

June 10, 2016

Shale gas development & health

Update on studies of the Geisinger Environmental Health Institute

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Environmental Health Sciences, Epidemiology, and Medicine

Geisinger Health System

Senior Investigator



JOHNS HOPKINS
BLOOMBERG SCHOOL
of PUBLIC HEALTH

GEISINGER
HEALTH SYSTEM

Overview

Assumption: you have some background knowledge about unconventional natural gas development (UNGD)

1. Brief orientation on UNGD in the Marcellus shale
2. The Geisinger Health System and its Environmental Health Institute
3. Environmental epidemiology using electronic health records
4. Completed and ongoing research
 - a. Radon
 - b. Pregnancy outcomes
 - c. Asthma exacerbations
 - d. Nasal and sinus, headache, and fatigue symptoms
5. Additional efforts
6. Questions

Johns Hopkins University

Karen Bandeen-Roche

Joan Casey (now UCB/UCSF)

Tara McAlexander (PhD candidate)

Meredith McCormack

Elizabeth Ogburn

Jonathan Pollak

Sara Rasmussen (PhD candidate)

Aaron Tustin (OEM resident)

Geisinger Health System

Sy Brandau

Joshua Crisp

Joseph DeWalle

Annemarie Hirsch

Jennifer Irving

Dione Mercer

Agnes Sundaresan

Brown University

David Savitz

SkyTruth

John Amos

David Manthos

(impoundments, flaring)

Harvard University

Peter James (greenness)

Gettysburg College

Rutherford Platt (impoundments)

**The following
represents the work
of many**

US Counties with UNGD through mid-2012

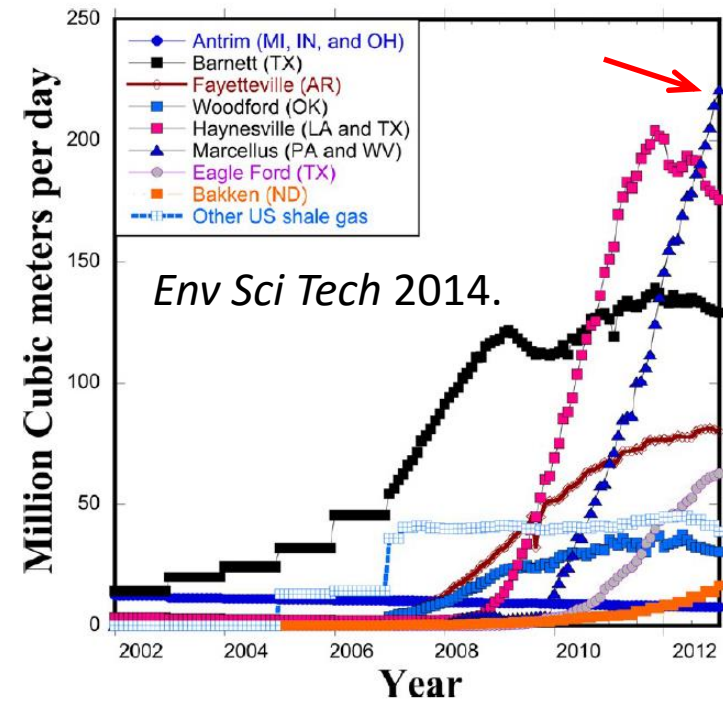
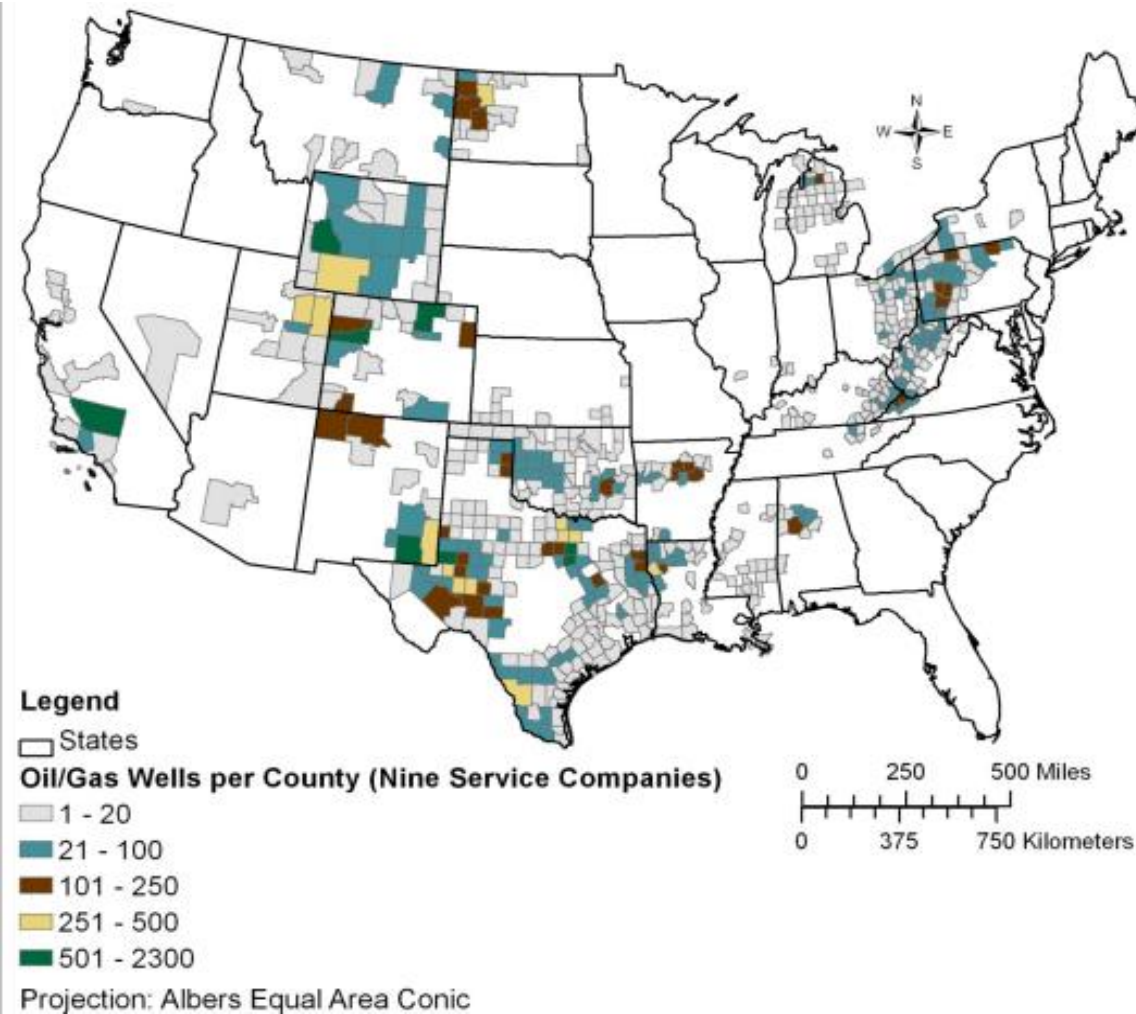
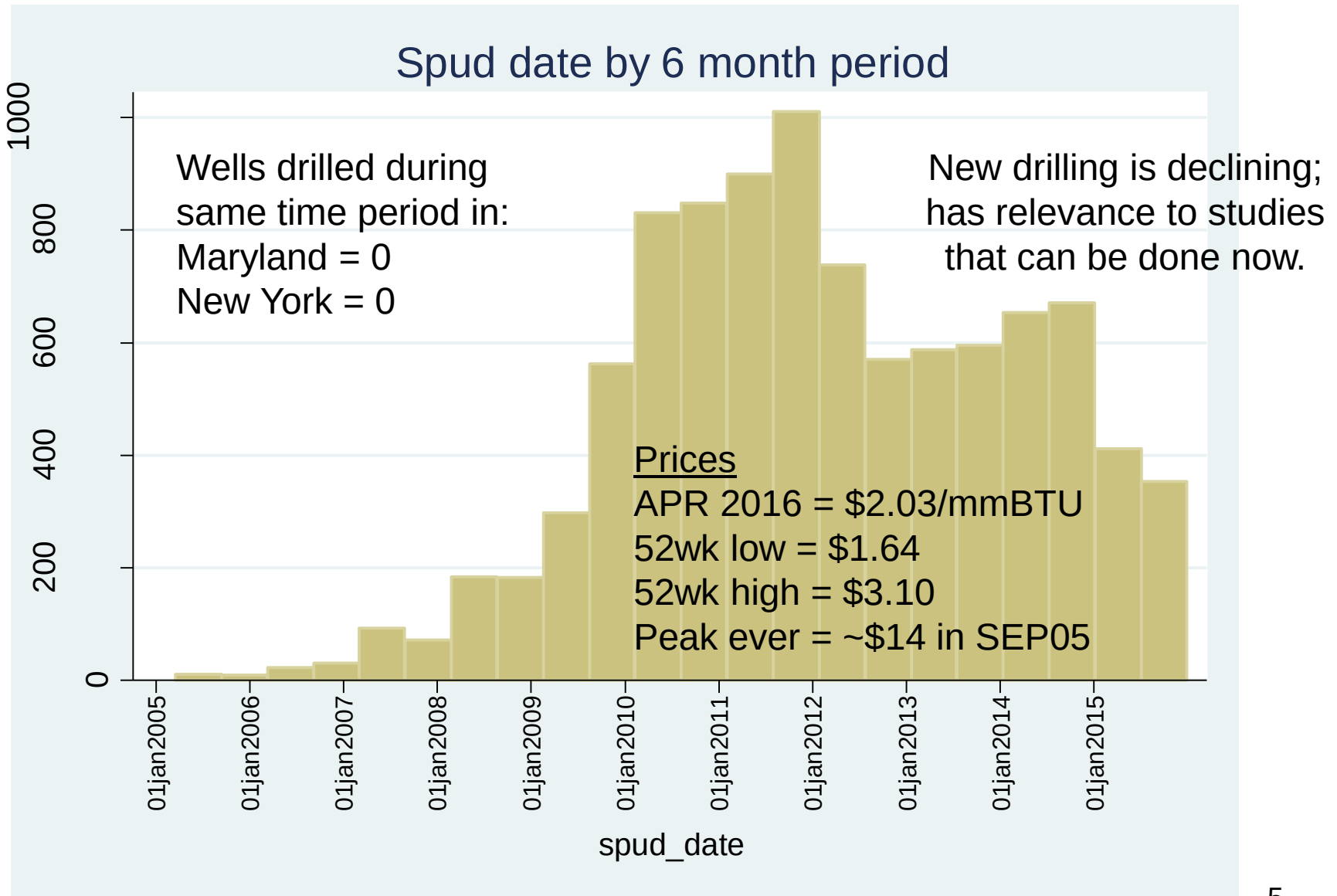


