

Blackout

in the Gas Patch CASE STUDY



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THE CARR FAMILY LAKE LYNN, FAYETTE COUNTY, PA

Summary

Phyllis Carr has lived on the same quiet, wooded road in rural Lake Lynn for much of her life. Her daughter Jeaney and her husband moved in next door to raise their four children. Phyllis will gladly and proudly say that even if the family doesn't have a lot in the way of material wealth, they have riches in faith, family, and deep connections to the land and community.

But events of recent years have changed the lives of the Carrs so dramatically that they're thinking of packing up and moving away. Although there was some coal mining and conventional gas drilling in the area before, the Lake Lynn community has been hit hard by the recent drilling boom. Particularly troubling has been the expansion of the Springhill Compressor Station, located on the same road as the Carr's home.

Our research on gas wells and facilities in the area revealed plausible reasons why both gas wells and the compressor station could compromise air quality and cause related health problems. In addition, the Pennsylvania Department of Environmental Protection (DEP) was aware when it reviewed the permit application for the Springhill compressor that it would emit formaldehyde, a known carcinogen with a range of short-term health effects—but green-lighted the project anyway based on a questionable emissions comparison.

The Carrs and their neighbors have filed many complaints about noise and odors with DEP, the National Response Center, and the local fire department and submitted statements to the US Environmental Protection Agency (EPA). But to date, no official link to gas development activities has ever been made. It isn't clear whether this has had to do with time and resource constraints, insufficient information and training provided to inspectors, minimal air testing at the site, or other factors.

For more about the Carr family's experiences and fight, see:

Article from Frack Check

www.frackcheckwv.net/2011/01/17/a-good-whiff-will-put-blisters-up-your-nose/

Article from Pittsburgh Tribune

<http://triblive.com/news/fayette/1811253-74/act-council-gas-carr-troutman-connellsville-oil-resolution-butela-health#axzz32BbOhCz>

PHOTOS

ABOVE: The Carr Family. Photo by Mark Schmerling

BELOW LEFT – RIGHT:

FLIR video still, Springhill Compressor Station showing VOC emissions. Photo by Frank Finan

Tanks venting. Photo by Frank Finan

Gas equipment in the front yard near home. Photo by Nadia Steinzor/Earthworks



The Carrs say the frequent odors remind them of paint thinner and chlorine. The entire family has developed health symptoms, including fatigue, congestion, sore throats, coughs, headaches, and skin rashes. Over time, the problems have become increasingly serious. Jeaney often suffers muscle weakness, forgetfulness, and loss of sense of smell. Her three sons have had frequent coughs, nosebleeds, and tremors, and sometimes difficulty concentrating on schoolwork. One of the family dogs would sometimes cough and get a runny nose when in the yard; another recently died of a hemorrhage.

