Role of Monitoring in Addressing Health Impact from Oil and Gas Development

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Willie Sutton

Application of the Wisdom of Willie Sutton to Environmental Monitoring of Shale Gas Drilling Activities

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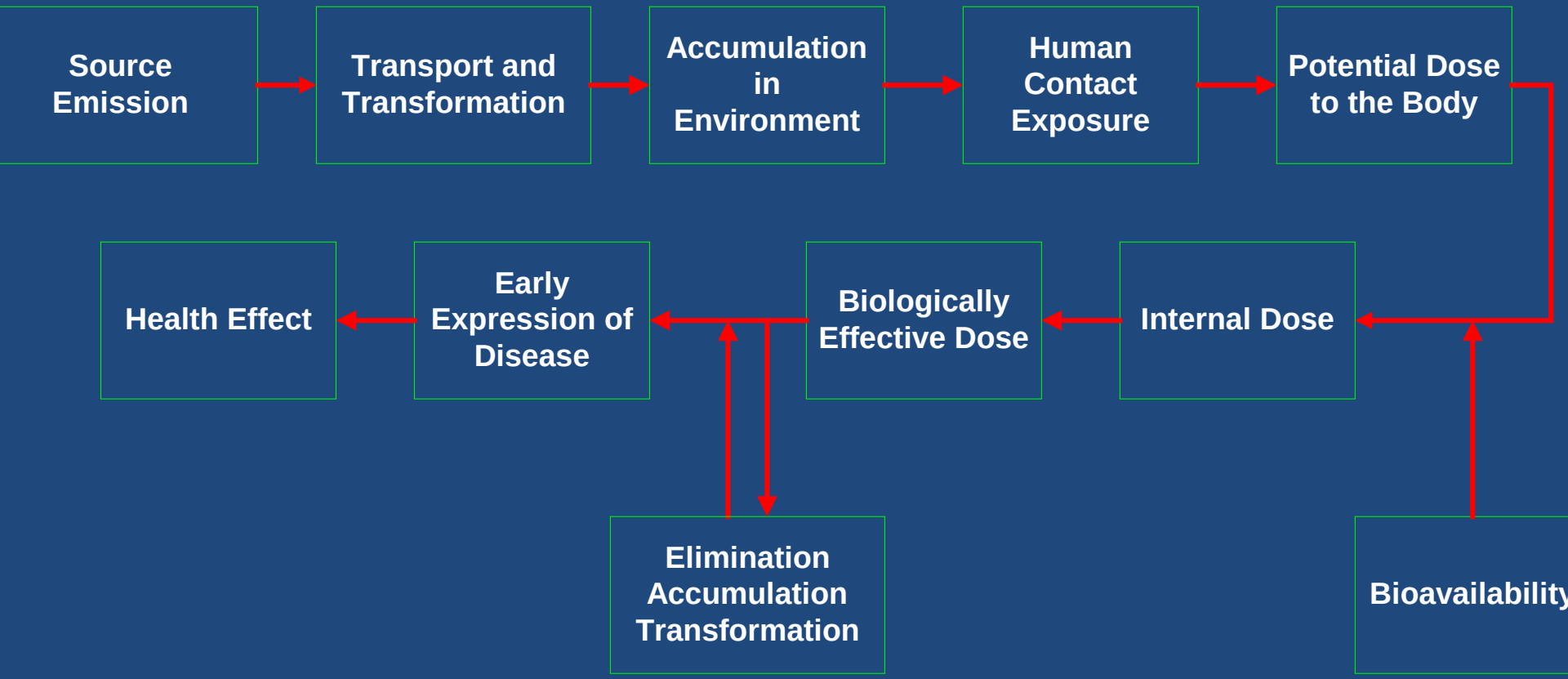
Continuum for the Emission of and Exposure to a Contaminant and the Expression of a Health Effect



P.J. Lioy, Env. Sci. & Tech. 1990

My View: What's the Rush to Drill?

- Unfortunately, there is no reasonable scenario in which non-fossil fuels or energy conservation will completely obviate our national need for fossil fuels in the next few decades
- During this time it is certain that virtually all of the US tight shale formations will be drilled for natural gas
- In contrast to the Gulf oil deposits, which might be tapped by other countries, the shale gas deposits of natural gas are ours
    - **So what's the rush?**

Potential Health Benefits of Natural Gas Development

- Replacement of coal in power generation leading to lesser emissions of particulates, sulfur oxides, nitrogen oxides and mercury

- Probable decrease in greenhouse gas impact of fossil fuels

Principles that Underpin an Effective Monitoring Program

(Based on the report of the Integrated Oil Sands Monitoring Plan Expert Panel– Environment Canada, 2011)

- **Adaptive and robust:** an approach that can be evaluated and revised as new knowledge, needs, and circumstances change and that ensures stable and sufficient funding.
- **Inclusive and collaborative:** an approach that engages concerned parties in the design and execution, including the prioritization of issues and setting of ecosystem goals.

Principles that Underpin an Effective UGD Monitoring Program

(Based on the Integrated Oil Sands Monitoring Plan Expert Panel–Environment Canada, 2011)

- **Holistic and comprehensive:** a systemic approach that incorporates multi-scale spatial measurements and recognizes the temporal dimension, from past to future.
- **Scientifically Rigorous:** a science-based approach that uses robust, consistent methodology and standardized reporting, including peer-review, that will result in independent, objective, complete, reliable, verifiable, and replicable data.

