Health Risks of Living in Close Proximity to Oil and Gas Development

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From Wellhead to Ethane Cracker: Shale Gas, Petrochemicals, and Health

SW PA Environmental Health Project

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Blowouts, Explosions, & Evacuations

Haley M, McCawley M, Epstein AC, Arrington B, Bjerke EF. Adequacy of Current State Setbacks for Directional High-Volume Hydraulic Fracturing in the Marcellus, Barnett, and Niobrara Shale Plays. Environ Health Perspect; http://dx.doi.org/10.1289/ehp.1510547 Feb 9, 2016

Marcellus Shale Blowouts- examples

- 7 June 2010 Moundsville WVa
  - **7 hospitalized in burn unit**
- June 2012 Tioga Co- **1 mi evac**
- March 2013 Wyoming Co
  - **1500' evac zone, 3 families**
- 11 Feb 2014 Dunkard PA- 3 wells
  - **1 worker killed, 1 injured**
- Oct 2014- Jefferson Co. OH
  - **400 families evacuated**

Avg evacuation zone in the 3 shales:

- **0.8 miles** (range 660-13,200 ft)

Avg no. of families/homes displaced

- **49** (range 3 to 500)

Image from Fox News, 6/7/10, re gas well explosion near Granberry TX. Fire visible 30 miles away

Risk of Burns from Blowout Fires

Haley M, McCawley M, Epstein AC, Arrington B, Bjerke EF. Adequacy of Current State Setbacks for Directional High-Volume Hydraulic Fracturing in the Marcellus, Barnett, and Niobrara Shale Plays. Environ Health Perspect; http://dx.doi.org/10.1289/ehp.1510547 Feb 19, 2016

500 feet from a well fire :

- 2nd degree burns
  - after 30 min

350 feet from a well fire:

- 2nd degree burns
  - after 22 secs

How long does it take to evacuate a school?

- Sandy Hook Elem:
  - 30 min

Texas RRC setback distances from well to a residence

- 200 feet

(For a typical gas well producing 5.8 cu ft / day, pipe diameter 6 in. Methane burns @ 3452 degrees F. Calculations for outdoor exposure.)

Image: theexaminer.com: gas well blowout in 2011, in Village Creek State Park in East Texas

How often do wells explode?

Is reporting "significant damage" transparent? Assessing fire and explosion risk at oil and gas operations in the United States, Blair et al, *Energy Research and Social Science* 11 May 2017

- No comprehensive US data base
- **Colorado** 116 events 2006-2015
  - Annual rate 0.03% per well
  - Avg 31 residences w/in 1 mile of an explosion, max 819
  - > 350,000 live w/in 1 mile of a well in Colorado D-J Basin
- **Utah** 67 fires/explosions
  - Annual rate 0.07% per well
- Utah has stricter reporting requirements

Image: Jerry Martin/ Greely Tribune 22 Dec 2017- Explosion at oil and gas site in Weld Co. 1 worker injured

Toxic Air Emissions: Benzene

A highly toxic carcinogen that occurs naturally in oil and gas

- **VOC-volatile organic compound**
- **Hazardous Air Pollutant (HAP)**

Long-term health effects

- Leukemia a "Group 1 Carcinogen"
- Life-threatening anemia
- Immune system suppression
- Possible fetal abnormalities