Figure 1. Evolution of the volume of natural gas production from different unconventional shale plays in the U.S. Data from the U.S. Energy Information Administration.⁴

End 2012: US shale gas was

- 29% = Marcellus
- 23% = Haynesville
- 17% = Barnett
- 31% = a dozen other basins

To DEC 2015: 9669 spudded wells in PA



Rapid Development far Ahead of Health Studies

Medical News & Perspectives | May 23 2012

JAMA The Journal of the
American Medical Association

Rigorous Evidence Slim for Determining Health Risks From Natural Gas Fracking

By Mike Mitka

Madelon Finkel (Cornell): “What we need for this whole issue of unconventional drilling is a good epidemiology study.”



Comment

The health implications of fracking

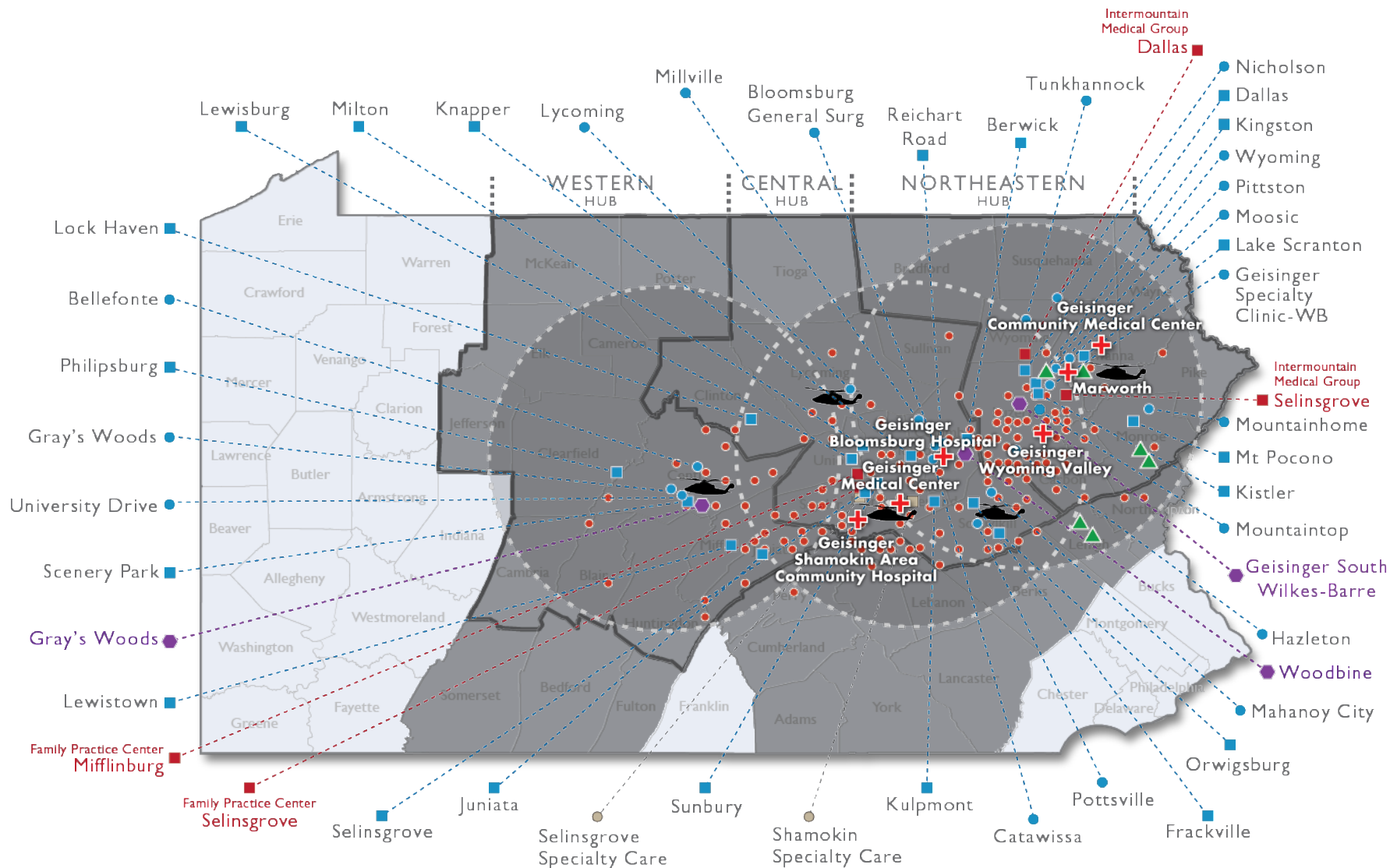
THE LANCET

Sari Kovats , Michael Depledge, Andy Haines, Lora E Fleming, Paul Wilkinson, Seth B Shonkoff, Noah Scovronick

Published Online: 27 February 2014

“Exposure and epidemiological studies – of which there are currently very few – are needed along the entire supply chain of shale gas to characterise and quantify associated health issues.”