Principles that Underpin an Effective Monitoring Program

(Based on the report of the Integrated Oil Sands Monitoring Plan Expert Panel– Environment Canada, 2011)

- **Transparent and accessible:** an approach that produces publicly available information (in forms ranging from raw data to analyses) in a timely manner that will enable concerned parties to conduct their own analysis and draw their own conclusions and that will make the basis for judgment and conclusions explicit.

Sutton's Law: Directly Measure Exposures or Effects in Receptors of Concern

Sutton's Law may be violated if:

1. The time and locations of all significant releases can be reasonably identified.
2. All intermediate pathways can be reasonably identified and measured.
3. The chemical and physical agents of potential concern are known and can be measured
4. The exposure measurement scale is pertinent to the geographic scale of concern

12 Types of Additives for Fracking (0.5% of fluid)

Additive	Example Chemical	Purpose
Acid	Hydrochloric acid or muriatic acid	Helps dissolve minerals and initiate cracks in the rock
Antibacterial agent	Glutaraldehyde	Eliminates bacteria in the water that produces corrosive by-products
Iron control	Citric acid	Prevents precipitation of metal oxides
Breaker	Ammonium persulfate	Allows a delayed break down of the frac gel
Corrosion inhibitor	n,n-dimethyl formamide	Prevents corrosion of pipe
Crosslinker	Borate salts	Maintains fluid viscosity
Surfactant	Isopropanol	Increases viscosity of the frac fluid
Friction reducer	Petroleum distillate	Minimizes friction
Gel Guar gum	Hydroxyethyl cellulose	Helps suspend the sand in water
Clay stabilizer	Potassium chloride	Brine carrier fluid
pH adjusting agent	Sodium or potassium carbonate	Adjusts and controls pH of the fluid
Scale Inhibitor	Ethylene glycol	Reduces scale deposits in pipe

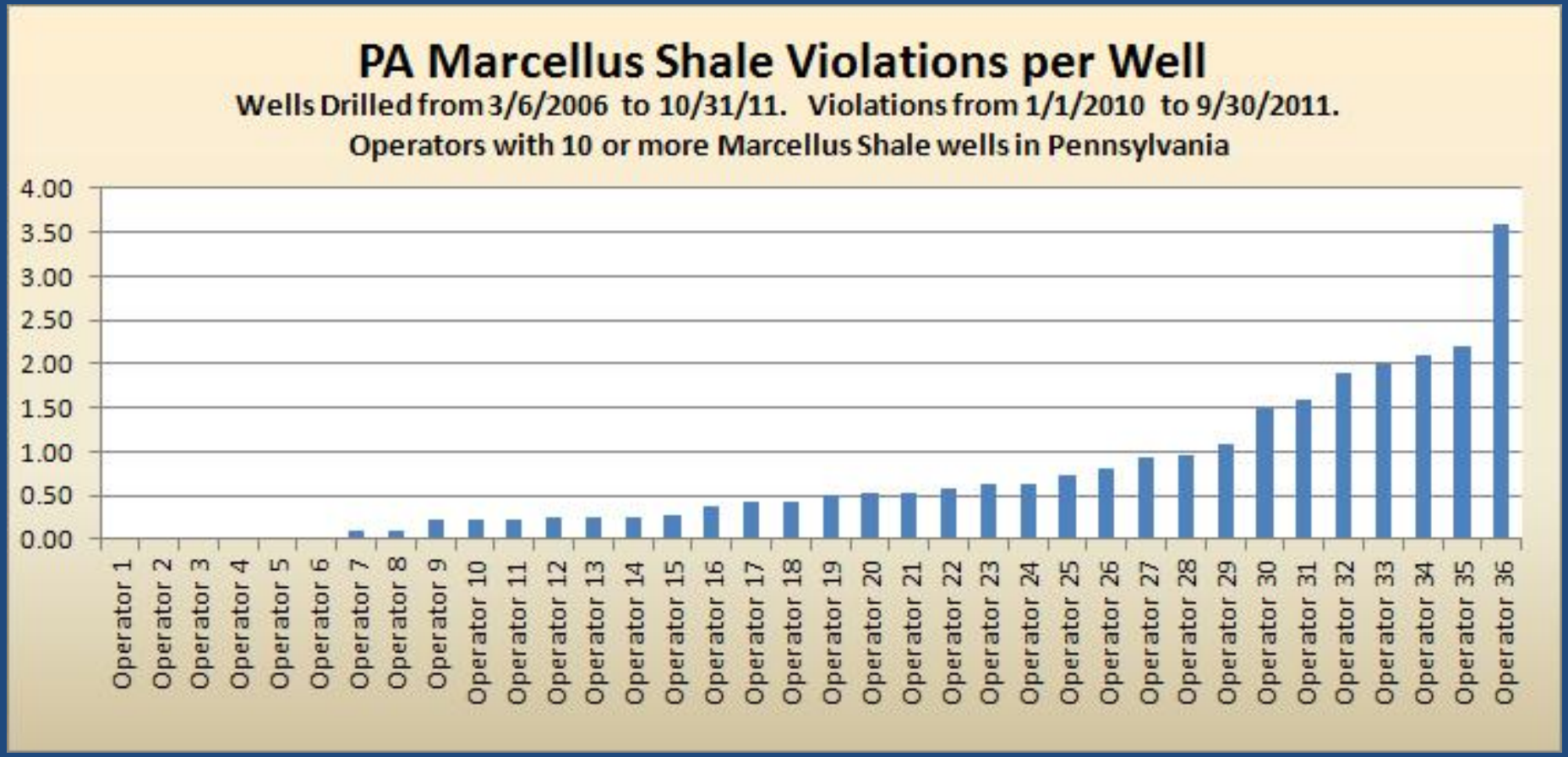
Sources: Earthworks. (2011). *Hydraulic Fracturing 101*. Retrieved Jan 11, 2012, from http://www.earthworksaction.org/issues/detail/hydraulic_fracturing_101#CHEMICALS;
EnergyIndustryPhotos. (2008). *What is Hydraulic Fracturing and What is it Used for?* Retrieved Jan 11, 2012, from http://www.energyindustryphotos.com/what_is_hydraulic_fracturing.htm

