmental data: where to find it</u>

Baseline health data provides the foundation for effective public health assessments. Numerous sources are available to develop a baseline dataset for specific locations and to identify susceptible populations. Primary resources are listed below.

The gathering of environmental data for assessment of health impacts would, in the case of compressor station air emissions, require accessing data on a subset of known chemicals emitted at similar sites (e.g. a similar size compressor station during normal operation including blowdowns and venting). The monitoring protocols at existing sites would need to address the realtime variations at compressor stations, capturing peak emissions as well as duration of peaks. Public health officials could then more accurately estimate health impacts for both acute and cumulative exposures to the local population.

Local baseline health statistics are necessary so that risk can be assessed in relation to a specific population. Baseline data sources include County, State and Federal health statistics databases. Nongovernmental resources include the American Lung

Association, American Cancer Society and the National Cancer Institute. Recommended baseline health topics and sources of data are listed below.

Physical health determinants:

- Major causes of morbidity and mortality: CDC Wonder; National Cancer Institute
- Life expectancy: CDC's Community Health Status Indicators
- Poor physical health days: Behavioral Risk Factor Surveillance System (BRFSS)
- Chronic disease: BRFSS
- Identification of vulnerable populations: County level health data and sociodemographic data
- Birth outcomes: Health Indicators Warehouse and National Vital Statistics System
- School data: New York State Department of Health, Health Data NY, Schools, Statistics and Chronic Diseases
- Hospital data: New York State Department of Health, Health Data NY, Hospital reports

Environmental health determinants:

- Baseline local air quality: requires targeted monitoring in addition to current NAAQS data
    - To estimate the impact of compressor station air emissions MCDOH suggests site specific air monitoring from comparable compressor stations to capture the intensity, duration and frequency of peak emissions that could impact public health (including blowdowns). A subset of known chemicals could be tested for including but not limited to BTEX, methylene chloride, formaldehyde, $PM_{2.5}$ and ultrafine particles.
    - This can be followed by the modeling of emissions dispersion that takes local topographic and meteorological data into consideration. In this way the potential for spikes in exposures can be estimated for different locations.
- Soil health: perform baseline soil tests for relevant chemicals to establish baseline levels in case of future potential contamination of local yards, play areas and gardens as well as local agricultural fields and farm products.
    - To be followed by periodic soil tests if permit is granted.
- Baseline local water quality: requires targeted testing of local wells and surface waters [of concern to residents]
    - To be followed by periodic monitoring of local water resources if permit is granted.
- Noise levels: compare current and projected levels.
- Traffic: compare current and projected levels.
- Construction: assess projected impacts from dust and diesel emissions.

Suggested references of reports that assess health impacts, including cumulative risks, related to UNGD

University of Maryland: Potential Public Health Impacts of Natural Gas Development and Production in the Marcellus Shale in Western Maryland. Maryland Institute for Applied Environmental Health School of Public Health University of Maryland, College Park. July 2014.[107]

New Brunswick, Canada: Chief Medical Officer of Health's Recommendations Concerning Shale Gas Development in New Brunswick. Office of the Chief Medical Officer of Health, New Brunswick Department of Health. 2012.[108]

Colorado School of Public Health: Battlement Mesa Health Impact Assessment, Colorado School of Public Health, February, 2011 [109]

State of Alaska: Health and Social Services Alaska Health Impact Assessment Program[110]

VII. Data gaps and other challenges for implementing a health assessment:

There are a number of knowledge gaps that make it difficult to perform a thorough public health analysis, yet each such effort contributes to the broader challenge of understanding the health consequences of living near UNGD installations, including compressor stations.

1. Baseline health studies: Studies on health status before infrastructure development are lacking, yet are critical for measuring health impacts.[111] Currently little is known about the direct consequences of living near these sites. Baseline studies in relation to UNGD are needed and should be followed by health status monitoring during development and production phases.