The Geisinger Health System = Clinic + Health Plan

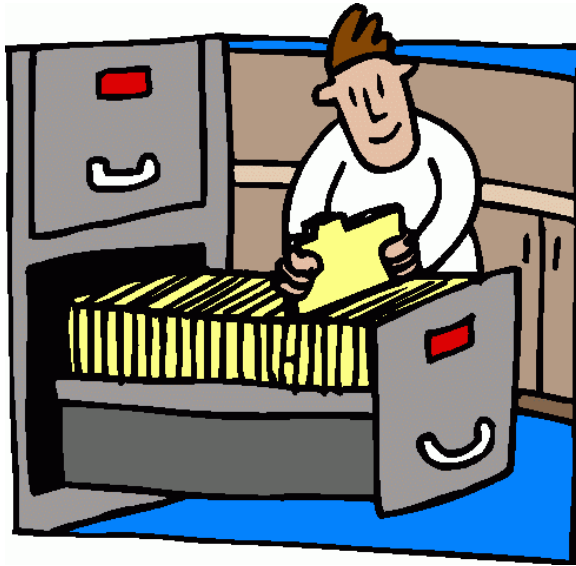


Revised 6-28-12. Geisinger PR & Marketing Department

The Geisinger Environmental Health Institute

- **Founded in 2007**
- **Investigating a number of environmental issues**
 - Unconventional natural gas development (UNGD)
 - Industrial food animal production, abandoned coal mine lands, built environment, land use, social environment, food environment
- **Investigating a number of health outcomes**
 - Pregnancy outcomes, asthma, type 2 diabetes, childhood obesity, mental health, methicillin-resistant *S. aureus* (MRSA), chronic rhinosinusitis, others
- **All Geisinger UNGD research now under EHI**
- **All EHI research is submitted for publication to peer-reviewed scientific journals**

In the “old” days ...

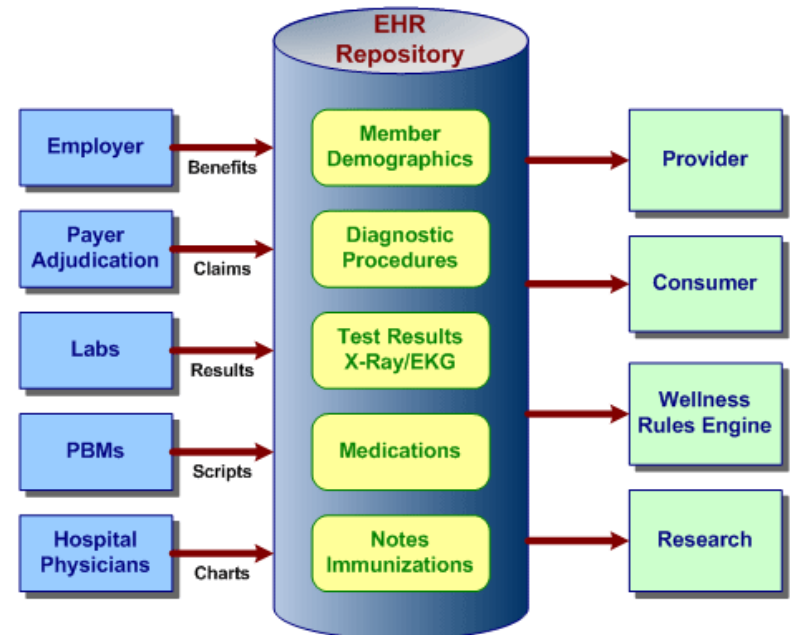


- Data collected by writing
- Stored in hard copy chart
- Not linked to any other information about patient
- Not easily accessible for research

Now ...



- Data entered into digital collection system
- Stored in electronic databases
- Linkable to many other data sources
- Accessible for research
- Two way communication can happen



The Geisinger Clinic

- **40+ community practice clinics, 5+ hospitals**
- **450,000+ primary care patients**
 - Representative of general population in region (40+ counties)
 - Need not have Geisinger insurance to use health system
 - Varied community types in region
- **Electronic health record (EHR) since 2001**
 - 30% of primary care patients have Geisinger Health Plan for insurance – can get claims data
- **EHR provides** (these and more)
 - Demographics, encounters (OPT, IPT, ED), dates
 - Physician orders, laboratories, procedures, medications
 - Vitals, ICD-9 codes, health insurance, problem list, clinical notes

Methods Common to All Studies

- Obtain patient data from EHR
- Geocode patients
- Consider how environment may contribute to disease burden
- Use geographic information systems (GIS) to create exposure metrics
- Link exposure and patient measures
- Biostatistical analysis – person, place, time

UNGD & Health

INDIVIDUAL EXPOSURES

- **Water quality** – surface & ground water
- **Air quality** – air pollutants, odors
- **Soil issues** – NORMs, spills, new pathways
- **Physical hazards** – noise, vibration, light
- **Psychosocial hazards** – cause stress*

COMMUNITY IMPACTS

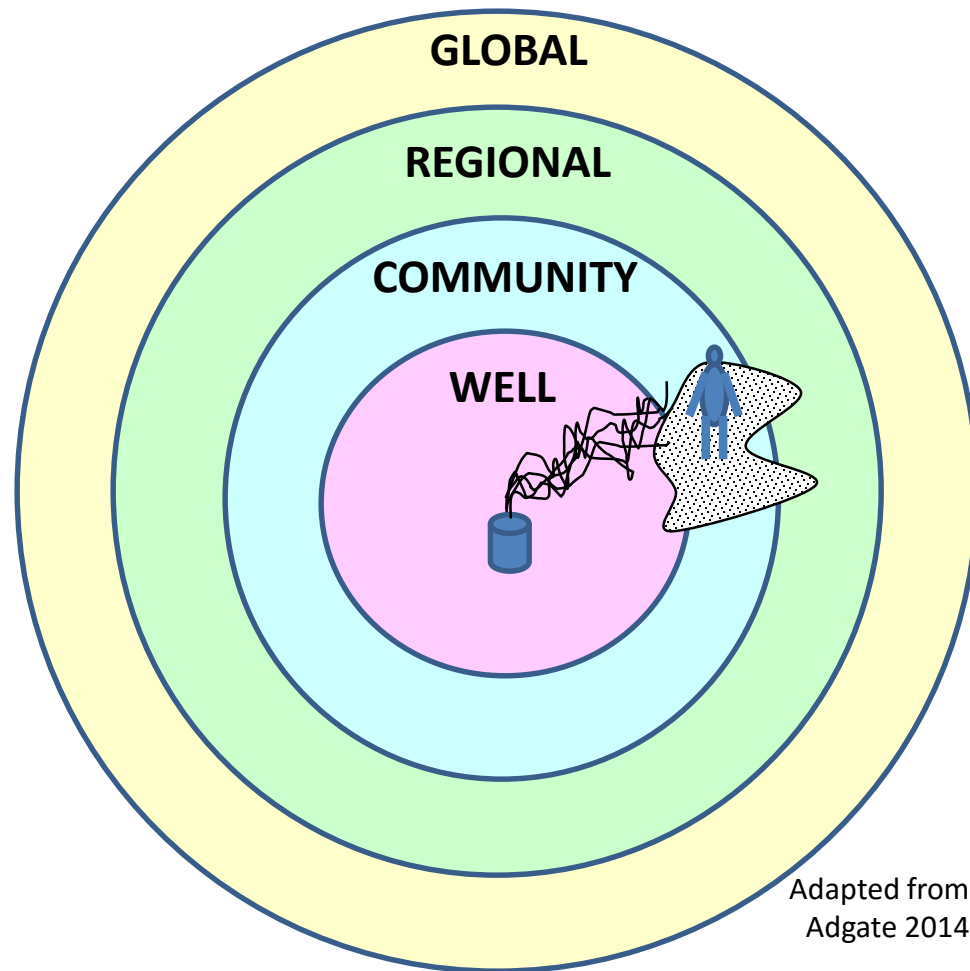
- **Built environment** – roads, green space, aesthetics, ecosystems, traffic
- **Social environment** – social capital, social support, disenfranchisement, rapid social change, crime, civic engagement