Many Agents of Potential Concern

- Three sources of toxicologically relevant agents
  - Hydrofracturing agents
  - Hydrocarbons and gases present in shale; methane, ethane, propane, BTEX, hydrogen sulfide
  - Natural constituents: brine components; barium, bromide, calcium, chloride, iron, magnesium, strontium; arsenic; radionuclides
  - ***Mixtures of any or all of above***
- Chemical reactions favored by higher temperatures and affected by other local conditions
  - Temperature in shale that favors natural gas production is ~480F
  - High pressure and salinity

Why Exposure Can Vary Greatly From Site to Site

- Different safety culture
- Different geology
- Different site-specific issues
- Different drilling technology
- Different hydraulic fracturing chemicals
- Different shale gas collection and distribution techniques
- Different flowback disposal techniques



Source: FracTracker. (2011). *FracTracker.* Retrieved Jan 11, 2012, from http://www.fractracker.org/

Potential Sources of Water Pollution with Hydraulic Fracturing Fluids

- Transport of agents to the site
- Storage and transfer on site
- The injection process
- Eventual disposal of the produced water

Potential Causes of Water Pollution with Hydraulic Fracturing Fluids

- Spills or leaks from transport or storage tanks
- Surface impoundment failures
- Leaching
- Overfills
- Vandalism
- Improper operation, including well failure

Site Development and Drilling Preparation

Resources for the Future—Survey on impacts of shale gas development, March 2012

- Clearing of land/construction of roads, well pads, pipelines, other infrastructure
- On-road vehicle activity
- Off-road vehicle activity

Drilling Activities

Resources for the Future—Survey on impacts of shale gas development, March 2012

- Drilling equipment operation at surface
- Drilling of vertical and lateral wellbore
- Casing and cementing
- On-road and off-road vehicle activity
- Use of surface water and groundwater
- Venting of methane
- Flaring of methane
- Storage of drilling fluids at surface
- Disposal of drilling fluids, drill solids, cuttings

Fracturing and Completion

Resources for the Future—Survey on impacts of shale gas development, March 2012

- Use of surface water/groundwater
- Perforation of well casing/cementing
- Hydraulic fracture initiation
- Introduction of proppant
- Flushing of wellbore
- Flowback of reservoir fluids
- Venting of methane
- Flaring of methane
- Storage of fracturing fluids at drill site
- On-road and off-road vehicle activity
- Fracturing equipment operation

Well Production/Operation

Resources for the Future—Survey on impacts of shale gas development, March 2012

- Well production
- Condensate tank, dehydration unit operation
- Compressor operation
- Flaring of methane

Fracturing Fluids, Flowback and Produced Water Storage and Disposal

- On-site or pond storage
- On-site tank storage
- Transport off-site
- On-site treatment and re-use
- Treatment, release by industrial wastewater treatment plants
- Treatment, release by municipal wastewater treatment plants
- Removal of sludge and other solids to landfills
- Deep underground injection
- Application of wastewater for road de-icing, dust suppression

