Examining the association between unconventional natural gas development and health

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(with several slides from Dr. Brian S. Schwartz, MD, MS, Johns Hopkins Bloomberg School of Public Health & Geisinger Health Institute)

Flow of tonight’s presentations

Peggy
Exposures + Toxicologic Evidence for Concern over UNGD

Irena
Epidemiologic Evidence for Concern over UNGD

Larysa/Ned
Policy & Advocacy for Health Protections from UNGD
UNGD Geology 101

PA accounts for ~25% of current U.S. production

Legend
- Assessed basins with resource estimates
- Assessed basins without resource estimates

(EIA 2015)
Environmental Epidemiology 101

Epidemiology is the study of the distribution and determinants of health-related states or events in specified populations, and the application of this study to the control of health problems.

- John Last, Dictionary of Epidemiology, 2001

1) Use prior knowledge to develop hypotheses about whether & how factors of interest could impact health.

2) Measure environmental exposure.

3) Measure health outcome.

4) Use biostatistics to identify associations and eliminate chance as an explanation for findings, adjusting to control for influence of confounders.

1) Develop hypotheses: Could UNGD Affect Children’s Health?

<table>
<thead>
<tr>
<th>Stages of UNGD Activity (and some Infrastructure Involved)</th>
<th>Initial Inquiry into the Scientific Basis of Health Concerns</th>
<th>Epidemiologic Studies</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Well site preparation &amp; road construction (trucks &amp; heavy machinery)</td>
<td>(2) Well drilling (drill rigs)</td>
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<td>(3) Well stimulation (hydraulic fracturing) &amp; well completion (wastewater ponds)</td>
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<td>(4) Production</td>
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<td>(5) Natural gas processing &amp; storage (compressors, separators, condensate tanks)</td>
<td>(6) Natural gas transmission (pipelines)</td>
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<td>(7) Well abandonment &amp; site rehabilitation</td>
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</table>
1) Develop hypotheses: Could UNGD Affect Children’s Health?

Potential Human Exposures

Individual exposures
- Water pollution
- Air pollution
- Soil contamination
- Physical hazards
- Psychosocial hazards

Community impacts
- Built environment
- Social environment
- Economic environment

Broader environmental threats
- Cumulative impacts from >10k wells over decades

What can environmental pollution do to human health?

Air pollution
- Nerve damage
- Lead
- Particulate matter
- Ozone
- Volatile organic compounds

Water pollution
- Bacteria
- Parasites
- Chemicals

Soil contamination
- Gastroenteritis
- Cancer risk
- Nausea
- Skin irritation

(EPA 2016)
Community Context Matters for Health

Just a few examples:

Review article
Contextual effects and cancer outcomes in the United States: a systematic review of characteristics in multilevel analyses
2017
Annals of Epidemiology

Review article
Area-level socioeconomic disadvantage and suicidal behaviour in Europe: A systematic review
2017
Social Science & Medicine

Contextual Determinants of Childhood Injury: A Systematic Review of Studies With Multilevel Analytic Methods
2015
American Journal of Public Health

Community Stress, Psychosocial Hazards, and EPA Decision-Making in Communities Impacted by Chronic Technological Disasters
2011
American Journal of Public Health

Why children are of extra concern

Not small adults -> fetuses, infants, children, and adolescents have unique characteristics that heighten susceptibility to environmental exposures:

- Biologic sensitivity (bodies still developing)
- Differences in exposure (eat & drink more per unit body weight, hand-to-mouth activity, more time outdoors)
- Longer future lifespan leads to greater cumulative exposure and more opportunity to develop disease
2) Measure UNGD Exposure

Pathways:

- Water Contamination -> Ingestion
- Air Pollution -> Inhalation
- Noise + Sleep Disturbance + Earthquakes + Community Impacts -> Stress

Challenges:

- Funding

UNGD activity past peak -> measuring historical exposures

2) Measure Exposure: Methods Used by Schwartz & Others

**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

**Process Diagram**

- **PAD**
  - Well pad development
  - Wells assigned to pads
  - Starts 30d before first well on pad spudded, ends on spud date

- **SPUD**
  - Start of well drilling
  - Starts with SPUD date
  - Ends up to 30d later as linear function of well total depth

- **STIM**
  - Stimulation
  - AKA "fracking"
  - Starts with ST M date
  - Ends 7 days later
  - \( \text{NUMERATOR} = \text{total depth} \)

- **PROD**
  - Production
  - Starts day of first non-zero production value
  - Continues every day with non-zero value
  - \( \text{NUMERATOR} = \text{production volume} \)
2) Measure Exposure: Methods Used by Schwartz & Others

UNGD activity metrics get BIGGER if you are surrounded by

- **Closer wells**
- **More wells**
- **Larger wells**

*All wells in state contribute:*
- **Closer**: distance residence to well
- **More**: number of wells
- **Larger**: total depth (STIM) or volume of production (PROD)

<table>
<thead>
<tr>
<th>Minimum</th>
<th>Reference Group</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Q1, Q2, Q3, Q4</td>
<td>Big #</td>
</tr>
</tbody>
</table>

3) Measure Health Outcome

**Options:**
- Governmental databases
- Health records
- Surveys

**Challenges:**
- Difficult to obtain access to healthcare records
- Bias toward more severe events being recorded in government databases, healthcare records, and surveys
4) Biostatistical analysis

Exposure to UNGD  

?  