Very high levels of exposure

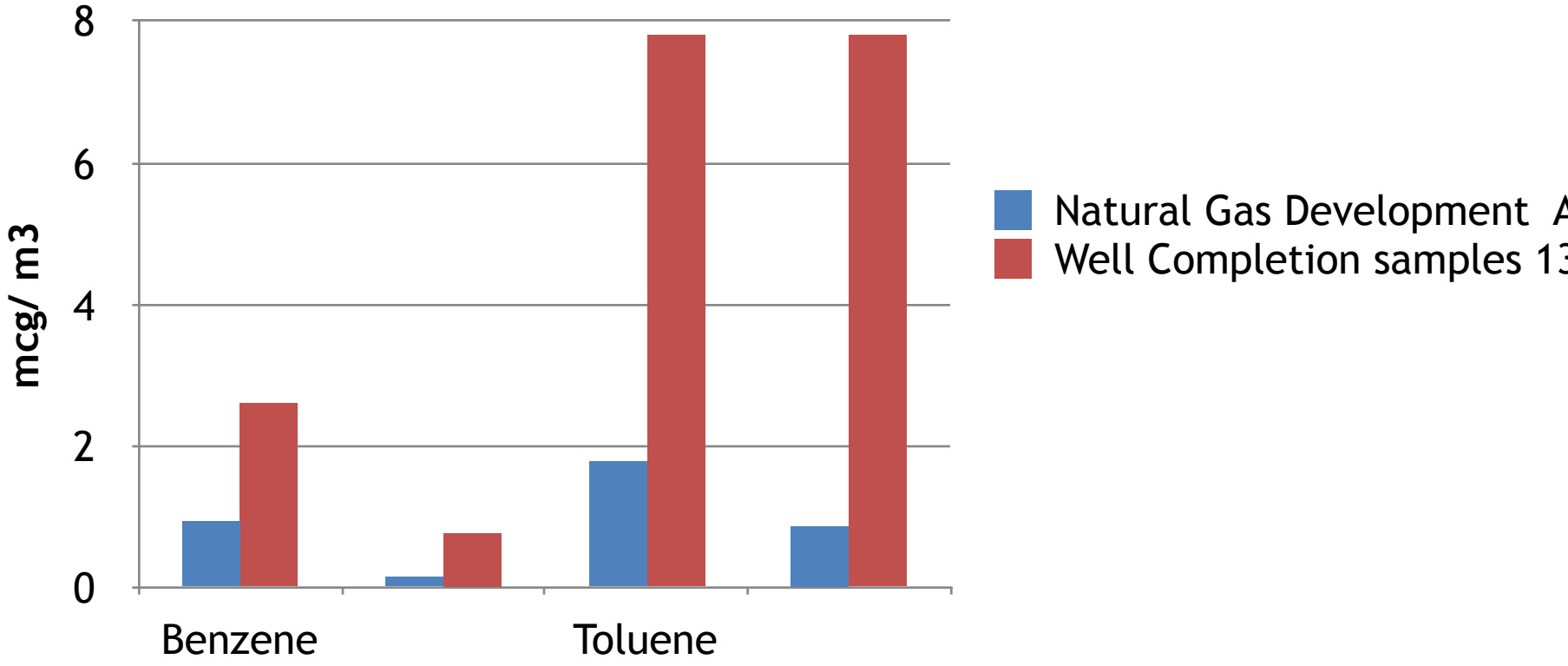
- Coma, seizures, irregular heart rhythms, fluid in the lungs, death

Children and developing fetuses are more vulnerable to all toxic air emissions

ATSDR August 2007, ww.atsdr.cdc.gov/toxicprofiles/tp3.pdf,
CDC Emergency Safety and Health Database
Paulson, Testimony before House Subcommittee Feb 2014

Median Air Toxin Concentrations During Well Completion in Garfield County CO

McKenzie et al, *Science of the Total Environment*, 22 March 2012



Assessing Environmental Impacts of Horizontal Gas Well Drilling Operations

McCawley, West Virginia Dept of Environmental Protection Division of Air Quality, May 3 2013

The Study

- Reason for Study: to assess whether 625 foot setback is adequate to protect public health
- Sample sites: 7 unconventional drilling sites in W. Virginia

Results

Benzene levels exceeded minimum risk levels for acute exposure (9 ppb for exposure of 14 days or less) in

- 5 out of 15 samples, from
- 3 out of 5 different sites

Benzene from Gas Leaks: TCEQ Barnett Shale Study 2009

- **94** monitoring sites surveyed 2009
  - Looking for leaks
  - Flyover, GasFindIR cameras, VOC monitors
- Air samples collected at **73** sites
- Benzene was detected above the long term health based comparison value (> 1.4 ppb) at 21 monitoring sites in 12 different areas
- **2** sites required immediate action for value > 180 ppb
  - 1 compressor station:1100 ppb
  - 1 gas well: 15,000 ppb (5 feet from the well)
  - Both repaired, came into compliance

TCEQ Interoffice Memo Jan 27, 2010, "Health Effects Review of Barnett Shale Formation Area Monitoring Projects" and Sadlier & Honeycutt, "TCEQ Barnett Shale Update" 2010

