Grant Application to Study - Significance of Emissions from Compressor Stations

David O. Carpenter, MD
Director, Institute for Health and the Environment
A Collaborating Centre of the World Health Organization
University at Albany

In November, 2014, New York Governor Andrew Cuomo announced that horizontal hydrofracturing ("fracking") would be banned in New York State. When Health Commissioner Zucker explained why this ban was being imposed, he waved our publication (Macey et al., 2014) on the air releases monitored in five states around fracking wells and compressor stations. These samples were taken at times of clear releases or smells, and therefore may represent a worst case event. However of the samples taken 40% exceeded federal guidelines for cancer and non-cancer health effects. Some of the largest releases in excess of standards were associated with the compressor stations, especially releases of benzene, 1,3-butadiene and formaldehyde (all rated as known human carcinogens by the International Agency for Research on Cancer). There were also releases of multiple volatile organics (VOCs), hydrogen sulfide, and particulates above regulatory limits.

While the banning of fracking in New York was widely viewed as a major action preventing exposure of New York residents to dangerous air pollutants, fracking has expanded in Pennsylvania, located just below New York, and there is now a rapid expansion of gas pipelines carrying Pennsylvania unrefined natural gas across New York to ports on the Eastern coast for refining and export. Gas pipelines require compressor stations every 25-50 miles, and these compressor stations now pose a potentially serious threat to New York residents living near to the sites where the compressor stations are to be located.

On April 28th, 2016 Dominion Transmission, Inc. was given final approval from the Federal Energy Regulatory Commission (FERC) to build two new compressor stations (Horseheads Compressor Station in Chemung County, operating at 11,010 horsepower (HP); Sheds Compressor Station in Madison County, operating at 10,880 HP) and a large upgrade of one of the existing compressor stations (Brookman's Corner Compressor Station in Montgomery County; increased by 11,132 HP). Currently this is an existing small facility with a single 7410 HP turbine compressor that runs only about once or twice a week, but with expansion to 18,543 HP this will allow transport of an additional 112,000 Dekatherms of gas per day. Final construction at all three sites now await approval by the NYS Department of Environmental Conservation and local governments. It is expected that these approvals will be granted sometime within the next several months, and that construction will begin this summer.

Previous studies (Litovitz et al., 2013; Field et al., 2014; Macey et al., 2014) have found that releases of VOCs, NO_2, $PM_{2.5}$, SO_2 and formaldehyde are much greater (orders of magnitude in most cases) from compressor stations than from natural gas transport, well drilling, fracking and production combined. ATSDR (2016) performed a Health Consultation on the Brigich compressor station in Pennsylvania, and found nine chemicals that exceeded health-based comparison values. This included hydrogen sulfide, formaldehyde and the BTEX compounds (benzene, toluene, ethylbenzene, xylenes). VOC exposure has long been known to cause respiratory irritation (Schenker and Jacobs, 1996; Wang et al., 2012), elevated risk of non-Hodgkin lymphoma (Fritschi et al., 2005), other cancers (Boeglin et al., 2006) and reduced cognitive function (van der Hoek et al., 2001; Allen et al., 2016). Exposure to benzene, a major component of natural gas, is known to increase risk of leukemia and lymphoma (Vlaanderen et al., 2011; Boberg et al., 2011), and there is some evidence that short-term, high exposures carry more risk than the same total exposure occurring over a longer period of time (Glass et al., 2003). This is particularly relevant to the releases than occur at compressor stations, which are often releases of high concentrations for brief periods of time. Loh et al. (2007) have ranked cancer risks from exposure to organic air pollutants as compared to ingestion of carcinogens. The highest risks, based on the California Office of Environmental Health and Hazard Assessment, were for benzene (18%), 1,3-butadiene, 17% and formaldehyde (18%). All three of these carcinogens are known to be released from compressor stations. Most of the other cancer risks came from ingestion of foods containing carcinogens. Benzene exposure also has been reported to alter immune system function in humans (Kirkeleit et al., 2006). Of particular concern is the fact that exposure to air-borne carcinogens will increase risk of cancer which will only appear many years later. Thus, if there are significant inhalation of these three carcinogens from air in the vicinity of these new and expanded compressor stations the elevated rates of cancer may not be detectable in the short term, but will be expected among exposed persons in the future.