ECONOMIC ENVIRONMENT

- Employment, land and home values, economic growth

OTHER ISSUES

- **Scale** – air pollutants are regional, fugitive emissions global (greenhouse gas)
- **Cumulative impacts** – tens of thousands of wells over decades



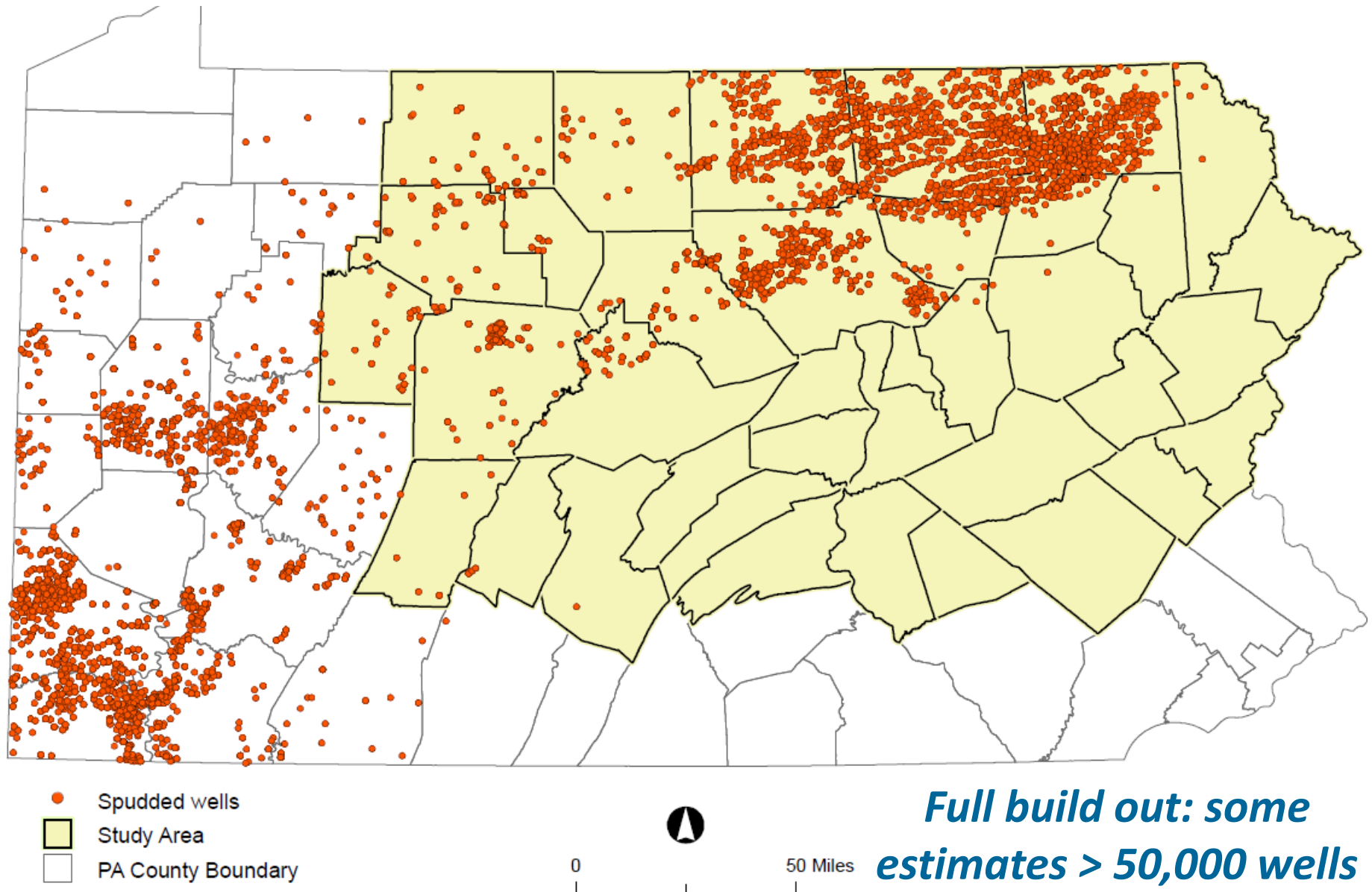
* “the dread I feel in the pit of my stomach,”
landowner in Marcellus region (Perry et al. 2013)

Exposure Assessment

1. How do we rank people (or buildings) along a gradient of exposure potential in epidemiologic studies?
2. How do we do this retrospectively?
3. Should we try to capture all these pathways at once? Or measure each one separately?

Spudded Wells in Pennsylvania to December 2014

(N = 8800, with 6289 in production) [Source: PA DEP]

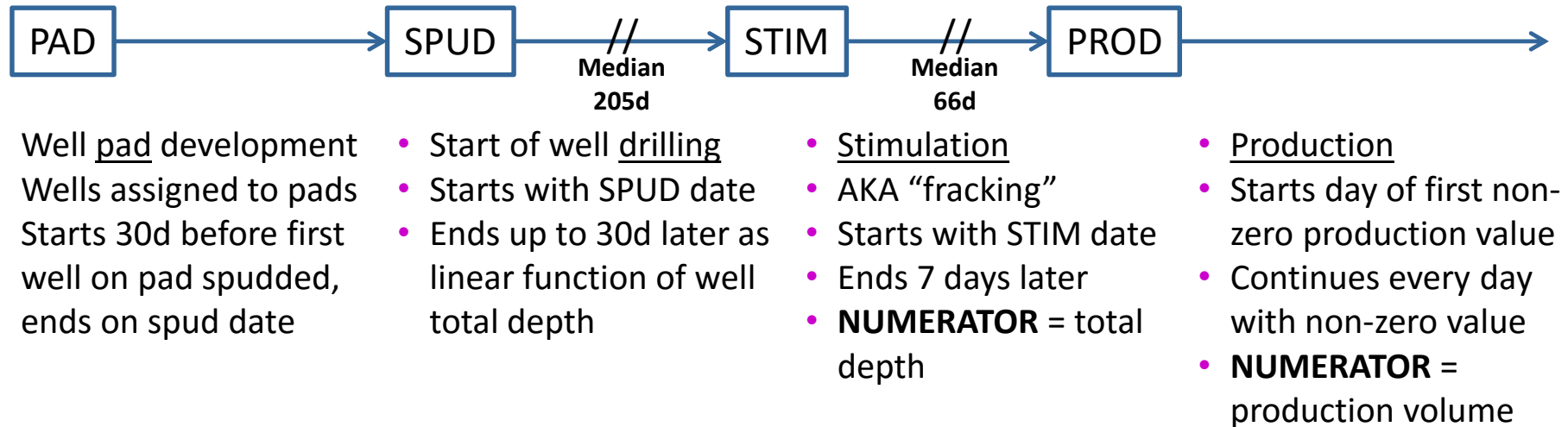


OUR STUDIES: UNGD occurs in stages; stages have known start dates, predictable durations, & exposures differ by stage; we incorporate well depth and production values; function of inverse-distance-squared ($1/d^2$)

