Public Health Impacts of Shale Gas Development and Production

John L. Adgate

May 30, 2013
Professor and Chair
Department of Environmental and Occupational Health
University of Colorado
Acknowledgements

• Bernie Goldstein and Lisa McKenzie
• Funding from the Colorado School of Public Health, the National Science Foundation (NSF CBET-1240584), and RPSEA
• CSPH Colleagues: Roxana Witter, Lee Newman, Ken Scott, Kaylan Stinson
• Garfield County Public Health: Jim Rada, Paul Reaser
Roadmap

• What have we learned?
  – Colorado Example
    • HIA
    • Exposures and Risks
  – Research on potential air and water exposures

• What do we need to know?
  – Uncertainties and Research Needs
Shale Gas D&P From a Public Health Perspective

• Systems Approach
  – Direct and indirect effects, environmental and social processes

• Well Development
  – Short term, repeated in many locations
  – Episodic and continuous exposures
  – Short- and long-term risks

• Well Production
  – Infrastructure: more continuous, less episodic
  – Accidents, Incidents, and Impacts
  – Long term PH Effects / Trade Offs
What effects does natural gas development have on human health?

Issues in B. Mesa:
- Air quality
- Water quality
- Traffic
- Noise
- Economic conditions
- Social conditions
- Health infrastructure
- Accidents/malfunction

NRC 2011
Battlement Mesa HIA/EHMS
Battlement Mesa Health Impact Assessment (2nd draft)

The Battlement Mesa Health Impact Assessment (HIA) is a document that provides objective information and evidence-based recommendations to increase the potential health benefits of natural gas drilling in the Battlement Mesa PUD, while minimizing potential health risks. On March 1, 2011, the second draft of the HIA became available for stakeholders in the community to review. We invited community stakeholders, including stakeholders in government, citizen groups, academia and the private sector, to submit questions, criticisms and comments that they may have about the HIA.
The Use of Health Impact Assessment for a Community Undergoing Natural Gas Development

Roxana Z. Witter, MD, MSPH, Lisa McKenzie, PhD, MPH, Kaylan E. Stinson, MSPH, Kenneth Scott, MPH, Lee S. Newman, MD, MA, and John Adgate, PhD, MSPH

The development of natural gas wells is rapidly increasing, yet little is known about associated exposures and potential public health consequences. We used health impact assessment (HIA) to provide decision-makers with information to promote public health at a time of rapid decision making for natural gas development. We have reported that natural gas development may expose local residents to air and water contamination, industrial noise and traffic, and community changes. We have provided more than 90 recommendations for preventing or decreasing health impacts associated with these exposures. We also have reflected on the lessons learned from conducting an HIA in a politically charged environment. Finally, we have demonstrated that despite the challenges, HIA can successfully enhance public health policymaking. (Am J Public Health. Published online ahead of print April 18, 2013: e1–e9. doi:10.2105/AJPH.2012.301017)

Many regions of the United States hold large natural gas reserves.\(^1\) Colorado is one of the states experiencing rapid natural gas development. Applications for permits to drill rose from 1939 in 2003 to 7870 in 2008\(^2,3\) and natural gas wells in the community, some of which would be approximately 500 feet from homes. The well development phase would be 5 years, followed by a 20- to 30-year production phase.

\(^1\)“complete physical, mental, and social well-being”\(^17\) and understanding that living environment is a determinant of health,\(^18\) we addressed a wide range of potential exposures from natural gas development and the subsequent effects these exposures could have on public health. Because we conducted the HIA before the project had begun, site-specific data for exposures were not available; instead we used exposure data from other local sites where natural gas development had occurred and medical literature to describe the known health effects of such exposures. Throughout the HIA process, we worked closely with county public health professionals and received technical guidance and support from experienced HIA practitioners. The full HIA and supporting documents are available on the county Web site.\(^19\)
HIA: Available Data and Information Gaps

Available

✓ Local air monitoring data
✓ Traffic and noise estimates
✓ Anecdotal reports of exposures and health symptoms
✓ Demographic, vital statistics, cancer, birth outcomes, hospital discharge, STI, school, crime data
✓ Scientific literature for possible exposures

Didn’t have complete exposure information

Didn’t have complete health outcomes data
HIA Findings: Potential Adverse Health Impacts

**Chemical**
- Acute (e.g., headache, nausea, respiratory tract irritation) and chronic (asthma/COPD exacerbation)
- Cancer risk