2. Chemical constituents: More site specific monitoring is needed to quantify and qualify the chemical constituents of compressor station emissions. Emissions can vary between sites as well as over time at each site. Normal operations will produce different emissions from venting, blowdowns or accidental releases. Targeted monitoring can help address this gap by providing information on the chemical identities and quantities along with timeline and duration of emissions that may lead to exposures.

3. Chemical toxicity and chemical mixtures: information on toxicity is lacking for some chemical constituents that have yet to be thoroughly studied. With no health standards, risks are difficult to assess. Even when health standards for each chemical

are known, understanding risks to chemical mixtures in air emissions poses a greater challenge. Research on how chemicals react with each other, as well as how mixtures then affect the human body are sorely lacking. These data gaps can be mitigated to some extent by conducting health impact assessments.

4.: Pipeline and metering station emissions: In addition to compressor stations, pipelines and metering stations also emit chemicals into the air. These emissions contribute to both environmental and public health impacts. Targeted monitoring would help in assessing regional air quality impacts, as well as local impacts for residential areas.

5., Radioactive emissions: Natural gas sourced from shale plays is known to contain radioactive elements. These elements build up in pipeline scale. The extent to which radioactive materials are emitted during venting, blowdowns or other events is not well known. Monitoring specifically for harmful radioactive substances is needed.

6. Air dispersion modeling: Determining how emissions travel from a source to nearby residents is an important part of understanding human exposure. The topography and the weather patterns of each local environment affect dispersal patterns. Consequently some residents may be impacted more than others. Targeted air dispersion modeling for specific industrial sites can contribute to anticipating local health impacts.

7. Soil and farm products: With the increased placement of natural gas transmission infrastructure through rural farming communities, the need for monitoring soils and farm products for chemical contamination also increases. As chemical constituents are identified, targeted soils and food testing can help bridge this knowledge gap.

VIII. Recommendations and mitigation (if permit granted)

In the event that the DTI New Market project is permitted by FERC, MCDOH would make the following recommendations so that public health can be adequately addressed :

1. Perform a baseline health study to establish population health status before the compressor station is built.

- A baseline health study would allow MCDOH to monitor and measure health impacts over time and support the development and initiation of mitigation for health consequences if any are found.
- A baseline study that includes air pollution monitoring would provide data to distinguish between background and additional impacts from compressor station emissions. With indoor air monitoring in residences, distinctions could be made between the use of natural gas in the home on a regular basis and the potential impact of emissions dispersing into residences. For example, a measure of spikes

that might occur from cooking (short-term) would look different from longer-term spikes that result from outdoor air pollution, or nighttime spikes that might occur due to weather conditions.

2. Require best practices to ensure that effective emissions control measures are kept up to date.
Technology is rapidly changing in this industry and while some improvements have been made in emissions controls and environmental impacts, there is room for more improvement. To protect public health, MCDOH recommends that upgrades to equipment be required for continued operation of the compressor station. [112]

The health effects of living near compressor stations include impacts from this constant source of noise. To reduce these health effects MCDOH requests the implementation of special noise abatement measures such as those in use at the Minisink Compressor Station. These include the addition of an "internal mass septum layer for the compressor building walls and roof; additional baffle length for the first and second stage exhaust silencers; high performance turbine exhaust and air inlet systems; low noise turbine lube oil coolers; and unit blowdown silencers." [113] It should be noted, however, that some residents near the Minisink Compressor station continue to report that noise and vibrations interfere with their quality of life. Continued upgrades would help to mitigate ongoing effects.

3. Establish an alert system for blowdowns or other large emissions and/or noise events. These types of events, while considered a normal part of compressor station operations, can potentially cause health effects for nearby residents. A system that alerts residents to the intensity and duration of these events is recommended.