Incidence, risk, or odds of the health outcome

Evidence of UNGD Affecting Children’s Health

Stages of UNGD Activity  
(and some infrastructure involved)  

Initial Inquiry into the Scientific Basis of Health Concerns  

Epidemiologic Studies

(HEI 2018)
Health Impact #1: Pregnancy, Birth, and Infant Outcomes

- Higher prevalence of low birth weight (Hill, 2012; Stacy et al., 2015; Currie et al., 2017)
- Higher odds of small for gestational age (Hill, 2012; Stacy et al., 2015)
- Lower 5-minute Apgar scores (Hill, 2012)
- Higher odds of congenital heart defects and neural tube defects (McKenzie et al., 2014)
- Lower average birth weight (Stacy et al., 2015; Currie et al., 2017)
- Higher odds of preterm birth (Casey et al., 2016; Whitworth et al., 2017; Whitworth et al., 2018)
- Higher odds of high-risk pregnancy (Casey et al., 2016)
- Higher odds of fetal death (Whitworth et al., 2017)
- Lower infant health index (Currie et al., 2017)

Two sensitivity analyses:
1. County not associated with asthma exacerbations
2. UNGD not associated with diarrhea illness among asthma patients
Health Impact #3: Various symptoms

- Higher odds of upper respiratory and dermatologic symptoms (Rabinowitz et al., 2015)
- Higher odds of chronic rhinosinusitis, migraine headache, & fatigue symptoms (Tustin et al., 2017)

Other Health Studies

- **Health impact assessments** — several (e.g., Witter, AJPH 2013; McKenzie, Sci Tot Env 2012; Boyle, PLOS One 2016)
- **Calls to action** — many (e.g., Finkel, AJPH 2013 & 2011; Bamberger, New Solut 2012)
- **Review articles, health** — several (e.g., Adgate, ES&T 2014; Hays, noise, Sci Tot Env 2017, Moore, ES&T 2014; Webb, Rev Env Health 2016; Hays, PLOS One 2016)
  - Hays 2016: “31 original research studies relevant to UNGD and public health hazards, risks, and health outcomes”
- **Qualitative research** — focus groups are concerned about potential health impacts and believe they are experiencing current health effects (e.g., Ferrar, IOEH 2013; Sangaramoorthy, Soc Sci Med 2016)
- **Survey research** — mainly convenience samples (e.g., Steinhor, New Solut 2013; Powers | Comm Health 2015; Saberi UERPH 2014)
Additional strengths & challenges of these epidemiologic studies

| Associations robust to increasing covariate control + in several sensitivity analyses | Can (should) only be investigating short-latency outcomes at this time (i.e. not cancer yet). |
| Associations are biologically plausible | We cannot identify mechanisms. |
| Large sample sizes (i.e. >1 million) in many of the studies | Threat to science from industry + politics |

But is it better than coal?

Natural gas is the cleanest burning of the fossil fuels, with lower emissions of carbon dioxide per unit of derived energy and virtually no release of combustion toxicants.

However, low natural gas prices are delaying renewables AND fugitive emissions of methane make UNGD worse for GHG emissions than coal if they exceed ~3% (and estimates range from 1-6%).

(Allen et al., 2013; Howard, 2015; Howarth, 2015; Jiang et al., 2011)
Contribution to Climate Change -> Health Impacts

- Injuries, fatalities, mental health impacts
- Asthma, cardiovascular disease
- Heat-related illness and death, cardiovascular failure
- Severe Weather
- Air Pollution
- Malaria, dengue, encephalitis, hantavirus, Rift Valley fever, Lyme disease, chikungunya, West Nile virus
- Changes in Vector Ecology
- Forcibly displaced populations, civil conflict, mental health impacts
- Extreme Heat
- Increasing Allergens
- Respiratory allergies, asthma
- Environ mental Degradation
- Water and Food Supply Impacts
- Water Quality Impacts
- Malnutrition, diarrheal disease
- Cholera, cryptosporidiosis, campylobacter, leptospirosis, harmful algal blooms
- CDC 2014

Fracking Ban in Maryland

2015: Maryland passes moratorium on hydraulic fracturing
Fracking Ban in Maryland

2016: Evidence of negative health concerns growing + strong advocacy campaigns

2017: Maryland passes ban on hydraulic fracturing

Health Professionals

Environmental Organizations

Religious Groups

Larry Hogan @LarryHogan 17 Mar
Because the legislature has failed to act on our tough regulations I have decided to announce my full support for Sen. Zirkin’s fracking ban

DON'T FRACK MARYLAND

Fracking Ban in Maryland

2018: Still health concerns in MD over pollution from other UNGD infrastructure
- Compressor stations
- Pipelines
- Impoundments
Hope for child health protections in PA?

Gas wells not allowed on land zoned for homes or farms, high court rules

Questions?

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