Resources for the Future—Survey on impacts of shale gas development, March 2012

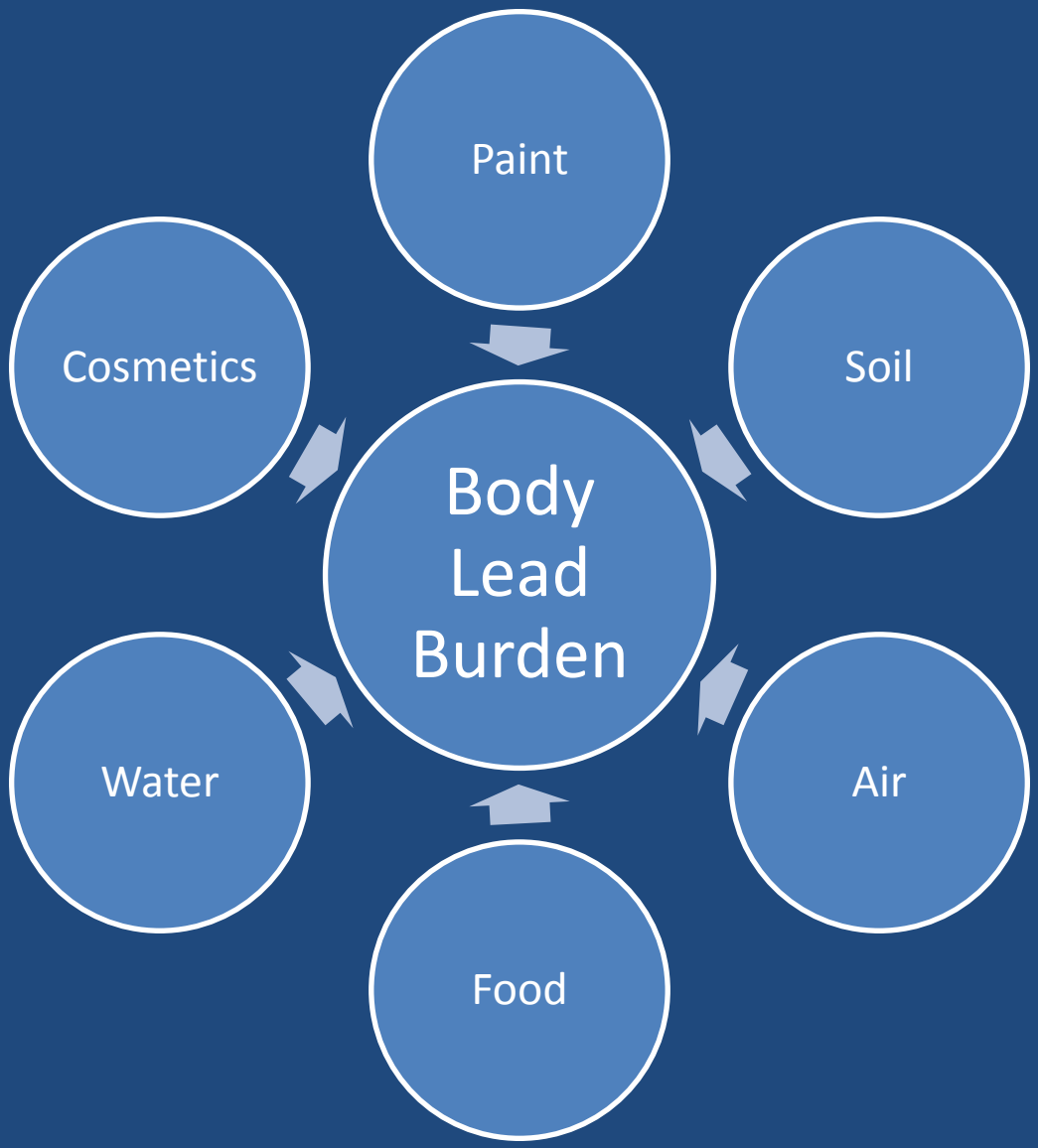
Other Activities

Resources for the Future—Survey on impacts of shale gas development, March 2012

- Shutting-in
- Plugging and abandonment
- Workovers
- Downstream activities (e.g., pipeline operation)

Potential Pathways for Human Health Impacts Related to UGD

- Safety Issues
- Air Pollution
  - Worker and community exposure to HF chemicals, silica, diesel exhaust and drilling compounds
  - Community exposure to air toxics, including benzene; nitrogen oxides, diesel exhaust, ozone
- Water Pollution
  - HF chemicals; flowback and produced waters on site or off site; reactants
- Light and Noise
- Psychosocial Effects
  - Exacerbated by lack of transparency and trust issues


Paint
Soil
Air
Food
Water
Cosmetics
Body Lead Burden

Measurements of methane emissions at natural gas production sites in the United States

David T. Allen, Vincent M. Torres, James Thomas, David W. Sullivan, Matthew Harrison, Al Hendler, Scott C. Herndon, Charles E. Kolb, Matthew P. Fraser, A. Daniel Hill, Brian K. Lamb, Jennifer Miskimins, Robert F. Sawyer, and John H. Seinfeld.

PNAS 110:17768–17773, 2013

Sponsors

- Environmental Defense Fund
- Anadarko Petroleum Corporation
- BG Group plc
- Chevron
- Encana Oil & Gas (USA) Inc.
- Pioneer Natural Resources
- SWEPI LP (Shell)
- Southwestern Energy
- Talisman Energy USA
- XTO Energy, an ExxonMobil subsidiary

- Allen, D. T., Torres, V. M., Thomas, J., Sullivan, D. W., Harrison, M., Hendler, A., . . . Seinfeld, J. H. (2013). Measurements of methane emissions at natural gas production sites in the United States. Proceedings of the National Academy of Sciences. doi: 10.1073/pnas.1304880110

Measurements of methane emissions at natural gas production sites in the United States

- Measurements were made of methane emissions during 27 completion flowback events.
- The duration of the completions ranged from 5 to 339 h (2 wk). Measured methane emissions over an entire completion flowback event ranged from less than 0.01 Mg to more than 17 Mg with an average of 1.7 Mg and a 95% confidence interval of 0.67-3.3 Mg.
- Potential emissions for the wells in this work ranged from 0.2 Mg to more than 1 Gg methane, with an average of 124 Mg.

Allen, D. T., Torres, V. M., Thomas, J., Sullivan, D. W., Harrison, M., Hendler, A., . . . Seinfeld, J. H. (2013). Measurements of methane emissions at natural gas production sites in the United States. Proceedings of the National Academy of Sciences. doi: 10.1073/pnas.1304880110

Measurements of methane emissions at natural gas production sites in the United States

- The nine unloading events reported in this work were varied in their characteristics. Methane emissions ranged from less than 0.02 Mg to 3.7 Mg. Some unloadings were as short as 10-15 min with uninterrupted flow for short periods and periods of no flow for much of unloading period. Some of the wells sampled only unloaded once over the current life of the well, whereas others were unloaded monthly.
- The sampled population reflected a wide range of emission rates, with a population of high emitting wells and a population of low hitting wells.