UNGD Well
Activity
Metric

$$= \sum_i^n \frac{m_i}{d_{ij}^2}$$

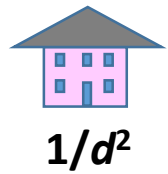
- FOUR metrics
- For every well i and patient residence j
- m_i = 1 for PAD, 1 for SPUD, total depth for STIM, daily gas volume for PROD
- d = distance well to residence
- Four analyzed separately or combined



PRIOR STUDIES: Once drilling of a well begins, associated exposures occur forever, are unchanging, do not differ by well or phase, function of inverse distance ($1/d$)



- **Asthma**: accounts for all UNGD in state; separately for each of FOUR phases; on single day before date of asthma exacerbation (e.g., H = hospitalization)



$1/d^2$

Distance

3km

4.5km

6.2km

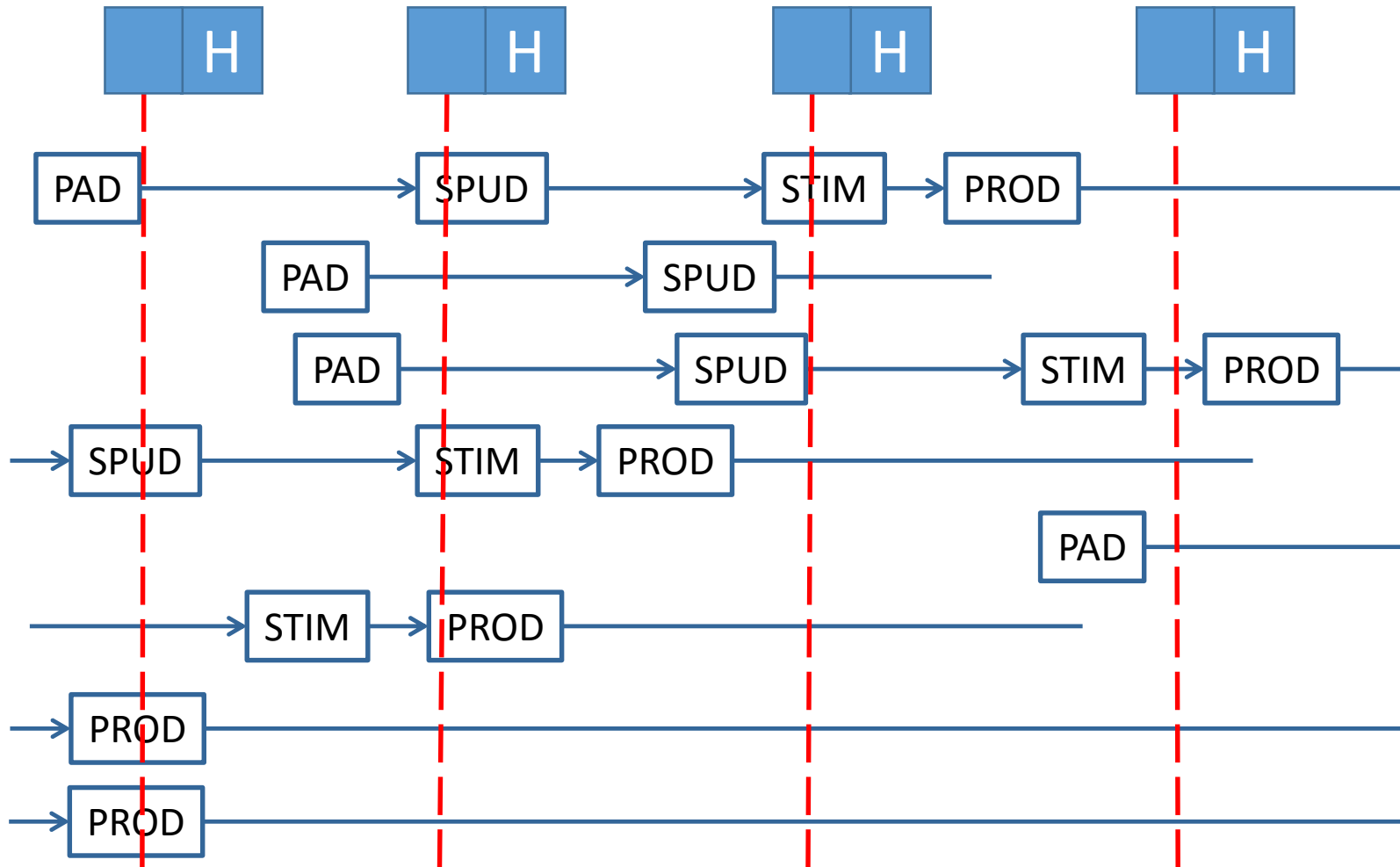
8km

9km

9.4km

12.1km

12.3km



- **Radon**: same but SPUD and PROD only, during duration of radon test
- **Pregnancy**: same but (1) duration of pregnancy; (2) summed four phases for single index
- **Symptom studies**: same as pregnancy except summed for three months

UNGD activity metrics get BIGGER if you are surrounded by

Closer wells
More wells
Larger wells

All wells in state contribute:

- Closer: distance from residence to well
- More: number of wells
- Larger: total depth (STIM) or volume of production (PROD)



Radon Study

Joan Casey, started as doctoral student
(JHU), finished as post-doctoral fellow
(UCB/UCSF)