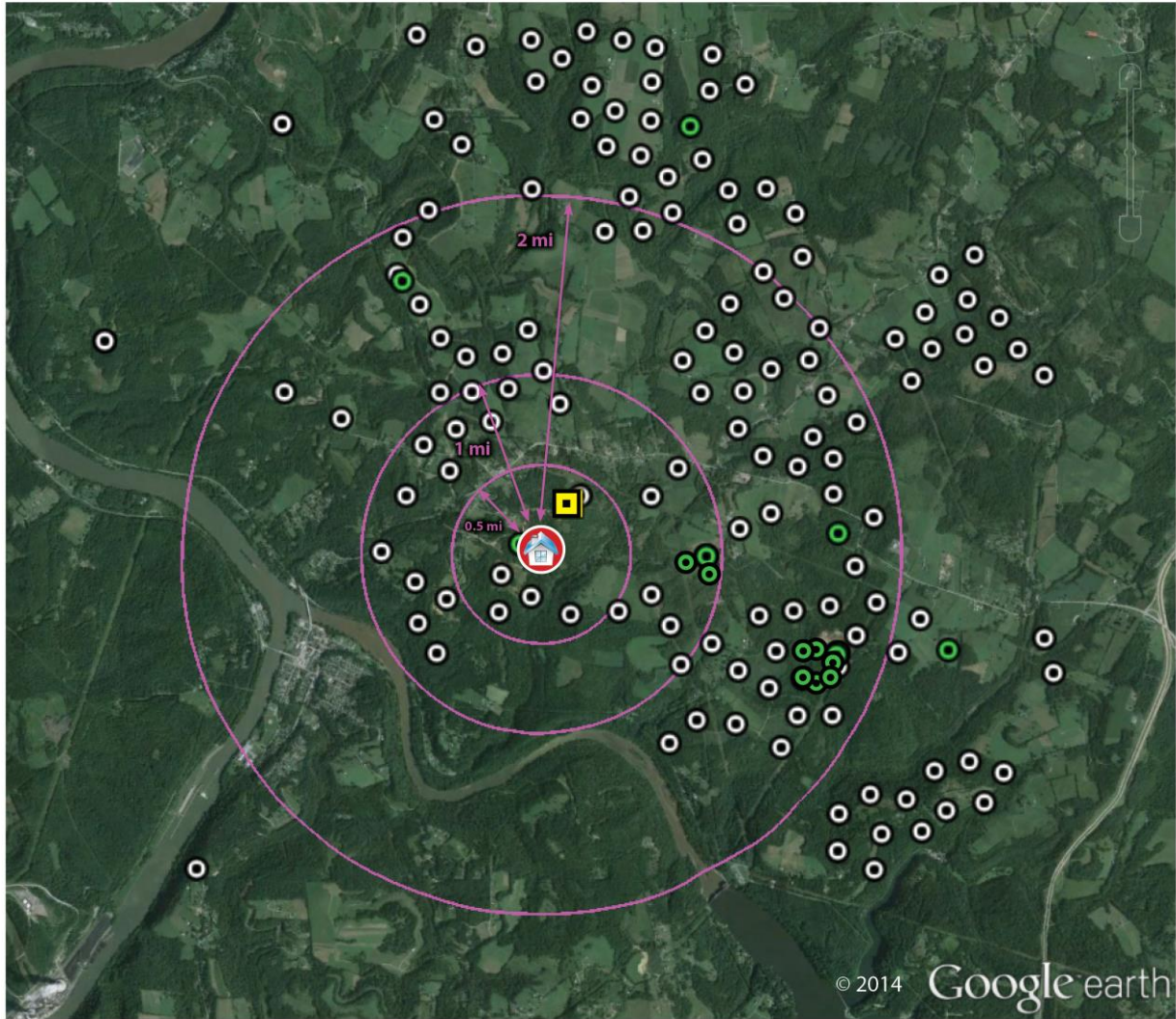
The Carrs have visited doctors in Pennsylvania and West Virginia on a long quest for answers about the pollutants to which they've been exposed. They've spoken out at town, state, and national oil and gas hearings. Together with neighbors having similar experiences, they formed a group to pressure local officials and the compressor station operator to take steps to reduce odors, noise, and emissions. Last year, a donor provided an air filter through the Southwest PA Environmental Health Project, and Jeaney and her children say they feel better when they stay indoors.

Wells and Facilities Around the Carr Home

Four unconventional and 24 conventional wells have been drilled within one mile of the Carrs. The unconventional wells were drilled in 2009-2011 and the conventional wells in 1998-2007.¹ The Springhill compressor station is located about one-third of a mile from their home.

Nine unconventional wells and 51 conventional wells are located between 1 and 2 miles of the Carrs. Two unconventional wells were drilled in 2009 and drilling has been ongoing at seven wells since late 2013.² The conventional wells at this distance were drilled in 1996-2008. See map on the next page.





KEY

- Unconventional gas well
- Conventional gas well
- Compressor station

Inspections and Violations

The following table shows oil and gas well inspections at sites within one mile of the Carr home.

Table 1. Inspections at wells and facilities within 1 mile of the Carr home (through 2013) based on data from DEP's Environment Facility Application Compliance Tracking System (eFACTS).

	Unconventional wells	Conventional wells	Compressor
Number of wells	4	24	N/A
Number of inspections	43	57	11
Average inspections per well	10.8	2.4	N/A
Wells with zero inspections	0	5	N/A
% of wells with zero inspections	0	21	N/A
Complaint inspections	0	2	5

Two DEP inspections were conducted in response to complaints about conventional wells (Baker 3 and Uphold 1), which resulted in DEP finding problems and issuing violations for discharge of polluting material to water resources of the Commonwealth and failure to notify DEP of a pollution incident. Between 1 and 2 miles, residents filed complaints about the Wolf 22 and Wolfe 25 (both conventional wells) and Wolf 27 (an unconventional well). A series of complaints have been filed related to the Springhill Compressor station; according to Pennsylvania's Environment Facility Application Compliance Tracking System (eFACTS), five of these resulted in DEP inspections of the facility.