Allen, D. T., Torres, V. M., Thomas, J., Sullivan, D. W., Harrison, M., Hendler, A., . . . Seinfeld, J. H. (2013). Measurements of methane emissions at natural gas production sites in the United States. Proceedings of the National Academy of Sciences. doi: 10.1073/pnas.1304880110

Measurements of methane emissions at natural gas production sites in the United States

- For the unloading events without plunger lift, 100 of the 2,901 wells (3%) in the survey account for 50% of the estimated emissions. Ninety percent of the estimated emissions in the API/ANGA survey are due to one-half of the wells. Because a small population of the wells (3%) accounts for one-half of the emissions, if this relatively small population of high emitting wells is not adequately sampled, it is not possible to accurately estimate national emissions. The wells sampled in this work uploaded relatively infrequently. In contrast, some wells in the API/ANGA survey, including some of the highest emitting wells, unload with a daily or weekly frequency. An average frequency of unloading for the wells in the API/ANGA survey is 32.57 events per year, compared with an average observed in this work of 5.9.

Allen, D. T., Torres, V. M., Thomas, J., Sullivan, D. W., Harrison, M., Hendler, A., . . . Seinfeld, J. H. (2013). Measurements of methane emissions at natural gas production sites in the United States. Proceedings of the National Academy of Sciences. doi: 10.1073/pnas.1304880110

Measurements of methane emissions at natural gas production sites in the United States

- Average methane emission rates for a single unloading ranged from roughly 100 g/min to in excess of 30,000 g/min. These rates are much larger than emission rates for production sites (typically tens of grams of methane per minute per well) or from completions (typically a few hundred grams per event per minute). At these emission rates, a single unloading event could, during the short period that it is occurring, result in emissions that are the equivalent of up to several thousand wells in routine production.

Allen, D. T., Torres, V. M., Thomas, J., Sullivan, D. W., Harrison, M., Hendler, A., . . . Seinfeld, J. H. (2013). Measurements of methane emissions at natural gas production sites in the United States. Proceedings of the National Academy of Sciences. doi: 10.1073/pnas.1304880110

Measurements of methane emissions at natural gas production sites in the United States

- The uncertainty estimate does not include factors such as uncertainty in national counts of wells or equipment and the issue of whether the companies that provided sampling sites are representative of the national population.
- (BG: The goal of the Allen et al study was to determine average methane emissions relevant to a global scale problem. Methane emission is also a valuable marker of the emission of other natural gas components pertinent to local and regional air quality, including ozone levels)

Allen, D. T., Torres, V. M., Thomas, J., Sullivan, D. W., Harrison, M., Hendler, A., . . . Seinfeld, J. H. (2013). Measurements of methane emissions at natural gas production sites in the United States. Proceedings of the National Academy of Sciences. doi: 10.1073/pnas.1304880110

Definition of Obfuscation

- From Wikipedia:
  - Obfuscation (or beclouding) is the hiding of intended meaning in communication, making communication confusing, willfully ambiguous, and harder to interpret

Why Exposure Science for Shale Gas Drilling is Unnecessary

- We have decades of experience with no reported health problems
- The only question is whether the hydraulic fracturing chemicals released many thousands of feet underground percolate up to groundwater.
- The only possible concern is with chemical and physical hydrofracturing agents that are individually well-studied and of no particular toxicological concern at low concentrations.

Language of the Executive Orders Creating Unconventional Natural Gas Drilling Advisory Committees

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

"…task the Secretary of Energy Advisory Board (SEAB) with establishing a subcommittee…to develop, within six months, consensus recommended advice to the agencies on practices for shale extraction ***to ensure the protection of public health and the environment***" (emphasis added)

-President Barak Obama in
Blueprint for a Secure Energy Future (March 2011)

The Marcellus Shale Safe Drilling Initiative will assist State policymakers and regulators in determining how gas production from the Marcellus shale in Maryland can be accomplished ***without unacceptable risks of adverse impacts to public health, safety, the environment and natural resource***s" (emphasis added)

-Maryland Governor Martin O'Malley in
Executive Order 01.01.2011.11: The Marcellus Shale Safe Drilling Initiative (June 2011)

"WHEREAS, the Commonwealth takes seriously its responsibility to ensure the development of natural gas in a manner that ***protects the environment and safeguards the health and welfare of its citizens***" (emphasis added)

-Pennsylvania Governor Tom Corbett in
Executive Order 2011-011: Creation of Governor's Marcellus Shale Advisory Commission (March 2011)

Agencies, Sub-Agencies, and Commissions specified to receive funding from PA impact fee

(see Goldstein BD; AJPH December 12, 2013)

1. County Conservation Districts
2. State Conservation Commission
3. Pennsylvania Fish and Boat Commission
4. Public Utility Commission
5. Department of Environmental Protection of the Commonwealth
6. Pennsylvania Emergency Management Agency
7. Office of State Fire Commissioner
8. Department of Transportation
9. Natural Gas Energy Development Program (DEP)
10. Counties and municipalities
11. Housing Affordability and Rehabilitation Enhancement Fund
12. Commonwealth Financing Authority
13. Environmental Stewardship Fund
14. Motor License Fund (DOT)
15. Pennsylvania Infrastructure Investment Authority
16. Department of Community and Economic Development
17. Hazardous Sites Cleanup Fund

(BUT NOT THE PA DEPARTMENT OF HEALTH)