4. Put Emergency Plans in place. The application filed by DTI states that the company is not required by the USEPA to prepare a risk management plan for the New Market Project. Because of the risk of chemical accidental (or intentional) release at levels that could harm human health, MCDOH recommends that emergency plans be put in place for both pipeline release events, metering station events and compressor station accidents. In association with emergency plans, MCDOH further recommends that :

- First responders be properly trained for these specific scenarios
- Local health providers receive training for specific environmental exposures
- An evacuation plan is put in place

5. Institute a monitoring strategy at the Sheds compressor station and surrounding locations. To adequately protect public health it is necessary to measure air emissions at the source and to determine air pollution impacts locally. MCDOH recommends monitoring air emissions such as formaldehyde, VOCs and particulate matter at residences within one mile of the compressor station. MCDOH also recommends monitoring impacts to soil and crops within one mile of the compressor station to

assess impacts on farm products. With realtime monitoring in place, DTI would have the capability to respond to events that jeopardize human health and adjust venting events accordingly.

6. Institute a health registry. MCDOH recommends that a regional health registry be established so that long-term health effects from natural gas infrastructure, including the Sheds compressor station, can be adequately assessed. Ideally this registry would be part of a larger state and/or national level registry, since the infrastructure for natural gas energy is increasing across the USA.

IX. Summary of Questions for FERC to address in assessing risks to public health

1. What is the health status of the local population?
2. What chemicals will be emitted, at what concentrations and in what mixtures?
3. How often do releases occur (frequency), how long do they last (duration) and at what intensities? What times of day do they occur?
4. What is the health effect downwind, especially at night for residences within 1 mile of the compressor?
5. Will radioactive material be emitted (intentionally, as fugitives or accidentally) and if so, at what levels?
6. Are adequate emergency/notification plans in place?
7. Are adequate mitigation strategies in place?

X. Glossary of Abbreviations

CDC	Centers for Disease Control
DTI	Dominion Transmission, Incorporated
EPA	Environmental Protection Agency
HAP	Hazardous Air Pollutants
MCDOH	Madison County Department of Health
NAAQS	National Ambient Air Quality Standards
PM	Particulate Matter
REL	Reference Exposure Level
UNGD	Unconventional Natural Gas Development
VOC	Volatile Organic Compound
USA	United States of America
USEPA	United States Environmental Protection Agency

[1] FERC Notice of Intent to Prepare an Environmental Assessment for the Proposed New Market Project, Request for Comments on Environmental Issues and Notice of Public Scoping Meeting. Letter Dated September 18, 2014. Received by the Madison County Department of Health.

[2] USEPA Office of the Inspector General : EPA Needs to Improve Air Emissions Data for the Oil and Natural Gas Production Sector http://www.epa.gov/oig/reports/2013/20130220-13-P-0161.pdf Accessed September 29, 2014.

[3] See: McKenzie LM, Witter RZ, Newman LS, Adgate JL. Human health risk assessment of air emissions from development of unconventional natural gas resources. Sci Total Environ 2012;424:79–87. See also: McKenzie LM, Guo R, Witter R, Savitz DA, Newman LS, Adegate JL. Birth Outcomes and Maternal Residential Proximity to Natural Gas Development in Rural Colorado. Environmental Health Perspectives. 2014; 122(4):412-417. See also: Rabinowitz PM, Skizovskiy IB, Lamers V, Trufan SJ, Holford TR et al. Proximity to natural gas wells and reported health status: Results of a household survey in Washington County, Pennsylvania. Environmental Health Perspectives. 2014; DOI:10.1289/ehp.1307732.

[4] Dominion Transmission, Inc., Abbreviated Application for a Certificate of Public Convenience and Necessity ,New Market Project, filed June 2, 2014. Hereafter referenced as "DTI Application".

[5] DTI Application, p. 9-17.

[6] DTI Application, Table 9.1-4, p. 9-18

[7] DTI Application, p.9-18.

[8] DTI Application, Appendix 9-A,

[9] DTI Application, p.9-26.

[10] DTI Application, p.9-25.