Image: VOC emissions captured on infrared camera by TCEQ 2009: Aruba facility

A new look at methane and non-methane hydrocarbon emissions from oil and natural gas operations in the Colorado Denver-Julesburg Basin

Petron et al, *American Geophysical Union*, May 2014

National Oceanic and Atmospheric Administration (NOAA)

- A "**Top Down**" evaluation of benzene and other toxic air emissions, as well as methane
- Airborne measurements of air pollutants – 12 flights in May 2012
- Correlated with atmospheric data
- Results: Benzene emissions were 7 - 9 times higher than estimated by State of Colorado inventories
  - Clean Air Act requires states to keep inventories of O &G emissions: based on expected emissions under normal operating conditions, summed across multiple facilities
- Methane emissions were 3 times higher than EPA inventories

Image Credit: Will von Dauster, NOAA

Atmospheric Benzene Observations from Oil and Gas Production in the Denver-Julesburg Basin in July and August 2014

Halliday et al, J. Geophys. Research: Atmospheres 20 Sept 2016 10.1002/2016JD025327

Measured **benzene** levels in the midst of the Wattenberg Gas field w/ 25,000 active wells NW of Denver

- NASA's DISCOVER-AQ campaign
- Continuous sampling at ground sites
- 5 airplane spiral flights

Findings

- Unexpectedly high benzene levels found over gas field > Denver
- Multiple analyses show that the primary source of benzene was O&NG activity, not urban vehicles
- Benzene levels were significantly higher at night, with a repeated peak exposures, up to 29 ppb (nighttime levels missed by previous studies), raising the statistical averages
- Hot spot of benzene emissions- tanks

Image credits: NASA

Aerial Surveys of Elevated Hydrocarbon Emissions From Oil and Gas Production Sites

Lyon et al, Environ Sci & Technol: 05 April 2016

Helicopter-based Infrared survey of 8220 well pads, June–Oct 2014

- Stratified random sample

Super-emitters of VOCs & Methane

- Brakken 13.8%
- Barnett- 3.5%
- Eagle Ford- 5.4%
- Fayetteville- 4.4%
- Marcellus- 1.2%
- Uintah- 6.6%
- **All basins- 4.0%**

Emission sources

- Tank hatches & tank vents- **92%**
- Mostly random, unpredictable events

Zavala-Araiza, *PNAS* 2015

- Discrepancy between top-down and inventory-based estimates of methane emissions attributed largely to **leaks**, some to inaccurate facility counts

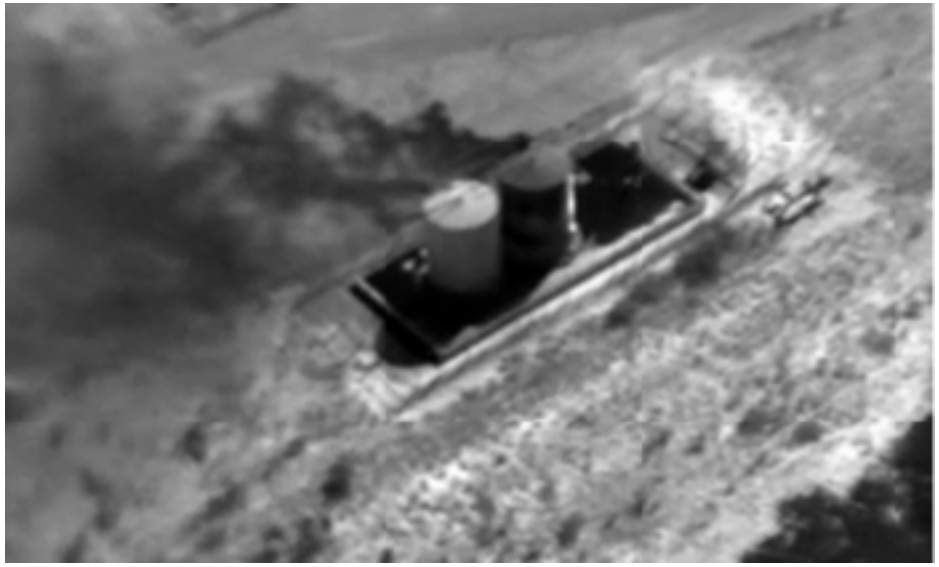


Image credit: EDF http://earthzine.org/2016/03/01/methane-observation-inspires-action/