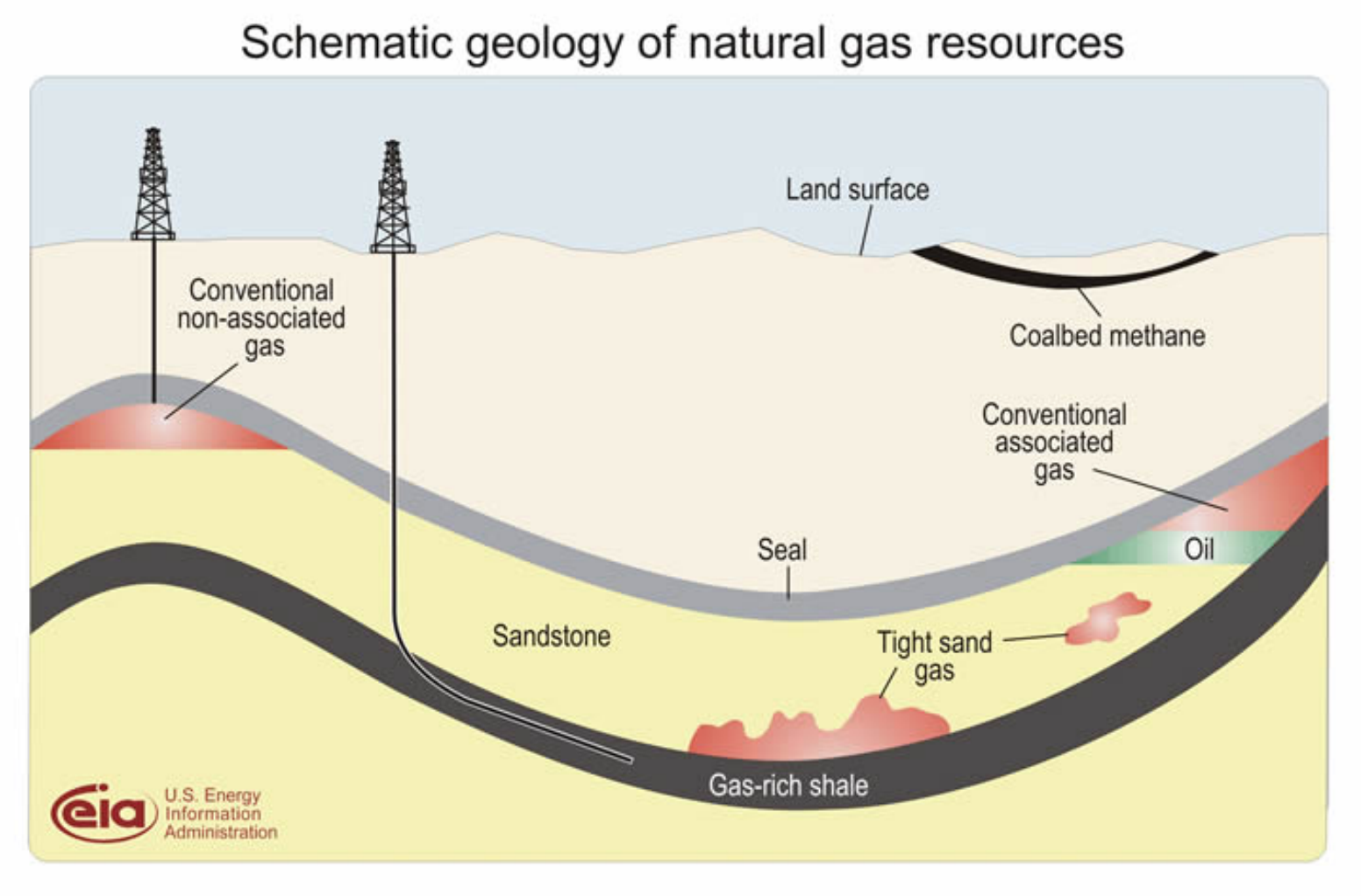
Managing the Story Through Obfuscation

Is hydrofracturing old or new?

1) To the nation's benefit, new hydrofracturing-related technology now permits extraction of gas that we have long known is trapped in the tight shale formations

2) We have been doing hydrofracturing for decades so there is nothing to worry about

Conventional and Non-conventional Natural Gas Extraction Methodologies



Childhood Cancer Incidence in Pennsylvania Counties in Relation to Living in Counties With Hydraulic Fracturing Sites.