[11] Southwestern Pennsylvania Marcellus Shale Short-Term Ambient Air Sampling Report. Pennsylvania Department of Environmental Protection. November 2010.

[12] Southwestern Pennsylvania Marcellus Shale Short-Term Ambient Air Sampling Report. Pennsylvania Department of Environmental Protection. November 2010.

[13] http://www.atsdr.cdc.gov/ToxProfiles/tp110.pdf. Page 216.

[14] Ibid., Appendix A, p.31.

[15] "Emission Inventory." Pennsylvania Department of Environmental Protection. http://www.dep.state.pa.us/dep/deputate/airwaste/aq/emission/emission_inventory.htm 2010.

[16] 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.

[17] Ibid.

[18] Wolf Eagle Environmental. Town of DISH, Texas Ambient Air Monitoring Analysis Final Report. September 15, 2009.

[19] 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.
[20] Southwest Pennsylvania Environmental Health Project internal review of intake materials, August 2014.
[21] 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.
[22] Ibid.
[23] 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
[24]http://www.transcanada.com/docs/Our_Responsibility/Blowdown_Notification_Fact sheet.pdf
[25]http://www.transcanada.com/docs/Our_Responsibility/Blowdown_Notification_Fact sheet.pdf
[26] Personal communication with staff at SWPA-EHP.
[27] http://www.cleburnetimesreview.com/godley/x489007782/Compressor-station-blows-up.
[28] http://www.madisonvillemeteor.com/news/article_bb02293e-656e-11e2-b466-0019bb2963f4.html
[29] http://www.caller.com/news/natural-gas-explosion-in-jim-wells-county-shoots
[30] http://www.newschannel10.com/story/24605246/four-people-injured-in-workplace-accident
[31] http://www.sunad.com/index.php?tier=1&article_id=26535
[32] 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
[33]ATSDR. http://www.atsdr.cdc.gov/csem/csem.asp?csem=8&po=5.
[34] Dyrszka L. Potential Health Impacts Proposed Minisink Compressor Station. October 9, 2012. Unpublished affidavit.
[35] 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.
[36] 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.
[37] 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.
[38] 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.

[39] 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.

[40] 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.

[41] 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.

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

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

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

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

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

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

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

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

[50] 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.

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

[52] 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

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

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

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

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

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

[58] 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.

[59] Personal communication, David Carpenter. August 20, 2014. Research article under review.
[60] 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.
[61] http://www.epa.gov/pm/health.html
[62] 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.
[63] Ibid.
[64] 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 molecultes in humans. Environmental Health Perspectives 2006; 114(1): 51.
[65] Donalson K, Stone V, Clouter A, Renwick L, MacNee W. Ultrafine particles. Occupational & Environmental Medicine 2001; 58:211-216.
[66] 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.
[67] 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 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.
[68] 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.
[69] 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.
[70] 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
[71] Ibid.
[72] 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
[73] 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.

[74] 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.

[75] Mills NL et al. 2007.

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

[77] 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.

[78] 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).

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

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

[81] 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.

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

[83] 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.

[84] 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

[85] 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.

[86] 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.

[87] 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.