Carr Events Timeline

The following events related to natural gas development occurring within one mile of the Carr home have been compiled from DEP inspection reports and other information available through file reviews, included in eFACTS and DEP's Oil and Gas Compliance Database, and provided by residents. Given that some inspection reports were missing from files and other documents are unavailable to the public, this timeline is not necessarily complete.

Events related to natural gas development within one mile of the Carr home.

Date	Event
6/29/04	Uphold 1: A DEP inspector finds that the freeboard inside a brine tank is high, a brine valve is leaking, and there is a discharge of brine down the slope, resulting in saturated gravel at the bottom. The inspector recommends diverting the site's stormwater away from Tomcat Hollow Road and issues a violation.
9/26/07	Baker 3: In response to a call from the property owner to the National Response Center (NRC), DEP inspects the site and reports, "...found oil floating on water located around rig and water tank. There was also an area of oil stained soil on the drill pad...The Yost driller stated that approx. fifty gallons of hydraulic oil had been spilled on the ground...The DEP was not notified of this spill in timely manner." The property owner also reports to NRC that in attempting to clean up the spill, the driller sprayed water over the oil and spread it onto a larger area of land. An NRC report on a different call earlier that day states, "Caller reported that a shaft broke on a drilling rig and released 150 gallons of motor oil onto the ground. Caller stated that they are washing the oil with water over a hill and doesn't know what is on the other side."
3/11/09	Zinn Unit 2: DEP issues an alternative waste management waiver (known as form OG71) for the onsite burial of drill cuttings, which Atlas Resources states will be done using cement for solidification. The Carrs have said that a waste pit on the Zinn site was buried upslope from their property, and have wondered whether surface seepage of an oily fluid behind their house might be from the pit leaking. The only way to confirm that the waste pit was buried, its dimensions, and what it may have contained would be with a well restoration report, which operators are required to file with DEP; however, the restoration report for Zinn 2 is long overdue and was missing from the hard copy DEP file we reviewed.
10/05/10	Springhill 2 Compressor Station: According to eFACTS, DEP conducts an inspection in response to a complaint. However, this inspection report was not in the hard copy file we reviewed and no complaint for this date was included in any of the Complaint Tracking System records provided by DEP.
11/02/10	Springhill 2 Compressor Station: According to eFACTS, DEP conducts inspection in response to a complaint. However, this inspection report was not in the file we reviewed and no complaint for this date was included in any of the Complaint Tracking System records provided by DEP.
2/16/11	Zinn 3, 4, 5: A DEP inspector conducts a follow up inspection due to a complaint filed the day before about an explosion in Lake Lynn. According to DEP's Complaint Tracking System, the complainant reported that it shook houses and caused property damage.
2/23/11	Springhill Township: A DEP complaints record notes that the NRC received a call "Advising a smell from a compressor and a dehydrator on a natural gas drilling site has been reported. The smell is affecting the health of the people in the nearby areas. This has been going on for over a year. Point of contact is Complainant #1." In response, a DEP inspector visits the Springhill Compressor Station and notes in a report that, "No odors out side of fenced in area. E&S [Erosion & Sedimentation] is outstanding. Air Quality is doing annual inspection today... No excessive noise on this location."
3/25/11	Springhill 2 Compressor Station: A DEP inspector notes in a report, "Investigated allegations of unauthorized construction and chemical odors...No odors or malodorous emissions were observed...Construction activity was limited to pipeline work and parking lot expansion. The compressor station itself has not been constructed upon since 11/2/2010 visit."
7/22/11	Springhill 2 Compressor Station: DEP conducts an inspection in response to a complaint and notes in a report that, "Investigated 3rd party allegation that unpermitted engines had been installed. Found site unchanged since Mar. 25 visit. No evidence of additional construction."
3/15/12	Chico 3H: A DEP inspector performing an administrative review in June notes that Chevron reported a spill of two barrels of synthetic oil-based drilling mud due to a burst hose, stating that it was properly reported and cleaned up and the material was reused for drilling.