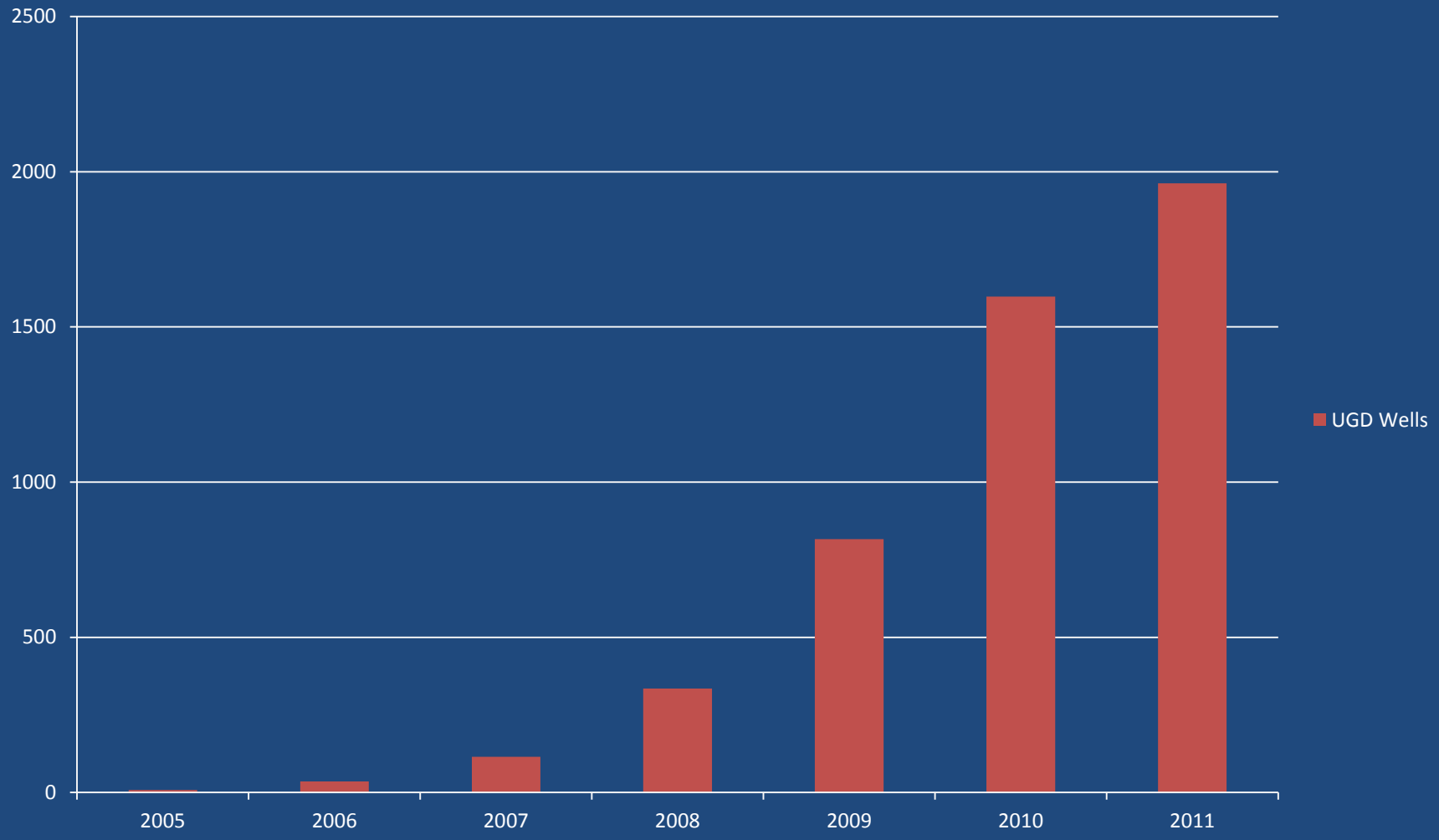
Fryzek et al JOEM 55:796-801, Jul 2013

(Response: Goldstein & Malone JOEM 55:1376-1378 Nov 2013)

Abstract

- "CONCLUSIONS: This study offers comfort concerning health effects of HF on childhood cancers".

UGD Wells in Pennsylvania



PA Department of Environmental Protection (DEP). (2013) Online Spud Data Report Database.Accessed 7-17-13
http://www.depreportingservices.state.pa.us/ReportServer/Pages/ReportViewer.aspx?/Oil_Gas/Spud_External_Data