[88] 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

[89] Wilma Subra, President, Subra Company P. O. Box 9813 New Iberia, La 70562.
[90] Summary tables posted at http://lu zernecountycleanair.com/health-affects/ . Accessed July 29, 2014.
[91] Ibid.
[92] Korfmacher Katrina Smith, Elam S, Gray KM, Haynes E, Hughes MH. Unconventional natural gas development and public health: toward a community-informed research agenda. Reviews on Environmental Health. DOI 10.1515/reveh-2014-0049
[93] O ' Fallon LR, Wolfle G, Brown D, Dearry A, Olden K. Strategies for setting a national research agenda that is responsive to community needs. Environmental Health Perspectives 2003;111:1855 – 60.
[94] Two of these written comments came from four residents (married couples) who also sent comments to FERC.
[95] Bamberger, M. & Oswald, R. E. Impacts of gas drilling on human and animal health. New Solutions 2012, 22 (1), 51-77.
[96] Laramie, R. Expanded site investigation - analytical results report. URS Operating Services, Inc., *2010;* 1-86.
[97] Nadal, M. Schuhmacher, M. & Domingo, J.L. Metal pollution of soils and vegetation in an area with petrochemical industry. Science of the Total Environment 2003: 321, 59-69.
[98] Orrechio, S. Contamination from polycyclic aromatic hydrocarbons (PAHs) in the soil of a botanic garden localized next to a former manufacturing gas plant in Palermo (Italy) Journal of Hazardous Materials 2010; 180:590-601.
[99] Kirk, J. L., Muir, D. C. G., Gleason, A., Wang, X., Lawson, G. Frank, R. A., Lehnherr, I. & Wrona, F. Atmospheric deposition of mercury and methylmercury to landscapes and waterbodies of the Athabasca oil sands region. Environmental Science & Technology 2014; 48, 7374-7383.
[100] Muehlenbachs, L. Spiller E, and Timmins C. Shale Gas Development and Property Values: differences across drinking water sources. Resources for the Future. Discussion paper July 2012.
[101] Radow, EN. Homeowners and Gas Drilling Leases: boon or bust? New York State Bar Association Journal (2011) v.83 no.9
[102] Kiviat, E. Risks to biodiversity from hydraulic fracturing gas in the Marcellus and Utica Shales. Annals of the New York Academy of Sciences 2013; 1286, 1-14.
[103] Adgate, JA, Goldstein BA and Mckenzie LM. Potential Public Health Hazards, Exposures and Health Effects from Unconventional Natural Gas Development

Environmental Science and Technology. 2014. dx.doi.org/10.1021/es404621d
[104] Ibid, page D.
[105] Ibid, page E.
[106] Goldstein BD, Kriesky J, Pavliakova B. Missing from the Table: Role of the Environmental Public Health Community in Governmental Advisory Commissions Related to Marcellus Shale Drilling. Environ Health Perspectives 2012; 120:483–486; http://dx.doi.org/10.1289/ehp.1104594 (accessed July 29, 2014).
[107] Potential Public Health Impacts of Natural Gas Development and Production in the Marcellus Shale in Western Maryland. Maryland Institute for Applied Environmental Health School of Public Health University of Maryland, College Park. July 2014.
[108] Chief Medical Officer of Health's Recommendations Concerning Shale Gas Development in New Brunswick. Office of the Chief Medical Officer of Health, New Brunswick Department of Health. 2012.
[109] Battlement Mesa Health Impact Assessment, Colorado School of Public Health, February, 2011 http://www.garfield-county.com/environmental-health/battlement-mesa-health-impact-assessment-ehms.aspx
[110] http://www.epi.alaska.gov/hia/
[111] Schmidt, CW, "Blind Rush? Shale Gas Boom Proceeds Amid Human Health Questions", Environ Health Perspectives 2011; 119: a348-a353. http://dx.doi.org/10.1289/ehp.119-a348
[112] Health Impact Assessment of Shale Gas Extraction: Workshop Summary - Workshop On The Health Impact Assessment Of New Energy Sources: Shale Gas Extraction. Sponsored By Roundtable On Environmental Health Sciences, Research, And Medicine April 30–May 1, 2012, House Of Sweden, 2900 K Street NW, Washington, DC. Copyright National Academy of Sciences. "For example, for compressor stations, technology such as oxidation catalysts, selective catalytic reduction, and stoichiometric combustion engines with three-way catalysts can reduce the emissions of NOx, VOCs, and formaldehyde."
[113] Comments Of Millennium Pipeline Company, L.L.C. Regarding Environmental Assessment Docket No. CP11-515-000. 04.04.2012. p.6.