**Industrial Activities**
- Traffic and other accidents
- Noise
- Fire/explosion risks

**Community Changes**
- Decreased physical activity
- School enrollment turnover
- Decreased social engagement
- Psychosocial stress
HIA Recommendations

• **Pollution Prevention**
  – reduce the opportunity for residents to be exposed to industrial chemicals

• **Promote Safety**
  – promote safe industry operations in a residential neighborhood

• **Communication**
  – foster constructive interaction between stakeholders
HIA to Quantitative Risk Assessment

- Ambient air data collected over several years was available
- Applied standard EPA methodology for screening level risk assessment
- One of many tools used to evaluate human health
# Uncontrolled Emission Estimates from NG Completion Operations (USEPA 2011)

<table>
<thead>
<tr>
<th>Well Completion Category</th>
<th>Emissions (Mcf/event)</th>
<th>Emissions (tons/event)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Methane</td>
<td>Methane</td>
</tr>
<tr>
<td>NG Well Completion w/o Fracturing</td>
<td>38.6</td>
<td>0.80</td>
</tr>
<tr>
<td>NG Well Completion with Fracturing</td>
<td>7,623</td>
<td>158.6</td>
</tr>
</tbody>
</table>

~200X more air pollution from uncontrolled NG well completions
Air Quality During Well Completion

  - Human Health Risk Assessment
  - Limited number of “flowback” samples as well as area samples
  - Risk of sub-chronic and chronic non-cancer health effects and lifetime excess cancer risk
Human Health Risk Assessment

• “Screening” Risk Estimates Using EPA methods
  – EPA Reference Concentrations (RfCs), inhalation unit risks, and other health-based guidelines when RfCs or cancer potency estimates not available
  – Scenario-based chronic and subchronic assessments for nearby residents

• Quantitative Risk Assessment
  – Non Cancer (Systemic): Hazard Index
    • Ratio of estimated exposure to RfC and/or health-based guidance level
    • Index sums potential effects of multiple chemicals
    • Are these greater than 1?
  
  – Cancer: Lifetime Excess Cancer Risk, multiple chemicals
    • Are risks greater than 1 in a million ?
    • Are risks greater than 1 in 10,000 ?
Hazard Indices by Duration of Exposure and Distance from Source

- Chronic, Far: 0.4
- Subchronic, Far: 0.2
- Chronic, Near: 1
- Subchronic, Near: 5

Level above which health effects may occur
Hazard Indices by Health Endpoint: Near Wells, 20 Month Exposure Scenario

- Neurological Effects: 4
- Respiratory Effects: 2
- Hematological Effects: 3
- Developmental Effects: 1
Non-Cancer Risk Drivers

- Trimethylbenzenes: 50%
- Alkanes: 26%
- Xylenes: 15%
- Benzene: 5%
- Others: 3%
Excess Lifetime Cancer Risks

Summary of Excess Lifetime Cancer Risk

Risk where EPA requires remediation

EPA's Target of 1 in a million

Excess Cancer Risk per one Million Individuals

Residents > 1/2 mile

Resident ≤ 1/2 mile

Exposure Scenario

Colorado School of Public Health
Excess Lifetime Cancer Risk Drivers

- Benzene: 87%
- Ethylbenzene: 35%
- Styrene: 1%
- 1,3-Butadiene: 7%
Risk Assessment Summary

• Residents living near well completion activities potentially exposed to substantial levels of air toxics.

• Estimated cancer risks and chronic non-cancer hazard indices are greater for residents living nearest the well pads, but are within generally acceptable range.

• **Subchronic non-cancer cumulative and endpoint specific hazard indices are greater than one for residents living near well pads.**
Uncertainties, Limitations & Unanswered Questions

• Limited data exists on emissions on primary, secondary, and engine-related air pollutants at well completion sites
  – Understanding spatial and temporal variability in exposures is key

• Non-methane pollutant emissions vary by field type, number of well heads, completion process used and controls in place

• These data do not tell us how far is far enough nor how close is too close to well development sites
Water
Concerns About Water

