AERMOD Compressor Station Emission Dispersion Impacts & Sensitivity Analysis

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INTRODUCTION

The rise of the Marcellus Shale play, and natural gas fracking methods have led to the installation of over 200 compressor stations in Pennsylvania. Compressor stations help maintain the flow of natural gas in transportation from the well-pad to the market via pipelines. While doing so, they emit air pollutants such as NO2, SO2, and PM2.5, in concentrations that could affect the health of residents at the setback perimeter of 500 meters.

At 5 select compressor stations in the Marcellus Shale, meteorological data and Gaussian Plume models developed through the AERMET & AERMOD programs were used to quantify the impact of such pollutant exposure, in terms of potential people exposed, and additional economic costs like health care coverage.

1 of 5 stations analyzed was the Tonkin Compressor Station, located in West Union, WV, where the setback distance is 625 meters.

OBJECTIVES

- Answer the following questions:
  - How does the air dispersion of SO2, NO2, and PM2.5 impact the residents' health/safety in the area surrounding the compressor station setback perimeter?
  - How large of a role does downwash from the stacks' tip play in pollutant dispersion and concentration magnitude?
- Account for the conditions where the variance in precipitation rate and terrain changes affect the absorption/dispersion of air pollutants from a point source.
- Quantify the number of households that would have been exposed to air pollutant levels above the EPA regulatory daily and annual limits.
- Estimate the economic costs, if any, from decreased health.

METHODS

- Primarily applied PA DEP data sums to find NO2, SO2, and PM2.5 emission totals for compressor stations.
- Plotted 37 stacks across 5 compressor stations as point sources in AERMOD - UTM coordinates extracted from Google Earth imagery.
- Extracted meteorological surface data and upper-air sounding data for input into AERMET.
- Terrain data download for model extents set within AERMOD.
- AERMOD used a multitude of calculations to ultimately to construct a 1x1 km concentration matrix over 1600+ different receptor points – which can be smoothed into a dispersion contour graph.
- Body proportions and average height data from online sources were used to estimate the average height of the nostril entrance of a person in the United States for the breathing-level plane for air pollutants.
  - This determined the z (height) plane at which the pollutant concentrations would be modeled at.
- Online sources were used to factor in local average temperatures, instead of the standard 25 degrees C, when converting from the ppb & ppm levels to micrograms per cubic meter ($\mu g/m^3$).

$$C_d\{x_r, y_r, z\} = \frac{Qf_p}{\sqrt{2\pi}\tilde{u}} F_y \cdot \sum_{j=1}^{2} \sum_{m=0}^{\infty} \frac{\lambda_j}{\sigma_{zj}} \left[\exp\left(-\frac{(z - \Psi_{dj} - 2mz_i)^2}{2\sigma_{zj}^2} \right) + \exp\left(-\frac{(z + \Psi_{dj} + 2mz_i)^2}{2\sigma_{zj}^2} \right) \right],$$

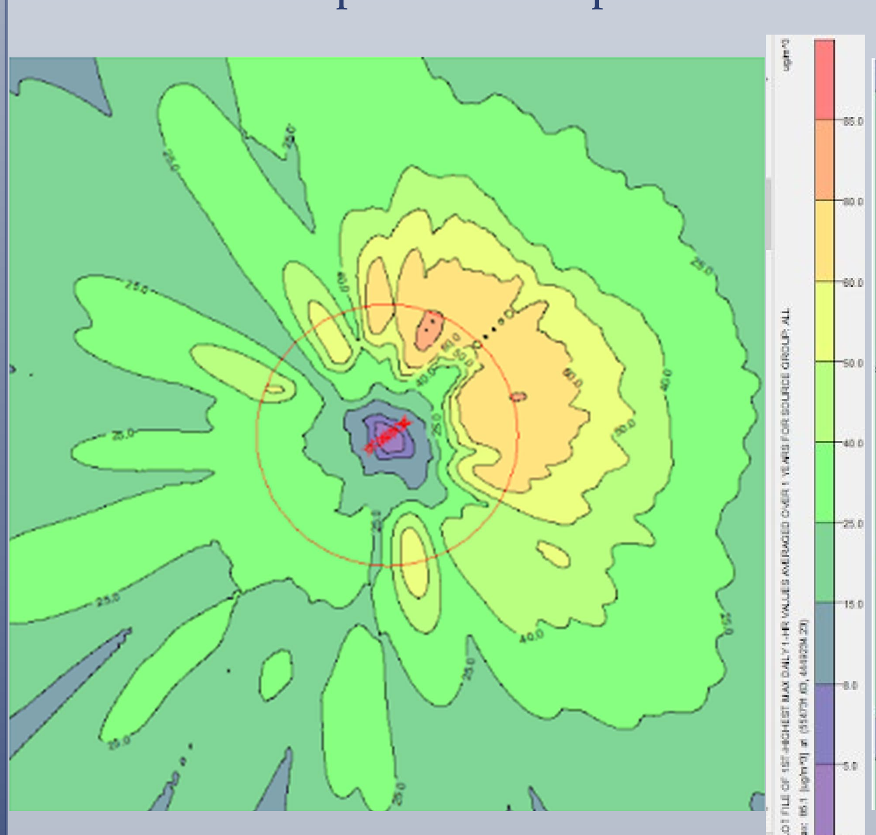
Pollutant [links to historical tables of NAAQS reviews]		Primary/ Secondary	Averaging Time	Level	Form
Nitrogen Dioxide (NO_2)		primary	1 hour	100 ppb	98th percentile of 1-hour daily maximum concentrations, averaged over 3 years
		primary and secondary	1 year	53 ppb [2]	Annual Mean
Particle Pollution (PM)	$PM_{2.5}$	primary	1 year	12.0 $\mu g/m^3$	annual mean, averaged over 3 years
		secondary	1 year	15.0 $\mu g/m^3$	annual mean, averaged over 3 years
		primary and secondary	24 hours	35 $\mu g/m^3$	98th percentile, averaged over 3 years
	PM_{10}	primary and secondary	24 hours	150 $\mu g/m^3$	Not to be exceeded more than once per year on average over 3 years
Sulfur Dioxide (SO_2)		primary	1 hour	75 ppb [4]	99th percentile of 1-hour daily maximum concentrations, averaged over 3 years
		secondary	3 hours	0.5 ppm	Not to be exceeded more than once per year