STATUS: published in *Environmental Health
Perspectives* 2015

Pennsylvania Has A Particularly Fractured Geology

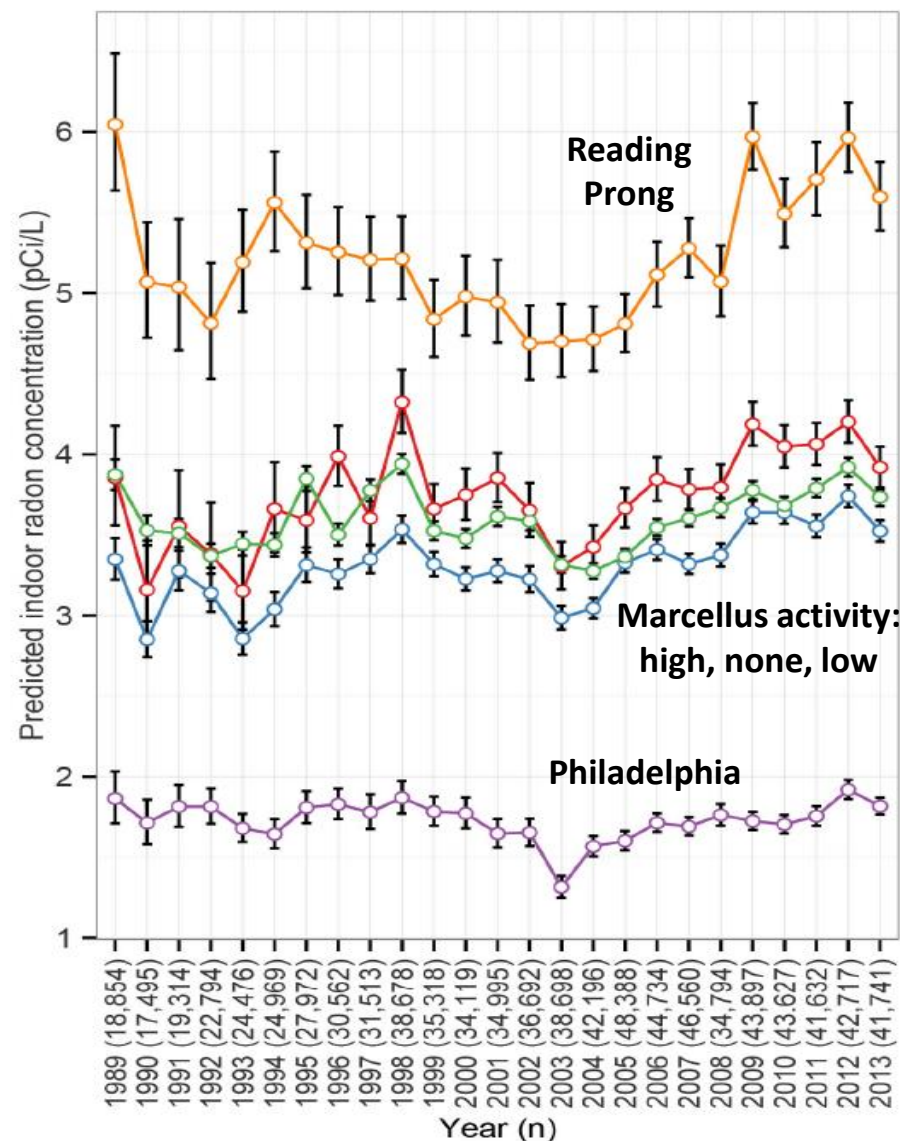
- Estimated 325,000 oil & gas wells drilled 1860-2000
 - DEP records: 88,300 regulated & operating, 44,700 plugged, 8000 abandoned, status of 184,000 unknown
- *Our question: can UNGD work with this fractured geology to provide radioactivity pathways?*

Radon pathways to buildings: soil diffusion through foundation cracks; natural gas; well water; ambient air

Predictors of Indoor Radon Concentrations in Pennsylvania, 1989–2013

Joan A. Casey, Elizabeth L. Ogburn, Sara G. Rasmussen, Jennifer K. Irving,
Jonathan Pollak, Paul A. Locke, and Brian S. Schwartz

- Linked PA DEP radon data 1987-2013 to UNGD data
- Modeled predictors of building radon levels (866,735 measurements)
- Adjusted for geology, well water, building characteristics, season, weather, community SES, community type
- **Three primary UNGD findings**
 - Radon levels increasing recently, higher in high activity counties
 - PROD model associated with basement radon levels statewide
 - SPUD model associated with first floor measurements in summer within 20km of a well

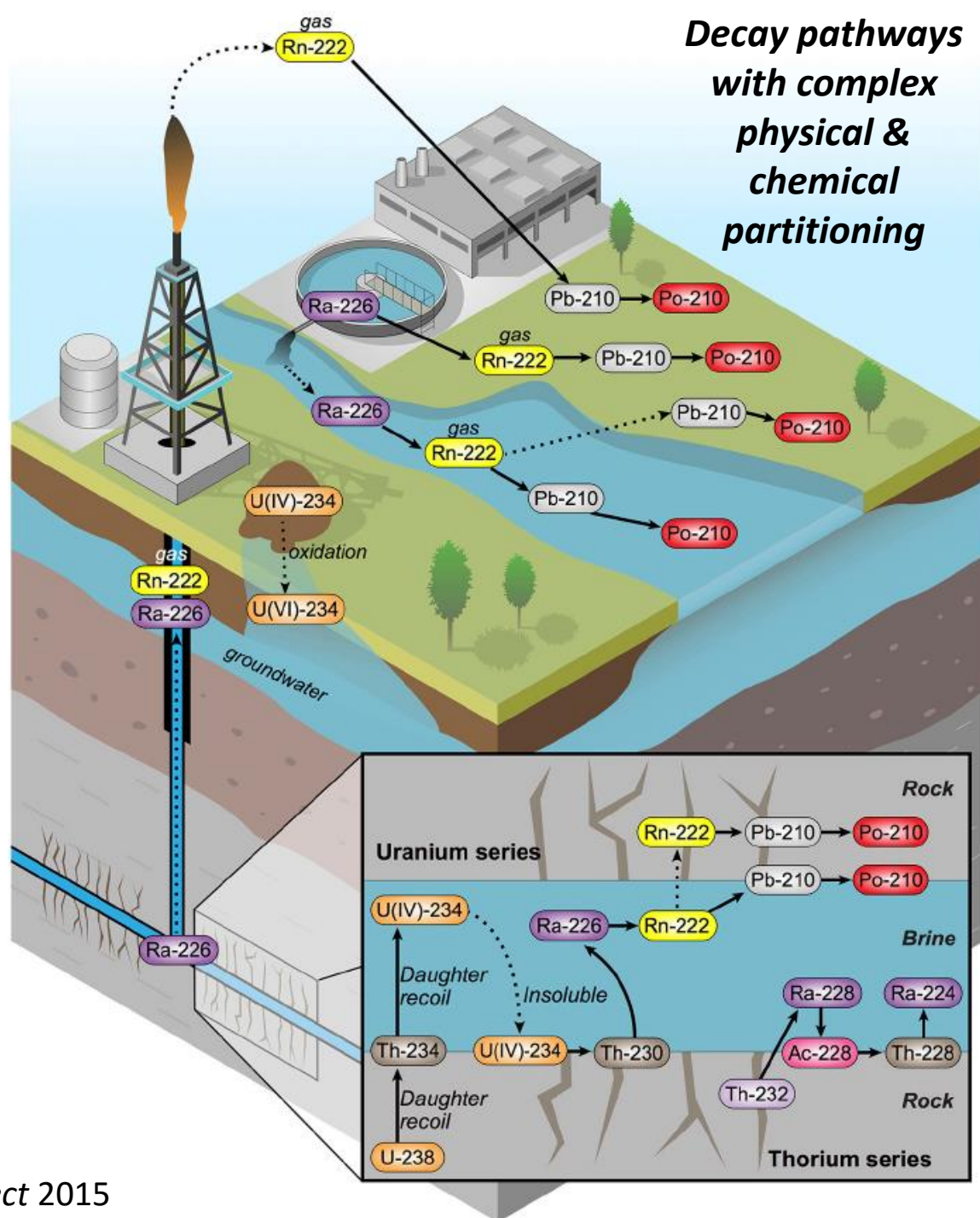


Can UNGD Emissions Travel?

- Analyzed ambient ethane measurements from EPA monitoring stations near Baltimore
 - Ethane good marker of fugitive emissions from UNGD
 - Most wind trajectories to Baltimore pass through PA UNGD
- Daytime ethane concentrations have significantly increased since 2010
 - From 7% to 10% of total non-methane organic carbon
 - Ethane near Atlanta, GA does not show this trend
- Concluded this could be due to rapid UNGD upwind of Baltimore monitoring station

Properly Evaluating Radioactivity Risks?