3/19/12	Springhill 2 Compressor Station: DEP conducts a complaint inspection and notes in a report that, "...Toured station inside and out. New construction below station...Spoke with complainant about gas odors. Incident reported on 3/6/12." Perhaps because this inspection was conducted nearly two weeks after the complaint was filed, the DEP inspector also noted, "No stray gas reported by station operator. No odors off property while we were there."
9/17/12	Springhill Township: A DEP complaint record notes that while a resident called DEP about possible water contamination, "...this complainant also said she has air quality issues - allegedly tested /collected air data from monitoring on her property showing potential compressor station issues."
2/14/13	Chico 1H: A DEP inspector performing an administrative review indicates that Chevron reported a small (0.012 gallons) spill of motor oil from a leaking truck, but states that it was properly reported and cleaned up.
6/4/13	Uphold 1: A DEP inspector finds that the operator (Oil & Gas Management Inc.) spilled a mixture of oil and brine onto the ground around a tank and did not report the spill to DEP.
10/15/13	Springhill Township: A record in the DEP Complaints Tracking System notes, "Construction of Springhill to Bezjak Pipeline has caused dimunition to pond...Pond water level is dropping and water appears to be thick, black and tar-like and owners are afraid it is becoming stagnant." (The Bezjak property is next to the Springhill Compressor and across the road from the Carrs.)

Water Quality

According to DEP information provided to the Scranton Times-Tribune and mapped by the FracTracker Alliance, the closest water complaint to the Carrs was 1.92 miles away.³ Two complaints were made related to water contamination in spring 2010, but DEP's investigation did not establish a link to oil and gas operations.

Nonetheless, the Carrs and their neighbors have had concerns about drilling potentially compromising the city water supply to which they are connected. In February 2012, the local water authority sent letters to Lake Lynn residents about drinking water standards being exceeded for haloacetic acids (HAA5), a byproduct of water disinfection processes.⁴ According to a copy of the letter shown to Earthworks, some people drinking water with excessive levels of HAA5 "may experience problems with their livers, kidneys, or central nervous system, and may have an increased risk of getting cancer."

A September 2012 record from DEP's Complaint Tracking System notes, "Water has haloacidic [sic] (HAA5s) acid in it and complainant feels her and her neighbors are developing serious health issues from this...Notice was mailed by Albert Gallatin MA regarding HAA5s detected in the public water distribution system. This is apparently a by-product of disinfection. This is not related to drilling or gas compressor stations." It is worth noting that elevated levels of trihalomethanes (another disinfection byproduct) have been associated with gas drilling, due to the interaction of chlorination and bromides in the wastewater—and that such a process may also occur with HAA5.⁵

Air Quality

The 4 unconventional wells and 24 conventional wells drilled within 1 mile of the Carr home have contributed to air pollution during drilling and completion stages, and many continue to release emissions on an intermittent or continual basis. The nearby Springhill compressor station is an ongoing source of local air emissions. In addition, 2 unconventional and 51 conventional wells located between 1 and 2 miles from the Carr home have been drilled and are producing gas, and contribute to regional air pollution.

Emissions from unconventional wells and facilities

DEP's emissions inventory database includes the Springhill 2 Compressor Station and the 4 unconventional wells that are within 1 mile of the Carrs: Zinn Unit 2 (0.13 miles) and Chico Unit wells 1H, 2H, and 3H (0.92 miles). The table below shows emissions levels at these locations in 2011 and 2012.

Table 2. Emissions from wells and facilities within 1 mile of the Carrs (DEP emissions inventory data).