LIMITATIONS/ASSUMPTIONS

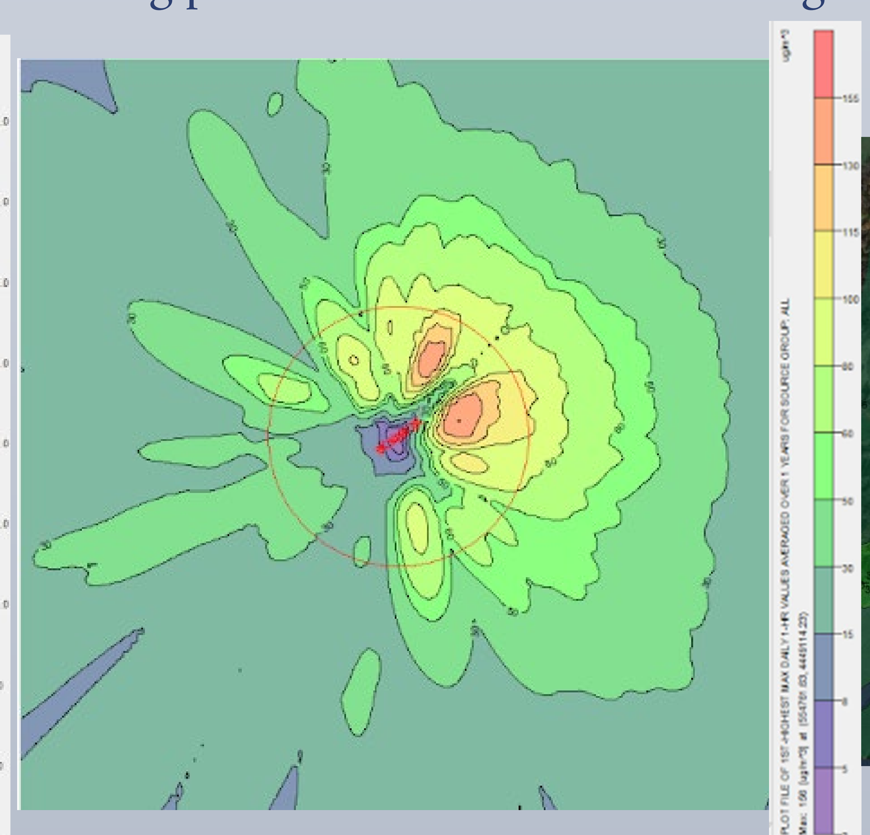
- Missing meteorological variables, such as dew point temp., are AERMOD-interpolated from adjacent hourly data.
- Assumed compressor station plant grounds have a 20 m radius from which the 500 ft (152.4 m) setback distance from which the commercial and residential buildings extend outward from.
- Trees and buildings are not accounted for in the Terrain data
- Meteorological data from the closest airports will vary slightly compared to the actual weather experienced at sites. Weaknesses of using the AERMOD Regulatory Modeling process include:
  - Wind gusts are not truly accounted for under hourly wind speed data – no AERMINUTE to obtain 1 Minute ASOS Data.
  - Stack tip diameter and height were estimated from compressor station & Google Earth imagery.
  - Does not include the existing-state air pollutant concentrations in its calculations.