- Current assessment of radioactivity in liquid wastes relies on just **radium**
- Role of radioactive ingrowth
- Closed system conditions: radioactive ingrowth led to under-estimation of total radioactivity by > 5X within 15d; total radioactivity increases for > 100y
- Long-lived, environmentally persistent Ra decay products (^{228}Th , ^{210}Pb , ^{210}Po) are being distributed by UNGD



Health Studies

(NIEHS funding ES023675)



National Institute of Environmental Health Sciences
Your Environment. Your Health.

OUTCOMES: have started with ...

- **Asthma:** mild, moderate, severe exacerbations
- **Pregnancy:** Apgar score, preterm birth, small for gestational age, birth weight
- **Symptom survey:** nasal and sinus, headache, and fatigue symptoms

EXPOSURE

- Incorporating aspects not considered in prior studies
- Using novel approaches
- By phase of development
- Large effort on compressor stations
- Working with SkyTruth on satellite data for ponds (aka impoundments), flaring, and cloud cover

Pregnancy Outcomes

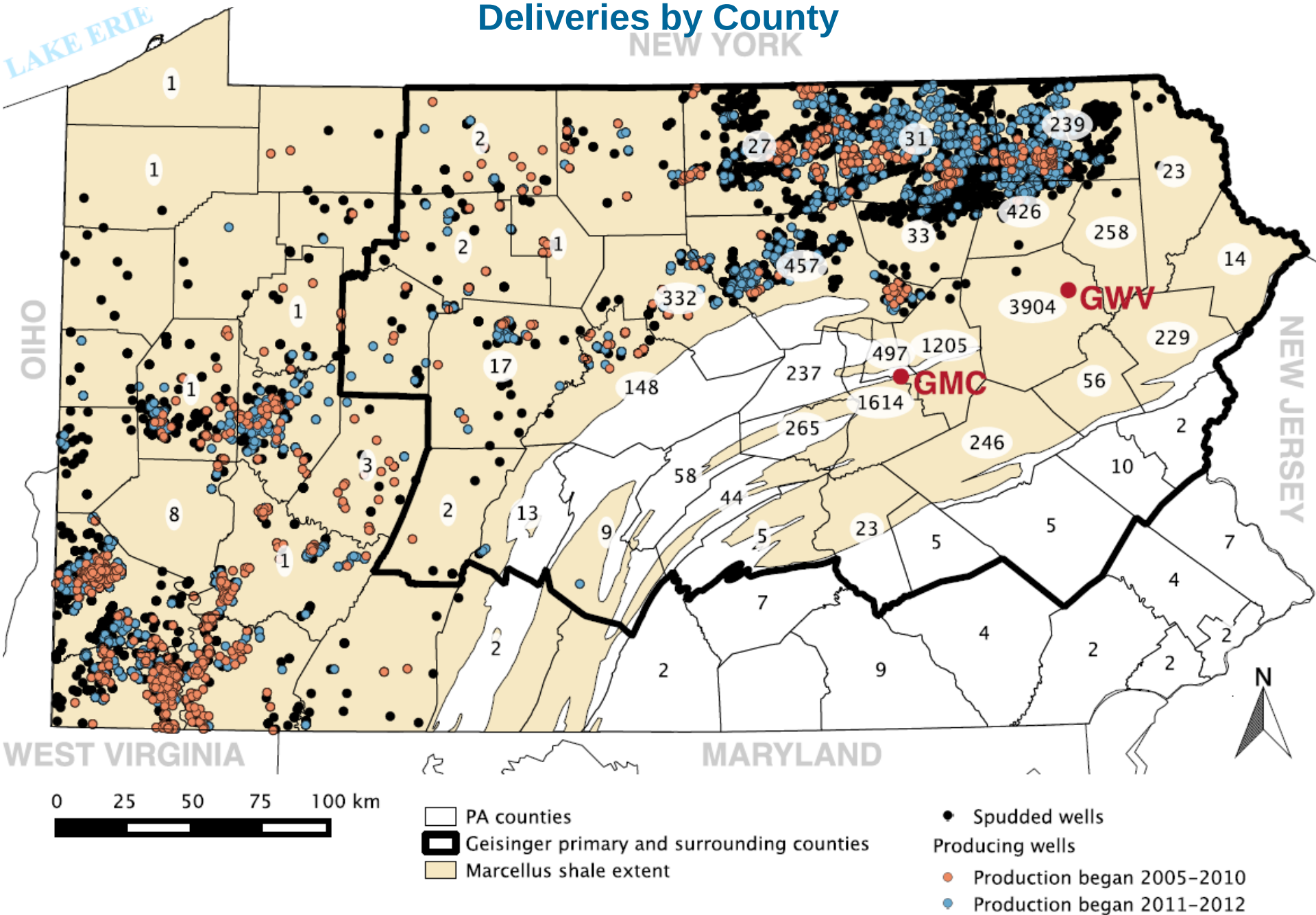
Joan Casey, post-doctoral fellow

STATUS: published in *Epidemiology* 2016

Methods

- **Study population:** 10,496 neonates, 9384 mothers Jan 2009 – Jan 2013, singleton births only
- **Outcomes:** birth weight, preterm birth, 5min Apgar score, small for gestational age; *post hoc* high risk pregnancy
- **UNGD activity metric:** summed 4 UNGD phases for gestation
- **Analysis:** linear or logistic regression, 3-level model
- **Adjustment:** child: sex, season of birth; mother: age, race/ethnicity, primary care, smoking, body mass index, parity, family SES, delivery hospital, distance to roads, well water; community: socioeconomic deprivation, greenness
- **Sensitivity analyses:** examples
 - Add year (2009-10 vs. 2011-13), gestational age (birth weight models), use Cox proportional hazards (preterm birth, gestational age timescale)
 - Assigned children born in 2006 the UNGD activity metric they would have had were they born in 2012 (expect no association; if yes → confounding)

Study Area, UNGD Wells, Marcellus Extent, Hospital Locations, and Deliveries by County



UNGD and Preterm Birth

Variable	Model 1 ^a	Model 2 ^b	Model 3 ^c
	OR (95% CI)	OR (95% CI)	HR (95% CI)
UNGD activity quartile	N = 9848	N = 9848	153,485 p-w
1 (reference)	1.0	1.0	1.0
2	1.18 (0.89-1.56)	1.30 (0.96-1.83)	1.07 (0.89-1.29)
3	1.27 (0.95-1.70)	1.63 (1.10-2.41)	1.29 (0.97-1.72)
4	1.41 (1.04-1.92)	1.86 (1.22-2.86)	1.51 (1.02-2.24)
Year of birth			
2011-13 vs. 2009-10		1.33 (0.99-1.79)	

^a Adjusted for variables on prior slide; ^b Further adjusted for year of birth; ^c Cox proportional hazards model, time to event, same adjustment

OR = odds ratio; HR = hazard ratio; p-w = person-weeks

- *Post-hoc* analysis: UNGD associated with physician-recorded high-risk pregnancy on problem list
- Q4 vs. Q1: OR (95% CI) = **1.34 (1.07-1.68)**

Other Results

- UNGD associated with lower term birth weight but association was not robust to adjustment for year
 - In contrast to preterm birth association – stronger with adjustment for year
- Future UNGD from 2012, estimated for and assigned to children born in 2006, not associated with preterm birth, Apgar score, or SGA
- Future UNGD associated with birth weight in 2006, suggesting unobserved confounding