Adverse health effects of particulates, particularly $PM_{2.5}$, are also well established. Acute exposure leads to airway inflammation and oxidative stress in asthmatic children (Liu et al., 2009), elevated mortality from cardiovascular and respiratory diseases (Atkinson et al., 2014; Crouse et al., 2012) and even elevation in fasting glucose concentrations (Peng et al., 2016). Our previous studies have reported elevations in hospitalization for asthma, respiratory infections, bronchitis and chronic obstructive pulmonary disease among individuals living near to hazardous waste sites (Ma et al., 2007) and fuel-fired power plants (Liu et al., 2012). These results all raise the possibility that living near to an operating compressor station will increase risk of cancer, respiratory infections and chronic respiratory disease, and adverse effects on central nervous function. Hydrogen sulfide is not known to be a carcinogen, but has both central nervous system and respiratory toxic effects (Ahlborg, 1951: Collins and Lewis, 2000) in addition to its unpleasant odor.

Even though much is known of the human health hazards of benzene and other VOCs, formaldehyde, hydrogen sulfide and particulates, there is no definitive evidence that releases specifically from compressor stations pose a significant threat to human health, as no studies have systematically addressed this issue. Preliminary studies at a different compressor station (Minisink) by Dr. Brown and colleagues at the Southwestern Pennsylvania Environmental Health Project (SWPA-EHP) using the Speck air monitors (see below) have shown brief periods of peak ambient air pollution levels 5 to 10 times over baseline and occurring two or more times daily, which indicates episodic acute threats to health. While there are reports of elevations in illness among residents living near to fracking sites, these are almost always self-reported and are vulnerable to psychological fears that may influence results. The actual measurements of chemicals in the air near fracking sites are limited, and many, like our previous results (Macey et al., 2014), report sudden peaks of emissions, while most state monitoring programs average emissions over long periods of time that may mask more dangerous short-term releases. Thus it is important to obtain both longer term continuous monitoring so as to determine average exposure of time, but also to determine and measure large exposures occurring over much shorter periods of time. The magnitude and frequency of these large but brief exposures will be determined by the size and operation of the compressor station.

It is clear that natural gas is a cleaner burning fuel than coal, and that we are many years away from have adequate sources of renewable energy. The goal of this study is to determine whether or not there are significant releases of carcinogenic and other toxic gases from the operation of compressor stations in New York. We propose to systematically monitor releases at two of these sites before construction, during construction and after construction has been complete and operation has begun. If the concentrations of dangerous gases and particulates are not significantly above background, there is no threat to human health and complicated health studies do not need to be done. However if we find significant levels of carcinogenic and toxic substances being released from compressor stations, and can determine how far they spread from the site, this information will define the population at risk that should be studied for adverse health effects in the future. If there is no risk to human health from operation of these compressor stations it is important to provide that documentation to local residents who fear exposures. If there are significant releases it is important to document the concentrations and the distances from the site where exposure is elevated. This study has the potential to answer these questions. The results will be much more convincing provided that we can complete the measurements at both sites before construction begins, as well as during construction and operation. This is why the present application is time-sensitive.

Innovation

To date, no studies have been completed where it was possible to obtain measurements prior to construction and operation, information which is essential if one is to conclude that operation of a compression station poses threats to human health that counterbalance the benefits of obtaining energy from natural gas. This will be the first study to apply state-of-the-art monitoring for particulates, VOCs, formaldehyde, and hydrogen sulfide at compressor station sites before construction, during construction and during operation after construction. Furthermore by use of multiple sampling stations at each of the two sites, as well as using available meteorological data, we expect to determine the spread of air releases over distance so as to determine the population at risk. We will also obtain information under circumstances of low wind conditions and high cloud cover, both of which will exacerbate exposures.

There have been a number of investigations, including some by our colleagues from the SWPA-EHP (Brown et al., 2014; 2015) of air releases and self-reported health effects around fracking sites. These studies have documented self-reports of adverse health effects that correlate with spikes in release of air contaminants, particular particulates that were monitored with the Speck meters. In addition Dr. Brown and colleagues have conducted a pilot study at the Minisink compressor in Westtown, NY which has been in operation since 2013. A report of these findings is available on the EHP website (www.environmentalhealthproject.org). Four of five Speck monitors recorded elevated particulate levels compared to regional levels, and the levels were strikingly elevated at one monitor. Periods of low wind speed and at nighttime showed the highest concentrations. While the average particulate concentrations were around 5μg/m^3 (a "good" range), there were peaks of exposure that were as high as 426 μg/m^3 (a "very high" range), and sometimes these occurred several times in the same day. A total of 35 individuals self-reported adverse health effects or worsening of pre-existing conditions after the operation of the compressor station. Most were symptoms of respiratory illness, but there were also reports of neurological and dematological problems. Six of the subjects experienced nosebleeds, which they did not have before the compressor stations was in operation. Nosebleeds are unlikely to be psychosomatic, and are likely a result of inhalation of formaldehyde, which pickles the nasal epithelium, and inhalation of hydrogen sulfide, which forms a weak acid which degrades the damaged epithelium. This study suggests that there were sufficient emissions from this compressor station to adversely affect human health, and that the self-reported health effects were likely related to exposure to peak emissions, since the average particulate levels were not particularly high.