Facilities		CO	NOx	PM10	PM2.5	SOx	VOC	Benzene	Ethyl-benzene	Formaldehyde	n-Hexane	Toluene	Xylene	2,2,4-TMB*
Zinn 2 well	2011	0	0	0	0	0	0.012	0	0	0	0.006	0.003	0	0
	2012	0	0	0	0	0	0.009	0	0	0	0.004	0.002	0	0
Chico Unit 1H well	2011	0.78	3.99	0.131	0.131	0.119	0.147	0.002	0	0.002	0	0.001	0.001	0
	2012	1.84	7.61	0.278	0.278	0.173	0.338	0.004	0	0.003	0	0.002	0.001	0
Chico Unit 2H well	2011	0.89	4.59	0.151	0.151	0.137	0.169	0.002	0	0.002	0	0.001	0.001	0
	2012	2.54	11.34	0.400	0.400	0.273	0.478	0.005	0	0.005	0	0.002	0.002	0
Chico Unit 3H well	2011	0.42	2.15	0.071	0.071	0.064	0.079	0.001	0	0.001	0	0.000	0.000	0
	2012	2.01	8.51	0.307	0.307	0.197	0.371	0.004	0	0.004	0	0.002	0.001	0
Springhill 2 Compressor	2011	13.07	30.27	0.802	0.802	0.047	23.15	0.156	0.014	5.42	0.389	0.233	0.294	0.026
	2012	15.75	26.86	0.952	0.952	0.056	16.12	0.352	0.021	3.44	0.401	0.569	0.0636	0.030
TOTAL	2011	15.16	41.0	1.15	1.15	0.37	23.56	0.16	0.014	5.43	0.40	0.24	0.30	0.03
	2012	22.13	54.32	1.94	1.94	0.70	17.36	0.36	0.02	3.46	0.41	0.58	0.07	0.03

As seen from the table above, total emissions of most air contaminants from the wells and facilities within 1 mile of the Carrs were higher in 2012 than in 2011. This is in large part due to the continued drilling and completion of the Chico Unit wells.⁶ These activities typically release more air pollutants than do well sites that are completed and are in production. The Zinn 2 well did not have large emissions in either year, having been drilled and completed in 2009; the only reported sources of emissions from this site were tanks and fugitive emissions.⁷

The Springhill compressor was by far the largest single contributor to air emissions close to the Carrs. Compressor emissions of nitrogen oxide (NOx), Volatile Organic Compounds (VOCs), formaldehyde, and xylenes were considerably less in 2012 than in 2011, but during that time period all the other documented pollutants increased (such as benzene, toluene, and particulate matter). Given that DEP has collected and issued only two years of emissions data, it's not clear if the increase in emissions of various chemicals represents an upward trend, or whether the emissions will continue to fluctuate from one year to the next.

The close proximity of the Springhill compressor to the Carrs and their neighbors is a significant concern. A Colorado School of Public Health study of air emissions around gas well operations found that residents living less than a half mile away are at higher risk of respiratory, neurological, and other health impacts and have a higher lifetime risk for cancer, based on exposure to pollutants.⁸

As detailed in the timeline above, residents have filed complaints with DEP related to the compressor; complaint inspections that we reviewed related to “chemical odors” and “gas odors.”⁹ While both odors and visible emissions can dissipate quickly, they reflect the episodic nature of gas and oil field pollution events that impact health.¹⁰ In addition, odors can serve as a warning sign of the presence of a pollutant in the air and associated health risks.¹¹

To understand how the emissions from natural gas facilities compared to other sources of air pollution in Fayette County, we reviewed annual emissions information for major facilities in the state included in eFACTS. As seen in the table below, **if the four wells within one mile of the Carr home were considered as one facility, it would have been among the top five emitters of NOx, sulfur oxide (SOx), benzene, and formaldehyde in Fayette County in 2012. The Springhill 2 Compressor Station had the highest carbon monoxide (CO), benzene, and formaldehyde emissions of any facility in Fayette County, and was among the top five emitters of NOx, VOCs, and SOx.**

Table 3. Ranking of natural gas facilities near the Carr home, compared to top emitters in Fayette County, PA (eFACTS data, 2012).

Rank	CO	NOx	VOC	SOx	Benzene	Formaldehyde
1	Springhill Compressor	Fayette Energy Power Station	Hunter Panel Plant	German Twp Sewage Trt Plant	Springhill Compressor	Springhill Compressor
2	Gans Power Station	4 wells near Carrs	Brownsville Marine Prod.	4 wells near Carrs	North Summit Compressor	Shamrock Compressor
3	North Summit Compressor	Springhill Compressor	Fayette Energy Power Station	Shamrock Compressor	4 wells near Carrs	North Summit Compressor
4	German Twp Sewage Trt Plant	German Twp Sewage Trt Plant	Springhill Compressor	Springhill Compressor	Millsboro Steam Plant	Uniontown Compressor
5	Fayette Energy Power Station	Shamrock Compressor	Uniontown Compressor	Uniontown Compressor	Fayette Energy Power Station	4 wells near Carrs