Asthma Exacerbations

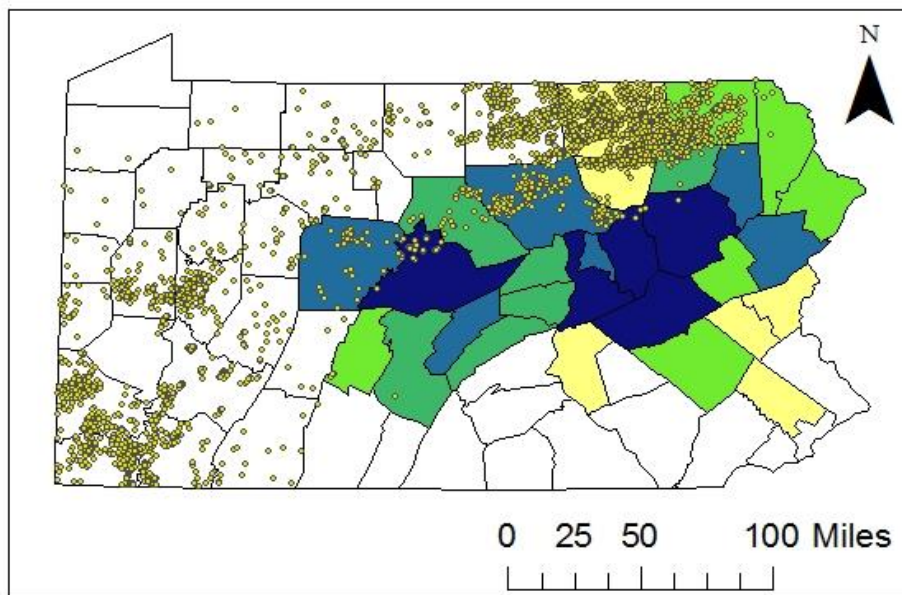
Sara Rasmussen, doctoral student

STATUS: *JAMA Internal Medicine*, in press

Embargoed until publication date: July 18,
2016

Asthma Exacerbations

(Sara Rasmussen, PhD candidate)



Legend

• Spudded wells

Number of asthma patients per county^a, quintiles

21 - 63

64 - 335

336 - 964

965 - 1955

1956 - 5734

□ Counties with less than 20 patients

^a Asthma patients in New York (n = 72) not shown.

- 35,508 asthma patients, aged 5-90y between 2005-12
- **Exacerbations:** 5600 severe (hospitalization), 2291 moderate (emergency visit), and 25,647 mild (new oral corticosteroid)
- Assigned exposure on day before event using four separate UNGD activity metrics
- Compared asthma patients with exacerbations to those without
- Adjusted analysis

Analysis: UNGD and Asthma Exacerbations

- Used logistic regression to evaluate associations of four UNGD activity metrics with three types of asthma exacerbations
- Adjusted for race/ethnicity, family history asthma, smoking, season, BMI, family SES, type 2 diabetes, CSD, distance to roads, maximum temperature day prior to event

Two sensitivity analyses:

1. UNGD is located in a mainly rural subset of Geisinger's counties. Could UNGD be associated with exacerbations because of differences among people by county of residence? Replaced UNGD activity metric with indicator for each county.
2. Is UNGD associated with **diarrheal illness**? *Should not be!*

Symptom Survey

Aaron Tustin, OEM resident

STATUS: *Environmental Health Perspectives,*
resubmitted after revision

UNGD and Symptoms

(NIAID U19 AI106683)

Design: used Geisinger electronic health record to select 23,700 patients; mailed 4-page survey; **7847** returned; analysis weighted for selection & response

- Designed for study of CRS epidemiology so did not identify UNGD as purpose

Nasal and sinus symptoms (EPOS* chronic rhinosinusitis criteria)

- Compared EPOS current CRS (n = 1866) to never CRS (n = 3888)

Migraine headache

- 3 validated screening questions for migraine headache (Lipton 2003)
- Collected as frequency of occurrence and assigned scores
- Compared 1765 with suspected migraine to 5277 without migraine

Fatigue

- 8 validated questions for fatigue (PROMIS fatigue short form 8a)
- Frequency of occurrence, assigned scores; severe fatigue = score 20+
- Compared 1878 with severe fatigue to 1840 with score $\leq$ 25th percentile

* EPOS = European Position Paper on Rhinosinusitis and Nasal Polyps

Results for Symptom Study

<u>Outcome</u>	<u>N</u>	<u>Q4 OR (95% CI)*</u>
CRS alone	738	1.11 (0.75, 1.65)
Migraine alone	580	1.43 (0.94, 2.18)
Fatigue alone	666	1.47 (0.996, 2.18)
CRS + migraine	266	1.49 (0.78, 2.85)
CRS + fatigue	347	1.88 (1.08, 3.25)
Fatigue + migraine	420	1.95 (1.18, 3.21)
All three	496	1.84 (1.08, 3.14)
Total	3513	

* Association for 4th quartile (vs. 1st quartile) of UNGD activity metric from truncated, weighted model, adjusting for sex, race/ethnicity, age, Medical Assistance, smoking status, and BMI (for CRS model). CI = confidence interval.

There were no consistent associations comparing 2nd or 3rd quartile to reference group (1st quartile) for any outcomes.

Other Ongoing Work

Other Activities

- **Health outcomes**
 - Mental health: survey August 2015, 4966 responded, analysis ongoing
 - Cardiovascular: heart failure in planning (Tara McAlexander)
- **Exposure assessment**
 - SkyTruth satellite data: impoundments, flaring
 - Compressor stations (Sara Rasmussen)
 - Kriging with EPA air quality monitoring data (Tara McAlexander) – are findings due to air quality impacts?
- Planning new NIH grants
- Pilot project program: awarded \$100,000 to investigators at 6 institutions; mainly ecology

Johns Hopkins University

Karen Bandeen-Roche (biostatistics)
Joan Casey (now UCB/UCSF)
Tara McAlexander (PhD candidate)
Meredith McCormack (asthma)
Elizabeth Ogburn (biostatistics)
Jonathan Pollak (biostatistics, analysis)
Sara Rasmussen (PhD candidate)
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John Amos
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(impoundments, flaring)

Harvard University

Peter James (greenness)

Gettysburg College

Rutherford Platt (impoundments)



Thank you for listening

Questions?

Contact information:

bschwar1@jhu.edu

Prior Symptom Studies

Bamberger and Oswald, *New Solutions* 2012

- Interviews with animal owners living near drilling operations
- Case series approach, not quantitative, not inferential
- *New Solutions* is a self-described progressive and activist publication; can raise concern among some scientists

Steinzor *et al.*, *New Solutions* 2013

- 108 persons in 55 households in 14 counties, AUG 2011 to JUL 2012
- Methods: “...respondent-driven and relied on word-of-mouth and a chain of referrals to reach more participants, such as ‘snowball’ and ‘network’ sampling”
- All respondents in “gas patch”; no comparison subjects; subjects likely knew that UNGD was the environmental exposure of concern
- Higher prevalence of many symptoms within 1500 feet of gas facility

Rabinowitz *et al.*, *EHP* 2015

- Questionnaire similar to above; identified environmental hazards as interest
- 492 persons in 180 randomly-selected households; single respondent answered for all in household; rigorous statistical analysis
- Dermal, respiratory, gastrointestinal, cardiovascular, and neurological symptoms
- Within < 1 km and > 2 km from nearest well, independent of phase of well
- Association with dermal and upper respiratory symptoms