- **Quantity**
  - 1-2 million gallons/drill
  - 2-5 million gallons/hydraulic fracture
- **Quality**
  - Chemicals
    - *Hydraulic fracturing, drilling muds and additives, naturally occurring*
    - Contamination of ground and surface water
- **Disposal**
  - Salts, metals, hydrocarbons, radioactivity (NORM)
  - Earthquakes
- **Mixtures**
<table>
<thead>
<tr>
<th>Additive</th>
<th>Example Chemical</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid</td>
<td>Hydrochloric acid or muriatic acid</td>
<td>Helps dissolve minerals and initiate cracks in the rock</td>
</tr>
<tr>
<td>Antibacterial agent</td>
<td>Glutaraldehyde</td>
<td>Eliminates bacteria in the water that produces corrosive by-products</td>
</tr>
<tr>
<td>Iron control</td>
<td>Citric acid</td>
<td>Prevents precipitation of metal oxides</td>
</tr>
<tr>
<td>Breaker</td>
<td>Ammonium persulfate</td>
<td>Allows a delayed break down of the frac gel</td>
</tr>
<tr>
<td>Corrosion inhibitor</td>
<td>n,n-dimethyl formamide</td>
<td>Prevents corrosion of pipe</td>
</tr>
<tr>
<td>Crosslinker</td>
<td>Borate salts</td>
<td>Maintains fluid viscosity</td>
</tr>
<tr>
<td>Surfactant</td>
<td>Isopropanol</td>
<td>Increases viscosity of the frac fluid</td>
</tr>
<tr>
<td>Friction reducer</td>
<td>Petroleum distillate</td>
<td>Minimizes friction</td>
</tr>
<tr>
<td>Gel Guar gum</td>
<td>Hydroxyethyl cellulose</td>
<td>Helps suspend the sand in water</td>
</tr>
<tr>
<td>Clay stabilizer</td>
<td>Potassium chloride</td>
<td>Brine carrier fluid</td>
</tr>
<tr>
<td>pH adjusting agent</td>
<td>Sodium or potassium carbonate</td>
<td>Adjusts and controls pH of the fluid</td>
</tr>
<tr>
<td>Scale Inhibitor</td>
<td>Ethylene glycol</td>
<td>Reduces scale deposits in pipe</td>
</tr>
</tbody>
</table>
Hazard Identification & Exposure Modeling
Rozell, 2012 Risk Analysis

- Probability bounds analysis
- Modeled 5 possible water contamination pathways
  - Casing failure, fracture migrations, surface contamination, transportation, disposal
- Wastewater disposal poses highest risk -- by several orders of magnitude
Industrial Activities
Silica
(NIOSH; Esswein et al 2013)

- OSHA-NIOSH HAZARD ALERT
- 11 sites in AR, CO, ND, PA, TX
- 116 Personal breathing zone, full shift samples
- Exceeded OSHA PEL, NIOSH REL, ACGIH TLV
- 31% w/ levels above what respirator could handle

http://www.osha.gov/dts/hazardalerts/hydraulic_frac_hazard_alert.html
Hazards Associated with Truck Traffic

- NY State/GAO estimates: 1,000+ truck trips per well
  - Multiply on multi-well pads
- Dispersed and well pad impacts
  - Living along haul routes
  - Round the clock operations
- Variety of hazards
  - Diesel exhaust
  - Dust
  - Noise, vibration
    - Engine braking
    - Grinding gears
  - Safety risks
    - School routes
Occupational Fatalities: Wyoming (Ryan 2011)

- Wyoming 2001-10 occupational fatality rate per 100,000 ranged from 2-3X the US rate
  - Oil/Gas: from 2001-8 there were 62 fatalities
    - 32 (52%) occurred on a drill rig
    - 25 (40%) were transportation-related
    - 5 (8%) related to distribution and off-site repair
- Overriding theme: “lack of a culture of safety”
Hazards Associated with Noise

30 dB: Sleep disturbance
55 dB: Fatigue, cognition, mood
70 dB: School performance

- Quiet room: 28-33 dB
- Forced air heat: 42-52 dB
- Kitchen exhaust fan: 69-71 dB
- Garbage disposal: 76-83 dB
- Lawn mower: 88-94 dB

- 30 dB: Sleep disturbance
- 55 dB: Fatigue, cognition, mood
- 70 dB: School performance

Hypertension
Cardiac disease
Regions and Communities
Regional Wintertime Ozone
Wyoming, Utah

NOx from combustion

VOC from wells, tanks, compressors

Sunlight
Snow reflection

Ozone
100-125 ppb

NAAQS 75 ppb

http://deq.state.wy.us/aqd/Ozone%20Main.asp
http://www.denverpost.com/business/ci_20042330
Predicted regional ozone impacts in TX and LA

- **Ozone Impacts of Natural Gas Development in the Haynesville Shale**
  - Increases of 5 ppm from increased precursors 2° to NG