In 2011 and 2013, Earthworks conducted air tests at the Carr home. As seen in the table below, eight different VOCs were detected, seven of which are considered to be hazardous air pollutants (HAPs).¹² Also known as toxic air pollutants or air toxics, HAPs cause or may cause cancer or other serious health effects, such as reproductive problems or birth defects, or adverse environmental and ecological effects, and are regulated by the EPA.¹³

In May 2013, DEP conducted sampling at the Carr home in response to an odor complaint. The DEP sample contained several of the same VOCs found in Earthworks’ samples (benzene, carbon tetrachloride, dichlorodifluoromethane, methylene chloride, trichlorofluoromethane, and toluene), as well as three additional VOCs that were not analyzed by the lab we used (propene, acrolein, and n-hexane; the latter two are HAPs).



According to DEP, some of the VOCs found near the Carrs are present in ambient air because they were once widely used and persist in the atmosphere, but several are likely related to Marcellus shale activities, including acetone, benzene, propene, and toluene.¹⁴

Nearby wells and the Springhill compressor station are the most obvious sources of chemicals in air around the Carrs. Both the number of chemicals detected and the concentrations of most chemicals were lower in our 2013 canister tests than in 2011—which makes sense given that all of the well drilling and completion activity to date within one mile of the Carrs was over by April 2013.

Table 4. VOCs detected in ambient air near the Carr home. (All Earthworks data except for DEP data marked *).

Concentrations are in micrograms per cubic meter (µg/m ³)	Oct. 12, 2011	May 1, 2013*	June 21, 2013	July 13, 2013	Aug. 17, 2013	Sept. 15, 2013
1,3-Dichlorobenzene			6.7	--	--	--
1,1,2-Trichloro-1,2,2-trifluoroethane	0.67		0.62	0.62	0.61	--
2-Butanone			1.2	--	--	--
Acetone			11	8.6	--	--
Acrolein		0.44				
Benzene	0.36	0.26	--	--	--	--
Carbon tetrachloride	0.60	0.60	0.60	0.67	0.58	0.56
Chloromethane	1.2	1.4	1.0	1.0	0.81	1.0
Dichlorodifluoromethane	2.5	3.1	--	--	--	--
Ethylbenzene	0.27		--	--	--	--
Methylene Chloride	2.3	0.33	--	--	--	--
n-Hexane		0.42				
Propene		0.77				
Toluene	0.78	0.1	0.95	0.71	0.90	0.68
Trichlorofluoromethane	1.6	1.4	1.5	1.5	1.4	1.3
Total chemicals detected	8	10	8	6	5	4

Blank cell – not analyzed

-- not detected

Note: DEP data converted from parts per billion volume (ppbv) to microgram per cubic meter (µg/m³).

Because most VOCs do not have associated air quality standards, it is difficult to assess the potential for each individual chemical, or the combination of several chemicals together, to cause health effects—underscoring the importance of paying attention to health symptoms and changes that residents report.

The concentrations of toluene measured at the Carr home were less than 1 microgram per cubic meter (µg/m³), which is lower than what has been measured in urban areas but higher than in some

undeveloped rural areas (which Lake Lynn is).¹⁵ Benzene concentrations at the Carr home detected on two occasions were also lower than what has been measured in many urban areas.¹⁶

The World Health Organization's (WHO) air quality guidelines for these contaminants, averaged over a week, indicate that people would be protected from non-cancer health effects at the concentrations detected at the Carrs. EPA estimates that if an individual were to continuously breathe the air containing benzene in the range found at the Carrs (i.e., an average of 0.13 to 0.45 µg/m³) over his or her entire lifetime, that person would theoretically have no more than a one-in-a-million increased chance of developing cancer.¹⁷

However, chronic exposure to even low levels of chemicals can cause short- and long-term impacts.¹⁸ In addition, WHO states that, "the approach taken in the preparation of the guidelines was to evaluate data on the health effects of individual compounds. Consequently, each chemical was considered in isolation. Pollutant mixtures can yield different toxic effects, but data are at present insufficient for guidelines relating to mixtures to be laid down."¹⁹ This reinforces a recent study that underscores how exposure to multiple chemicals such as inhalable particles (PM_{2.5} and PM₁₀) and air toxics (VOCs and HAPs) increases the dose synergistically, with a greater health effect felt than if these contaminants were inhaled separately.²⁰