This application is in response to an immediate public health concern of the people of Madison and Montgomery Counties about the construction and operation of these compressor stations. The problem has political, economic and public health aspects, and at present there is a lack of rigorous scientific data that can answer the major question, which is whether living near to a gas pipeline compressor station poses a significant risk to human health. The pipeline companies dismiss the self-reported health effects as being due to unjustified anxiety, and it is true that many local residents are fearful for their safety. There have been demonstrations throughout New York over the past year in opposition to these pipeline and compressor station constructions. Therefore there is an urgent need for rigorous and accurate documentation of releases from compressor stations. If releases do not exceed usual background levels this information will reassure local residents, and there is no need to do health studies. If they do exceed regulatory standards we need to define the degree of spread in the vicinity and identify the population at risk. But there is the added concern that long-term monitoring, as is usual by state and federal agencies, will miss peaks of emissions which can trigger acute health threats. Existing federal and state standards do not address the issue of these transient but sometimes very high exposures. Our approach will detect peak emissions with the Speck monitors as well as long term emissions with the Speck and others. We will also collect grab samples at times when there are scheduled blowdowns or others large releases insofar as they can be anticipated.

Another major innovative aspect of this proposal is the degree to which it is based within the local communities. The Madison County Department of Health is the organization that first reached out to initiate collaboration for such a study, and indeed through use of local funds the Director of Health, Mr. Faisst, and his staff have already collected significant information on background sources of pollutants. Dr. Julie Huntsman, DVM, in Montgomery County has organized initial efforts there to begin monitoring, and has been a major player in the development of local opposition. The site in Montgomery County has some particularly concerning features, in that it is located in a deep valley, which will contain emissions, and the valley has a number of farms owned and operated by Amish families, who do not use energy derived from natural gas but will be vulnerable to emissions.

This study will also allow us to determine emissions from the Montgomery County site coming from the existing compressor station which operates of 7410 HP turbine compressor that runs only about once or twice a week. However in their application to NYS Department of Environmental Conservation, Dominion reports that even the current compressor station releases about 1600 pounds of formaldehyde per year. These results taken before the expansion of the Montgomery County site will be valuable in comparison to those from Madison County, which is a totally new compressor station.

Dominion plans to significantly expand the Brookman's Corner compressor station in Montgomery County to 18,543 HP in order to transport an additional 112,000 Dekatherms of gas (and its associated contaminants) per day. There will also be a second 6393 HP turbine compressor, 2370 HP reciprocating compressors, coolers, and other equipment to be added. The upgraded facility will operate continuously. The Brookman's Corner compressor station is located in a valley next to Otsquago Creek, which is the center of a drainage basin which extends for approximately ten miles from the creek's headwaters to the village of Fort Plain. The prevailing winds also move in this direction. The top of the existing and proposed exhaust stacks are at a lower elevation than the valley rim, which will increase the likelihood of emissions being trapped in the valley. Dominion predicts that at full operation the Brookman's Corner site will release 4400 pounds of formaldehyde per year. There are techniques which could be applied that would reduce this amount of formaldehyde, but no current plans to implement them.

In their application to FERC, Dominion Transmission, Inc. made clear that the new turbines will burn natural gas. Using USEPA air quality modeling procedures, they report an expected emission of $PM_{2.5}$ of 13.1 tons per year from the Montgomery County site and 6.4 tons per year from the Madison County site. VOC emissions will be 24.3 tons per year from the Montgomery County site and 2.9 tons per year from the Madison County site. They anticipate a total greenhouse gas emission of 96,683 tons per year from Montgomery County and 54,351 tons per year in Madison County. The stack height in both counties will be 15.24 meters.