Emissions of VOCs from Petrochemical Facilities in the Houston Area- 2006

Parrish, D. D., et al. (2009), Overview of the Second Texas Air Quality Study (TexAQS II) and the Gulf of Mexico Atmospheric Composition and Climate Study (GoMACCS), J. Geophys. Res

Measurements of air pollutants via 4 research aircraft, a research ship, and ground-based monitoring stations

- Highly reactive VOCs from petrochemical facilities in the Houston area play a major role in forming high concentrations of **ozone** routinely seen in the Houston area
- As of 2006, **Houston area emission inventories underestimate VOC emissions by a factor of 10**

Image credit: R. Frasier/The Allegheny Front: Refineries and petrochemical plants , Houston Ship Channel

Understanding Excess Emissions from Industrial Facilities: Evidence from Texas

Nikolaos Zirogiannis , Alex J. Hollingsworth, and David M. Konisky, Environ. Sci. Technol., 2018

Analyzed TCEQ emission inventories for excess industrial emissions in Texas 2004-2015

- Only TX, LA, and OK systematically collect data on excess emissions

- Excess **VOC** emissions from shutdown, startups, malfunctions

  > 1 million tons

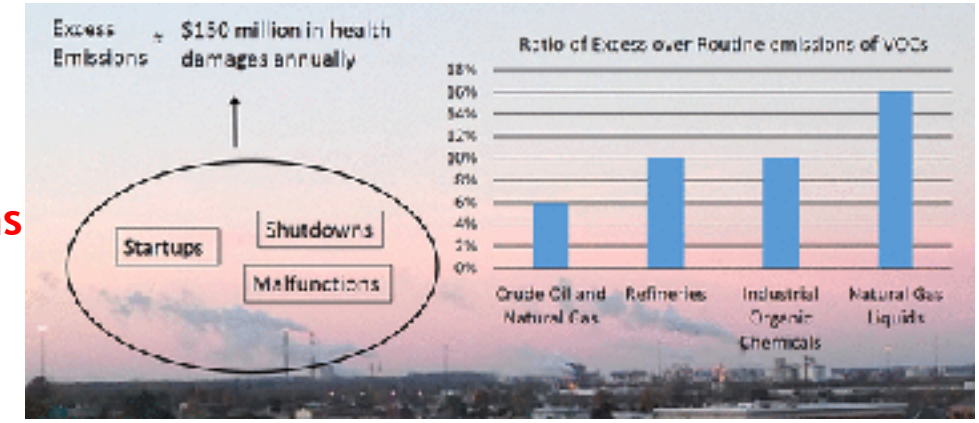
  7.5% above routine emissions

- Excess **benzene emissions:**

  776 tons

  5.5% above routine emissions

- **Superemitters**: Top 5% of facilities released more emissions than all the others combined
- Estimated health damages in Texas from excess emissions: **$150 million per year**



Ambient Nonmethane Hydrocarbon Levels Along Colorado's Northern Front Range: Acute and Chronic Health Risks

L McKenzie et al, *Environ Sci Technol 27* March 2018

Used Measured VOC levels to calculate **health risk indexes (HI)** at different distances

- Air pollution and health risks increased with decreasing distance

For residents living within **152 m (500 ft)**

- Mean **benzene levels** were 41 times higher than they were at 1600 m
- **Acute health risk** (HI) was above health risk threshold (neuro, heme, devel)
- **Chronic health risk** (HI) was above health risk threshold (heme, devel)
- **Benzene** was responsible >80% of risk
- **Risk of cancer** was 8.3x EPA's upper bound acceptable risk level of 1 in 10,000 **Benzene** caused > 95% of risk

Risk of cancer exceeded 1 in a million at all distances up to 1600 m

Image: Rocky Mountain PBS file: Erie CO

Conclusions about Benzene emissions from Oil and Gas Development

- Total benzene emissions are significantly higher than expected
- Benzene levels due to oil and gas can reach levels that pose a threat to human health in close proximity to wells, and in densely drilled regions
- Emission inventories seriously underestimate emissions
- A major source of unaccounted for emissions is unpredictable leaks and malfunctions
- About 4% of facilities are super emitters, and account for a large percent of total emissions