RESULTS

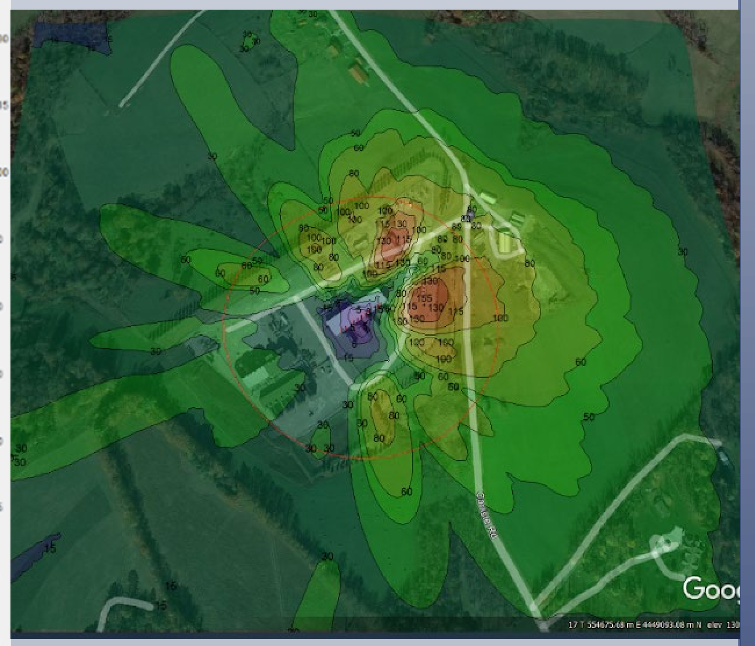
- 1x1 km air pollutant dispersion at a breathing plane of 1.56398 meters above ground:



Shaw Compressor Station's 2019 NAAQS NO2 dispersion without downwash – max. conc. of 85.08 $\mu g/m^3$ (located inside the setback distance), max. conc. outside of the perimeter is 82.28 $\mu g/m^3$.



Shaw CS's 2019 NAAQS NO2 dispersion with downwash – max. conc. of 155.95 $\mu g/m^3$ (located inside the setback perimeter), max. conc. outside of the perimeter is 107.52 $\mu g/m^3$.

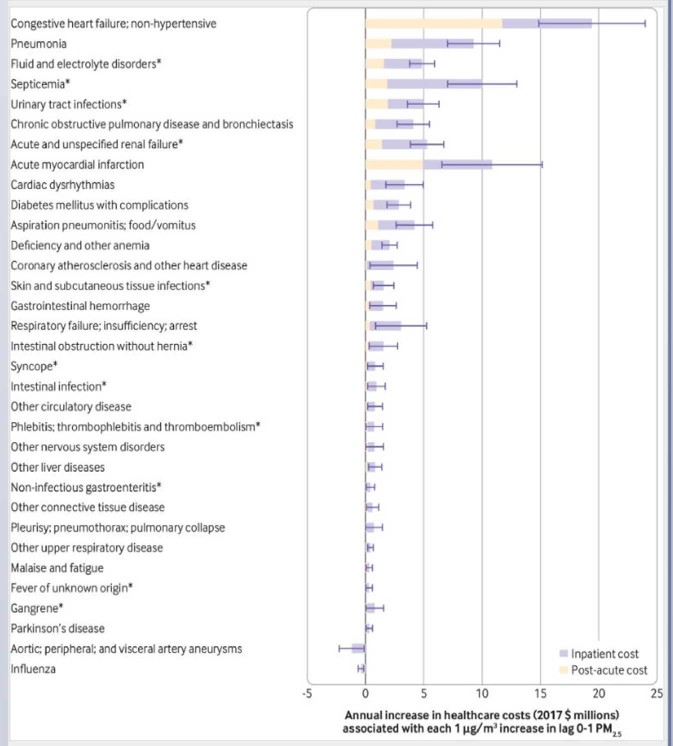


Google Earth Image of the center dispersion graph (same scale) –notice the houses that experience higher NO2 concentrations in 2019.

CONCLUSIONS

At the largest NO2 emitter of the 5 compressor stations (Shaw CS), there are no areas outside of the setback distance that had a conc. greater than the EPA's primary limit of 196.44 $\mu g/m^3$ (100 ppb), even when the Northeastern average NO2 level (EPA data averaged from 19 sites) of 76.93 $\mu g/m^3$ is added to the max. conc. outside the perimeter (107.52 $\mu g/m^3$). However, there is a significant area outside of the setback distance (most of the yellow area: 80-100 $\mu g/m^3$) that eclipses the 196.44 $\mu g/m^3$ limit when the 90th percentile of Northeastern NO2 levels (112.95 $\mu g/m^3$) is applied in addition to Shaw CS's point source NO2 conc. contributions (with downwash). Contrarily, there are no areas outside of the circle that eclipse the 196.44 $\mu g/m^3$ limit when there is no stack-tip downwash at the Shaw Compressor Station. Thus, it appears that stack-tip downwash can play a significant role in air emission dispersion from point sources.

For the largest PM 2.5 emitter of my researched stations, the Smith CS has a significant area outside of the setback perimeter that has a concentration of 0.9-0.996 $\mu g/m^3$. Some of the effects of a 1 $\mu g/m^3$ increase in PM 2.5 can be seen in the adjacent figure.



www.bmj.com/content/367/bmj.l6258 - figure 6

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