Approach:

Monitoring sites: Each of the two compressor stations are located in valleys that have a dominant wind direction from west to east. The goal of the monitoring program is to determine levels of particulates, VOCs, formaldehye and hydrogen sulfide at various distances from the compresor stations so as to be able to identify the geographic areas, if any, in which people are vulnerable to exposure and adverse health effects. We will obtain both average concentrations over periods of time ranging from days to weeks, as well as concentrations occuring during brief but high-release events such as blow-downs and stack tests, in so far as we have advanced warning that these will occur. Operators release gases during maintenance, start-up, and shutdown of equipment to release pressure in the pipeline system, which can result in large volumes of emissions in a short time. The largest single emission is the compressor blowdown, which can be scheduled or accidential. These blowdowns can trigger a gas plume extending upward of 30 to 60 meters, and can last for up to three hours. A related goal is to determine how often stagnant wind conditions, which could exacerbate exposures, occur over the monitoring periods.

We propose to build seven monitoring stations at each of the two compressor station sites, and obtain measures of each of the four contaminants over a period of 28 days before construction and/or expansion, during construction, during the stack test during construction, and after construction has been completed and regular operation begun. The sampling stations will be located in fields away from buildings, using fence lines after obtaining permission from owners of the property. We will place three monitoring stations directly downwind from the compressor station, the first within 0.25 mile of the compressor stations, the second at 0.75 mile and the third at 1.50 miles. We will also place two monitoring stations directly upwind from the compressor station as 0.25 and 0.75 miles, in order to catch changes in wind direction. The last two monitoring stations will be placed at right angles to the wind direction at 0.25 miles on either side of the compressor station.

Each station will be powered by a solar panel and a 12V battery, so as to be independent of needing connections to electricity and allow the monitoring to be done in open areas. This is essential, especially in Montgomery County where many of the local residents are Amish, who do not have electricity. In addiiton we hope to place many of the monitoring boxes away from buildings.

Monitoring equipment: Particulates ($PM_{0.5\text{-}3.0}$) will be determined using the Speck, a monitoring device designed by the CREATE Lab at Carnegie Mellon University (Taylor and Nourbakhsh, 2015). These small, inexpensive devices provide continuous monitoring of small particulates. The method of detection is optical, DSM501A. The Speck can display its measurement of the current concentration of fine particles in air in two different scales. The default scale is a count-based concentration – the number of particles per liter of air (ppL). The Speck counts particles in the size range 0.5 – 3.0 μM, and does not further distinguish by size.

Alternatively the Speck can report the fine particle concentration based on an estimate of the particle weight, where the units are micrograms per cubic meter of air (μg/m^3). The device has an Atmel XMEGA processor, and a sampling interval of between 5 seconds to 4 minutes. It operates either by connecting to electricity through a power adapter or through use of a battery. Speck has Wi-Fi built in, enabling optional connection to a wireless network located within 40 kilometers of a regulated $PM_{2.5}$ station. Once online, and after linking with a specksensor.com account, the Speck will continuously upload its data to specksensor.com where users can see its data in real time and explore it full history with a computer or mobile device. Each device comes already calibrated, and with established air quality ratings based on either particle counts or estimated mass. With particle counts the rating is good for 0-500 ppL, moderate for 501-1000 ppL, slightly elevated for 1001-2000 ppL, elevated for 2001-4000 ppL, high for 4001-8000 ppL and very high for 8001-16000 ppL.

Each Speck sampler will run for 28 consecutive days, and will capture information from measurement of the total area under the curve, the number of peaks, the height of peaks, and the time between peaks. Real time data from each Speck monitor will be analyzed to determine five parameters: 1) the number of peaks per day; 2) the duration of each peak in minutes; 3) the time between peaks in hours; 4) the aggregated exposure levels per day and per session; and 5) the total exposure concentration over the study period. Dr. Brown and colleagues at the SWPA-EHP have been using these devices for some time, and have considerable experience in data analysis (see Brown et al., 2014; 2015).