Hydrocarbon emissions from a storage tank observed with an infrared camera

Image: Lyons 2016

Health Hazards of Ozone

- Every 10 ppb increase in long-term ozone exposure increases the risk of death by 1.1%
  - Even for ozone levels < 50 ppb
- Regulated by the EPA under the Clean Air Act
  - Current standard 75 ppb
  - Standard revised in 2015 to 70 ppb, but old standard remains in force

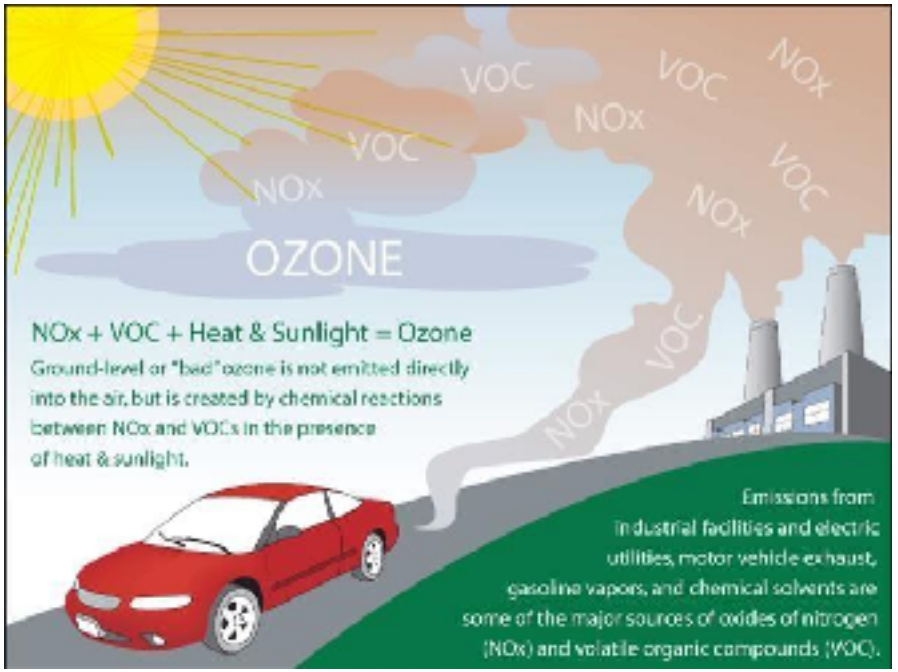


Image credit: EPA

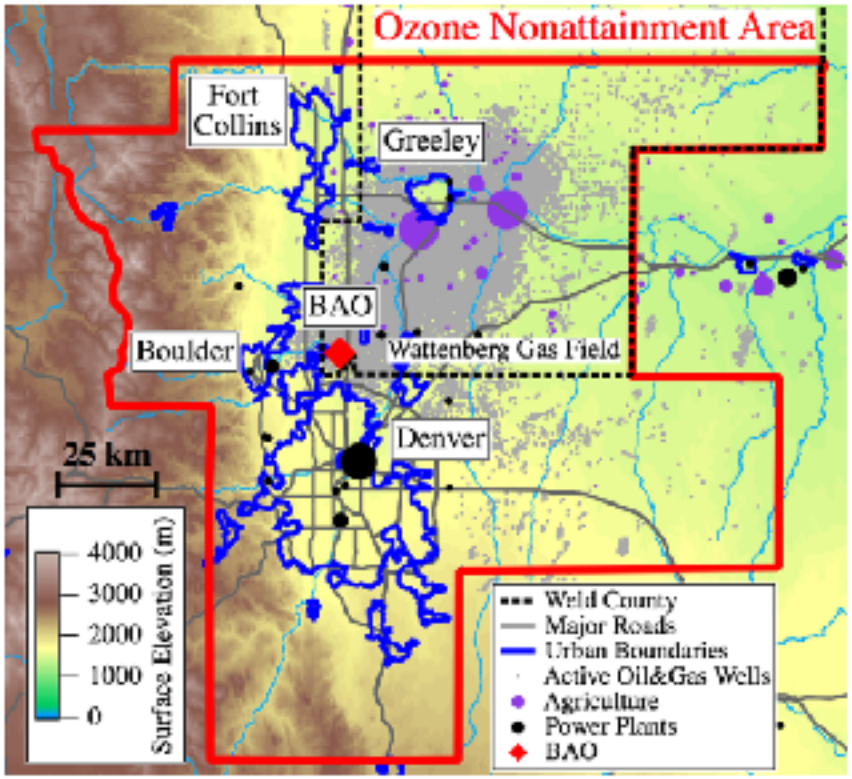
Influence of oil and gas emissions on summertime ozone in the Colorado Northern Front Range