The Earthworks canister samples were taken at times when we assumed that the Springhill compressor station was operating "normally."²¹ The DEP conducted air testing in response to an odor complaint, but it is unclear if odors were noticeable at the time that DEP collected samples. Compressor stations occasionally undergo maintenance or emergency situations where they are "blown down," which means they vent gas directly to the atmosphere. During these relatively short periods of time, nearby residents may be exposed to much higher concentrations of chemicals than are typical. Unfortunately, Pennsylvania does not require operators of compressor stations to monitor concentrations of chemicals at nearby residences during blowdowns. Without this information, it is not possible to fully assess potential health effects related to emissions from compressor stations.

In addition, the air canister samples did not measure pollutants of concern such as formaldehyde. Nor did DEP test separately for formaldehyde at any point, although according to eFACTS, the **Springhill compressor station releases tons of formaldehyde every year, more than any other Fayette County facility listed.** Formaldehyde has been classified as a known human carcinogen (cancer-causing substance) by the International Agency for Research on Cancer, and as a probable human carcinogen by the EPA.²² Although reaction to formaldehyde varies, when present in air it may cause some individuals to experience short-term effects such as burning or watery eyes; nose and throat irritation; coughing or wheezing; nausea; and/or skin irritation.²³

When the Springhill compressor project was being reviewed for issuance of an air quality permit, DEP stated that, "Formaldehyde is a known carcinogen and the primary HAP expected to be emitted from air contamination sources at Springhill."²⁴ However, DEP did not ask the operator, Laurel Mountain Midstream, to analyze the potential for its formaldehyde emissions to impact the health of nearby residents. Instead, DEP compared the Springhill Compressor's estimated formaldehyde emissions to those of two landfills. Air dispersion modeling and risk assessment showed that cancer and non-cancer risks related to formaldehyde emissions from the landfills were below DEP's human health risks benchmarks.

Because the potential “worst-case” levels of formaldehyde emissions from the Springhill Compressor were deemed to be less than those from the landfills, DEP appeared to accept that there would be no health impacts from the compressor. Yet DEP acknowledged that the comparison between the compressor and landfills was “not absolute due to possible differences in local terrain and meteorological data.”²⁵

The DEP’s use of landfill models to justify that emissions of formaldehyde from the Springhill Compressor would be within acceptable health levels is a highly questionable approach to analyzing risks and permitting a natural gas facility. As described in the *Good Practice Guide for Atmospheric Dispersion Modelling*, “If wind speed and/or direction are not known accurately, then the emissions from one grid cell can either add to or miss the other completely. This can result in errors of up to $\pm 100\%$ in the total concentration of emissions.”²⁶ DEP’s reliance on second-hand analyses that do not pertain to actual local air quality conditions and potential toxic exposures fails to protect the health of residents such as the Carrs, who live very close to facilities that emit large volumes of HAPs.

Endnotes

¹ Seven unconventional wells (Knight Unit 14H - 20H) were spud in December 2013, but there is no production on record yet. Production records lag, so it was assumed that these have been drilled. Also, there are drilling inspections that were conducted on these wells as recently as March 2014, so in all likelihood they have progressed beyond spudding, and therefore impacts such as drilling emissions would have occurred at these sites.

² Drilling was started on the Knight Unit wells (14H, 15H, 16H, 17H, 18H, 19H and 20H), i.e., they were spud, in late 2013. According to eFacts, these wells have all received numerous drilling inspections, some as recently as June 2014, but as of August 2014 the DEP Oil and Gas Production database does not show any gas production from the wells. (Sources: Efacts: <http://www.ahs.dep.pa.gov/eFACTSWeb/>; Oil and Gas Production database: <https://www.paoilandgasreporting.state.pa.us/publicreports/Modules/Welcome/Welcome.aspx>)

³ Scranton Times-Tribune, May 19, 2013. “Gas Drilling Complaints Map.” <http://thetimes-tribune.com/news/gas-drilling-complaints-map-1.1490926>.

⁴ US EPA. “Basic Information about Disinfection Byproducts in Drinking Water: Total Trihalomethanes, Haloacetic Acids, Bromate, and Chlorite.” <http://water.epa.gov/drink/contaminants/basicinformation/disinfectionbyproducts.cfm>.