Volatile organics will be measured by use of Summa canisters, with measurement of up to 61 VOCs, including benzene, toluene, ethyl benzene, xylenes, 1,3-butidiene and others. These mentioned and most others have a LOQ of 0.2 ppbv. Analysis will be by EPA test TO15 using GC/MS. It will include reports on Tentatively Identified Compounds (TICs). Summa canister data collected in Pennsylvania has shown that up to an additional 50% of contaminants may be detected as TICs. Methane is not monitored, as the molecular weight is too low to be captured by the analytical method. Since the Summa canisters can collect samples over a period of seven days, four seven-day samples will be collected over the 28 day period. Hydrogen sulfide badges will be used, and these can collect information over a 15 day period. Therefore we will collect two hydrogen sulfide badges over the 28 day period, and they will be analyzed by WET-SOP-13 method. Formaldehyde badges can collect data only over a period of 24 hours. We will collect one badge of formaldehyde data one day each week for four weeks, and analysis will be using OSHA 1007 method. All analyses for VOCs, hydrogen sulfide and formaldehyde will be performed by Galson Laboratory in East Syracuse, New York. Detailed information on the Summa canisters and formaldehyde and hydrogen sulfide badges is available on the Galson website (www.galsonlabs.com). Each of the Summa canisters and formaldehyde and hydrogen sulfide badges will be obtained already calibrated from Galson Laboratories. The costs of each is for the analysis, not the purchase of the devices as they are provided by Galson Labs. Since both Madison and Montgomery counties are not far from East Syracuse, the devices will be relatively easily picked and up returned to Galson Laboratories after use.

In addition to the monitoring to be done over longer periods of time, limited only by the maximal duration of each of the samplers, we will be prepared to take grab samples measurements at specific times when we know large releases are occurring, or when we are alerted by local residents of unusual releases. These events can last for a matter of one to many hours. We have been assured that we will be informed when a blowdown is scheduled to occur, and will collect grab VOC samples, as well as 8-hour formaldehyde and hydrogen sulfide samples. The brief peaks of emissions will be captured by the Speck samples as regularly used, since they record levels every four minutes, but the sampling periods for the Summa canister and the two types of badges will be different from those used otherwise. However by having knowledge of the period over which sampling has occurred we will be able to not only document spread of air pollutants from the site, but also calculate relative air concentrations relative to federal and state air quality standards.

Meteorological data:

The Speck analyzers record temperature, but other meteorological information will come from National Weather Service stations. The station closest to the two sites is in Syracuse, which collects wind rose and surface weather data suitable for use in air quality dispersion models. This data is accessible for our use. We will use this data in five or six-hour increments, as in the previous studies of Brown et al. (2015).

Statistical analysis:

Air sampling analysis: The main purpose of statistical analysis of air sampling is to determine the spread of air contaminates from the site and quantify the exceedance fraction which is the percentage of exposures that are greater than permissible exposure limit for each chemical pollutant. Equation 1 is appropriate for use given our assumption for log-normal distribution.

Equation 1

$$f = p[c > OEL] = p\left[z > \frac{\ln OEL - \overline{x_L}}{s_L}\right]$$

Geometric mean required for the computation of exceedance fraction level will be calculated using equation 2. The 95th percentile around geometric mean will be determined by each radii (air samples from different radii of surrounding environment around the residences).

Equation 2.

$$GM = \exp(\text{or } 10^\wedge)\{\overline{x_L}\} = \exp(or\ 10^\wedge)\left\{\frac{\sum x_{Li}}{N}\right\},$$

$$x_{95\%} = \exp(or\ 10^\wedge)\{\overline{x_L} + 1.645 s_L\}\ where\ \overline{x_L} = average\ of\ \ln(or\ \log)\, x$$

Modelling of spread of emissions from the compressor stations: The air emission screening model we will use is based on one used by the Nuclear Regulatory Commission for evaluation of emissions from nuclear reactors (NRC, 2012), and an air pollution dilution model developed by Pasquill (1962). It will be applied together with real time Speck monitor information to estimate 15 minute and 5-hourly impact of emissions from the compressor stations. Details of application of the model are found on the SWPA-EHP website (www.environmentalhealthproject.org/health/air/) and also in the report of Brown et al. (2015). The manual screening model has been converted for use in RStudio. It incorporates meteorological data, geographic factors and a defined emission level from the source. The model produces the expected frequency and intensity of exposure to the contaminants over a given amount of time at specific distances. This allows identification of periods of higher ambient air levels when air dilution in poorer. At the lowest wind speeds concentration plumes can drift near the ground for several hundred yards. The model will identify frequency of such periods and project the levels in the plumes. The model will be tested using the measured concentrations at the different positions of the monitors, but has the advantage that it will allow modelling of concentrations at distances where we do not have monitoring devices placed.

Summary: The goal of this time-sensitive study is to determine the degree to which construction and operation of new and/or expanded compressor stations results in release of air pollutants from unprocessed natural gas at concentrations that pose threats to human health. These levels will be compared to background concentrations before construction. This information is critical to residents who live near these sites, and will determine whether or not it is important to conduct human health studies after the compressor stations are in full operation.