EE McDuffie et al, Journal of Geophysical Research: Atmospheres 27 July 2016

- Colorado's northern Front Range
  - Out of compliance with national ozone standard since 2007
  - 27,000 O&G wells
  - City of Denver
- Measured ozone and precursors N0x and VOCs at the Boulder Atmospheric Observatory tower (NOAA)
- 2 campaigns, summers 2012 & 2014
- Custom model that included more than 15,000 chemical reactions.

Oil and Gas Emissions contributed

- **87%** of the total VOCs
- **17.4 % of the ozone (2.9 ppb)**



Info also from : esrl.noaa.gov/csd/news/2016/190_0808.html
Image: www.greencarcongress.com/2016/08/20160812-denver.html

Fracking and Human Health

High-Quality, Peer-Reviewed Studies

Childhood hematologic cancer and residential proximity to oil and gas development

McKenzie LM et al, PLOS ONE Feb 15, 2017 (Colorado School of Public Health)

All children with cancer rural CO 2001-2013

- **87 ALL**, 50 Non-Hodgkins Lymphoma
- Controls: 528 non-heme cancers

Exposure : All active O & G wells- (well density, a factor of number x distance) same time/location, 1- 10 yrs prior to diagnosis

- **Children ages 5-24 with ALL were 4.3 time more likely to live in highest tertile of well density compared to controls**
- **Risk of ALL increased with each tertile of increasing well density**
- No association was found for
  - ALL in children ages 0-4,
  - NHL in all children

Medical Note: ALL is the most common form of childhood cancer. With treatment, current 5-year survival rate is > 85%

mage credit: http://www.thechildren.com/health-info/conditions-and-illnesses/understanding-acute-lymphoblastic-leukemia

Association Between Unconventional Natural Gas Development in the Marcellus Shale and Asthma Exacerbations

Rasmussen et al, JAMA Internal Med July 18, 2016 (Johns Hopkins)

- **35,000 patients** with asthma attacks, 2005-2012 (Geiger Health System)
  - Mild, Moderate, Severe attacks
- **Controls**: asthma patients w/o attacks
- **Correlated with : UNG well activity exposure** the day before the attack
  - 4 Drilling phases & distance to well
  - Divided into 4 quartiles of well activity

Results

- **Asthma patients exposed to the highest level of well activity had 1.5 to 4.4 times greater odds of having an asthma attack than patients exposed to the lowest level of well activity**
  - Significant for 11 out of 12 measures
  - Increasing odds of an attack with increased exposure levels in 6/12
- Adjusted for multiple factors

Image credit: http://www.cdc.gov/asthma/management.html

Associations between UNGD and Nasal and Sinus, Migraine Headache, and Fatigue Symptoms in PA

Tustin et al, Environ. Health Persp. 25 August 2016 (Johns Hopkins)

- **7785 people** answering a questionnaire in PA 2014
  - Symptoms of nasal/sinus disease, migraine, and fatigue
- **Exposure: UNG well activity**
  - Divided into 4 quartiles

Results

- Compared to people in the lowest quartile of exposure, People in the **highest quartile** of UNG well exposure had a significantly greater likelihood of having
  - fatigue + nasal/sinus symptoms
  - fatigue + migraine symptoms
  - fatigue + nasal/sinus + migraine

Image credit: http://www.webmd.com/migraines-headaches/ss/slideshow-migraine-overview

Image credit: http://www.alternet.org/environment/fracking-has-now-been-linked-low-birth-weight-babies

OIL AND GAS EMISSIONS AND ADVERSE BIRTH OUTCOMES

Birth Outcomes and Maternal Residential Proximity to Natural Gas Development in Rural Colorado

McKenzie et al, *Environmental Health Perspectives*, 28 January 2014

- All **124,842 births** in rural CO 1996-2009
- Number/density of well exposure

Number of babies born with **congenital heart disease**

Compared to 0 wells w/in 10 miles:

10% increased risk for 1-3 wells/ mile , low exposure (281 births)

20% increased risk for 4-124 wells/ mile, medium exposure (300 births)

30% increased risk for > 125 wells/ mile, high exposure (355 births)

Statistical significance p< 0.001

Adjusted for multiple factors

Medical Note: These babies had critical congenital heart disease requiring surgery in the first year of life. This is the leading cause of infant death from a congenital birth defect.