Kembal-Cook, 2010 Enviro Sci Technology

Hazards Associated with Community Changes

Garfield County population
2000-09: ↑ 28%
2005-2009: ↑ 14%

Police Arrests

Sexually Transmitted Infections
Stress Exposure Public Health: Battlement Mesa HIA Quotes

“I feel angry…impending events weigh on my mind… stress, anger, anxiety, feelings of helplessness and (worry about) possible health problems…”

“There has been be personal distress… including depression, anxiety and insomnia…we don’t know what will happen or when…”
### Reasons given by those not in favor of UGD

(Goldstein et al, Env Hlth Persp 120:483-486, 2012)

Washington, PA public meeting with Natural Gas Subcommittee of the Secretary of Energy Advisory Board, June, 2011 (N=59)

<table>
<thead>
<tr>
<th>Reason</th>
<th>Percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental Concerns</td>
<td>76.3</td>
</tr>
<tr>
<td>Negative Effects on Water</td>
<td>66.1</td>
</tr>
<tr>
<td>Negative Effects on Air</td>
<td>42.4</td>
</tr>
<tr>
<td>Chemicals in Water</td>
<td>30.5</td>
</tr>
<tr>
<td>General Health Concerns</td>
<td>61.0</td>
</tr>
<tr>
<td>Health Problem in Family member attributed to drilling</td>
<td>20.3</td>
</tr>
<tr>
<td>Personal legal rights have been infringed upon by companies</td>
<td>11.9</td>
</tr>
<tr>
<td>Concerns about safety of drilling operations</td>
<td>33.9</td>
</tr>
<tr>
<td>Concerns about lack of regulation of industry</td>
<td>42.4</td>
</tr>
<tr>
<td>Bias, conflict of interest, or lack of expertise in desired subject area by members of the committee</td>
<td>18.6</td>
</tr>
<tr>
<td>Export of domestic natural gas resources</td>
<td>10.2</td>
</tr>
<tr>
<td>Depreciation in property values</td>
<td>3.4</td>
</tr>
</tbody>
</table>
Stressors Volunteered by Subjects Who Believe Their Health has been Affected by Marcellus Shale Activities (n=33) (Ferrar et al 2013)

<table>
<thead>
<tr>
<th>Top 6 Stressors</th>
<th>% of group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Denied or provided false information</td>
<td>79%</td>
</tr>
<tr>
<td>Corruption</td>
<td>61%</td>
</tr>
<tr>
<td>Concerns/complaints ignored</td>
<td>58%</td>
</tr>
<tr>
<td>Being taken advantage of</td>
<td>52%</td>
</tr>
<tr>
<td>Financial damages</td>
<td>45%</td>
</tr>
<tr>
<td>Noise pollution</td>
<td>45%</td>
</tr>
</tbody>
</table>
Stress and the Environment

(Morello-Frosche and Shenessa 2006; Clougherty and Kubzansky 2009)

• Allostatic load
  – Chemical and Non-Chemical Stressors
  – Stress affects immune function, susceptibility

• Community Level Effects

• Individual Level Effects
Community Level Effects

Air or Water Pollution → Fate and Transport → Exposure
Individual Level Effects

- Internal Dose
- Response and Resilience
- Health Effects
- Ability to Recover

Colorado School of PUBLIC HEALTH
Public Health Research
Needed Public Health Research

- Environmental concentrations
- Exposures
- Health outcomes tracking
- Community impacts
  - Noise, Traffic, etc.
  - Psycho-Social effects
Colorado Well Setback Rules

- Old Rules: 150/350 ft for rural/urban areas
- New Rules (Feb 2013): 500 ft, with mitigations for noise, traffic etc. up to 1000 ft
- Industry: too far
- Some Front Range Communities: not far enough
  - Bans of HVHF in Longmont, Erie, Fort Collins, Boulder
  - Litigation!

Photo credit: Denver Post, Hyoung Chang
What Do We Need to Know?

- Characterize the range of activities and environmental factors needed to develop smart setback policies
  - Descriptions of the variability in emissions, air levels, & human exposures
- Develop toxicity factors
- Understand the effects of chemical mixtures and noise/traffic/accidents on health & quality of life
- Incorporate stress in the individual and community level assessments
Final Thoughts

• Systematic **before, during, and after** data collection continues to be needed on exposure and health

• Chemical mixtures and non chemical stressors likely affect both workers and communities

• Public health prevention strategies should be directed at minimizing exposures during completion activities