⁵ Don Hopey, “Bromide: a concern in drilling wastewater.” *Pittsburgh Post-Gazette*, March 13, 2011. See also Shankar Chelam, “Bromide Influence on Trihalomethane and Haloacetic Acid Formation.” *Water Encyclopedia 2005*.

⁶ Data provided by M. Rudawski at PA DEP. Shows the source type of the various emissions.

⁷ To determine this, we used detailed natural gas inventory emissions inventory provided by DEP, which shows the source type of the various emissions. Data provided by M. Rudawski at PA DEP.

⁸ Lisa M. Mckenzie, Roxana Z. Witter, Lee S. Newman and John L. Adgate, Human health risk assessment of air emissions from development of unconventional natural gas resources. *Science of the Total Environment* March 21, 2012.

⁹ PA DEP Complaint ID: 278193. “Chemical odors” cited in 3/25/2011 inspection report; Complaint Inspection, eFACTS ID: 2051948 “Gas odors” cited in 3/19/2012 inspection report.

¹⁰ David Brown, Beth Weinberger, Celia Lewis, and Heather Bonaparte, “Understanding exposure from natural gas drilling puts current air standards to the test.” *Reviews on Environmental Health*, Vol. 29, 2014.

¹¹ S. Schiffman, “Science of Odors as a Potential Health Issue.” *Journal of Environmental Quality* Vol. 34, 2005.

¹² Including benzene, toluene, trichlorofluoromethane (CFC 11); 1,1,2-trichloro-1,2,2-trifluoroethane (Freon 113); trichloroethene/trichloroethylene (TCE); dichlorodifluoromethane (Freon 12); tetrachloroethylene/tetrachloroethene (PCE). See US EPA Air Toxics web site: “Original list of hazardous air pollutants.” <http://www.epa.gov/ttn/atw/orig189.html>

¹³ EPA Air Toxics website: “Pollutants and Sources.” www.epa.gov/ttn/atw/pollsour.html

¹⁴ PA DEP. *Southwest Pa. Marcellus Short-Term Air Sampling Report*. 2010.



¹⁵ World Health Organization. *WHO Air Quality Guidelines for Europe*. 2nd Ed. Chapter 5.14. Toluene. 2000. According to the WHO, 2-hour concentrations of toluene in forested, rural area of California were measured at 0.3-0.45 ug/m³, while urban samples contained 7.1 - 9.6 ug/m³. A screening study involving 14 US urban sites showed an average 24-hr concentration of 17 ug/m³.

¹⁶ Ibid.

¹⁷ US EPA website: "Benzene." www.epa.gov/ttn/atw/hlthef/benzene.html

¹⁸ David Brown, Beth Weinberger, Celia Lewis, and Heather Bonaparte. "Understanding exposure from natural gas drilling puts current air standards to the test." *Reviews on Environmental Health*, March 2014.

¹⁹ *WHO Air Quality Guidelines for Europe*. 2nd Ed. Chapter 3. "Summary of the Guidelines."

²⁰ David Brown, Beth Weinberger, Celia Lewis, and Heather Bonaparte. "Understanding exposure from natural gas drilling puts current air standards to the test." *Reviews on Environmental Health*, March 2014.

²¹ Nearby residents did not alert us to any strong odors or events during our sampling periods. There is no easy way for the public to determine if operators reported problems to DEP, and no way to determine if operators experienced problems that led to excessive emissions at any given time.

²² National Cancer Institute. "Formaldehyde and Cancer Risk." www.cancer.gov/cancertopics/factsheet/Risk/formaldehyde

²³ World Health Organization. *WHO Air Quality Guidelines for Europe*. 2nd Ed. Chapter 5.8. Formaldehyde.

²⁴ Parihar, J. Air Quality Engineering Trainee, to Air Quality Permit File GP6-26-00587B. January 9, 2012. "Review of General Permit Application Laurel Mountain Midstream Operating, LLC Springhill Compressor Station, Springhill Township, Fayette County." Auth# 894174, APS#7 59362, PF#7 19219.

²⁵ Ibid.

²⁶ National Institute of Water and Atmospheric Research, Aurora Pacific Limited, and Earth Tech Incorporated. *Good Practice Guide for Atmospheric Dispersion Modelling. Air Quality Technical Report 27. New Zealand Ministry of Environment*. 2004.