Maternal residential proximity to unconventional gas development and perinatal outcomes among a diverse urban population in Texas

Kristina W. Whitworth, Amanda K. Marshall, Elaine Symansk; PloS One July 21, 2017

- **160,000 births** 2010-2012, Barnett Shale
- Well activity exposure
  - No. of wells and distance from mother's residence
- Mothers exposed to the **highest level of well activity** had significantly higher likelihood of **preterm birth**.
- Weaker evidence for increased **fetal deaths** at high levels of well exposure

Image: Jamie Smith Hopkins/Center for Public Integrity- Dish TX

Drilling and Production Activity Related to Unconventional Gas Development and Severity of Preterm Birth

Kristina Walker Whitworth, Amanda Kaye Marshall, and Elaine Symansk; EHP 20 March 2018

- 160,000 births in the Barnett Shale (Texas)- same data set
- Mothers exposed to the highest level of **drilling** activity had
  - **20%** increased risk of **preterm birth**
  - **100%** increased risk of **extremely preterm birth**
- Highest level of **production** activity had:
  - **15%** higher risk of **preterm birth**
  - **53%** higher risk of **extremely preterm birth**
  - Greater risk of preterm birth if exposed during 1st and 2nd trimesters

Image credit: Cooper Neil (Denton TX)

Hydraulic fracturing and infant health: New evidence from Pennsylvania

Janet Currie, Michael Greenstone, Katherine Meckel; Science Advances 13 Dec 2017

- Case-control study
  - Before vs after
- >1.1 million births in PA 2004-2013
- **Maternal residence < 1 km from a well** associated with significantly worse infant health outcomes
  - 25% increase in risk of low birthweight
  - Significant decline in avg birthweight
  - Significant decline in Index of Infant health
  - Index of Infant health is a composite of birth weight, prematurity, congenital anomalies, and any other abnormality
- Lesser but significant declines in Index of Infant Health for maternal residence 1-3 km
- No significant effect > 3 km

Image: Scott Goldsmith

Perinatal Outcomes and Unconventional Natural Gas Operations in Southwest Pennsylvania

Stacy et al, *PLOS ONE*, June 3, 2015

15,471 birth records, 3 counties, 2007-2010
509 active UNG wells
Number/Distance w/in 10 miles

Image : http://learning.bmj.com/learning/module-intro/child-born-small-gestational-age.html?moduleId=10024266

Infants in the highest quartile of exposure (> 6 wells/ mile) were

- **34% more likely to have low birthweight, below 10th percentile**

Compare to infants in the lowest quartile of exposure (< 0.87 wells/mi)

- statistically significant (p = .02) adjusted for multiple factors

Medical Note: these babies are at increased risk of death during infancy compared to normal weight babies

- No increase found in premature birth

Unconventional Natural Gas Development and Birth Outcomes in Pennsylvania, USA

Casey et al, *Epidemiology*, accepted 19 August 2015

All 10,000 babies born in 2 hospitals in PA 2006-2015

Calculated babies' exposure to "well activity" within 20 KM during the pregnancy- 1177 new wells/ year

Results

Babies in the highest quartile of exposure (avg 124 wells/ 20 km) had a

- 40 % increased risk of premature birth (<37 weeks)

Compared to babies in the lowest quartile of exposure (avg 6 wells/ 20 km)

- Statistically significant, adjusted for multiple variables

Medical Note: These babies would be expected to have a 3 to 5-fold greater chance of death during infancy than babies who were not born prematurely.

Image Credit: Shutterstock

Health Risks of Living in Close Proximity to Oil and Gas Development

- Explosions and fires
- Benzene emissions
  - Leaks & superemitters
- Elevated Ozone levels
- Increase risk of illness:
  - Childhood Leukemia- ALL
  - Asthma attacks
  - Congenital heart disease
  - Preterm birth
  - Low birth weight
  - Nasal & sinus symptoms

Image: Emily Schmall/AP, Denton TX