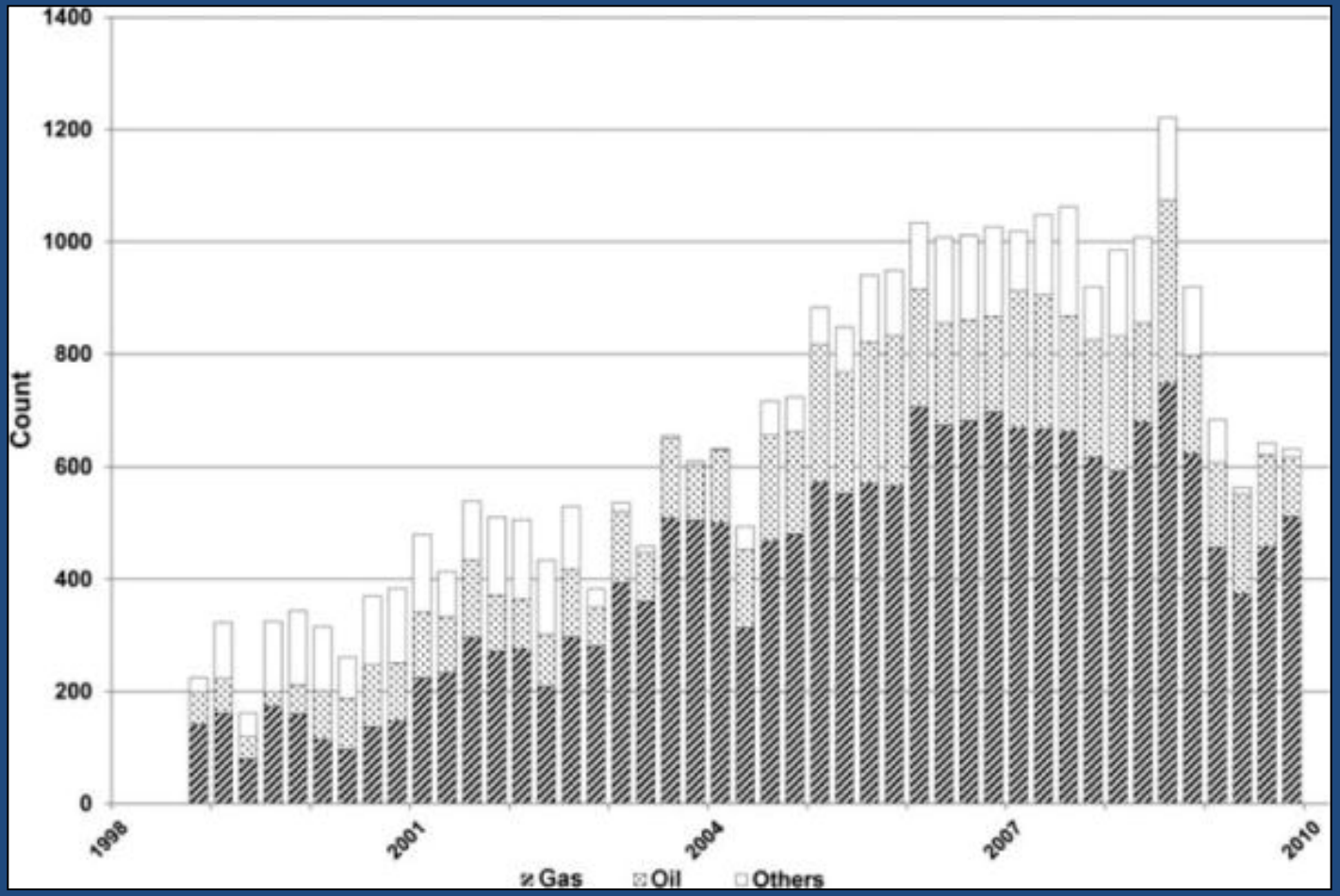


FIGURE 1 . Gas, oil, and other types of well drilling in Pennsylvania from January 1, 1998, to December 31, 2009.

Childhood Cancer Incidence in Pennsylvania Counties in Relation to Living in Counties With Hydraulic Fracturing Sites.
Fryzek, Jon; Pastula, Susan; Jiang, Xiaohui; Garabrant, David:
Journal of Occupational & Environmental Medicine. 55(7):796-801, July 2013.

Managing the Story through Obfuscation

Does hydrofracturing cause groundwater contamination?

1) There is no proven incident in which hydrofracturing has caused groundwater contamination

2) Major water contamination with hydrofracturing agents has occurred as a result of unconventional shale gas drilling activities

Congressional Testimony of Michael L. Krancer,
Secretary of the Department of Environmental Protection, Commonwealth of Pennsylvania

"There has been a misconception that the hydraulic fracturing of wells can or has caused contamination of water wells. This is false.

…hydraulic fracturing is only a temporary feature of natural gas development, which only lasts a few weeks.

Hydraulic fracturing of wells is not new in Pennsylvania, it has been going on here since about the 1950s and has been standard practice since about the 1980s."

From Nov. 16, 2011 testimony to the Congressional Subcommittee on Water Resources and Environment

Should information about agents to which they are potentially exposed be withheld from the public?

Dispersant used during the BP oil spill as an example

COREXIT 9500 MSDS: NALCO

(edited)

2. COMPOSITION/INFORMATION ON INGREDIENTS

Our hazard evaluation has identified the following chemical substance(s) as hazardous:

Hazardous Substance(s)	**(w/w)**
- Distillates, petroleum, hydrotreated light	10.0 - 30.0%
- Propylene Glycol	1.0 - 5.0%
- Organic sulfonic acid salt (Proprietary)	10.0 - 30.0%

Managing the Story

Industry is now supporting transparency in providing information about chemical agents related to unconventional shale gas drilling

1) Industry in CO, PA and other states has now agreed to be fully transparent about hydrofracturing chemicals at a local site except for the“minor” issue of Confidential Business Information
2) Industry need not tell us anything at all about naturally present chemicals brought up from underground; chemical reactants; or “unintentional” or “incidental” contaminants

Providing Information about Local HF Chemicals Benefits Industry

- There is virtually no disease or symptom that could not be caused by one of the more than 400 chemicals originally on the FracFocus list
- In contrast, there are many diseases and symptoms that would not be plausibly associated with a list that only contains a handful of chemicals.
- Relating a list of chemicals to a list of diseases requires exposure information

What his/her lawyer should tell a doctor who might want CBI

- Once you sign the document allowing you to obtain confidential business information (CBI):
  - If you release the information you are legally liable for any business loss sustained by the company. (Halliburton is said to value their hydrofracturing secrets at upwards of $200 million)
  - It is highly unlikely that any such law suit will be covered by your malpractice insurance. So you would need to hire your own lawyers.
  - If you think the CBI chemical could be causing health problems, state law probably requires you to divulge this secret information to public health authorities. It is not clear whether you are liable if the public health authorities then release the secret information

It would take an exceptionally brave (or foolhardy) health care provider to request CBI

Managing the Story

Should we be more worried about what is put underground or what is brought to the surface?

1) Our major toxicological concern should be the hydrofracturing chemicals
2) Our major toxicological concern should be what is brought up from underground

Environmental Recidivism: Disclosures Not Required Under PA Act 13

Notwithstanding any other provision of this chapter, a vendor, service provider or operator **shall not be required** to do any of the following:

(1) Disclose chemicals that are not disclosed to it by the manufacturer, vendor or service provider.

(2) Disclose chemicals that ***were not intentionally added*** to the stimulation fluid.

(3) Disclose chemicals that occur ***incidentally*** or are otherwise ***unintentionally present*** in trace amounts, may be the incidental ***result of a chemical reaction*** or chemical process or may be constituents of ***naturally occurring materials*** that become part of a stimulation fluid.

Emphases added

post-gazette.com
Pittsburgh Post-Gazette

Court reveals how shale drillers, Pittsburgh-area family agreed

August 12, 2013 1:54 pm

By Don Hopey / Pittsburgh Post-Gazette

The previously confidential agreement to settle a Washington County family's claims that its health and property value were damaged by nearby shale gas development contains lifetime bans on what they can say and do, and also places restrictions on where they may live. …

The 17-page settlement agreement also includes the Hallowiches' previously reported payoff of $750,000, and notes they will continue to receive oil and gas royalties under the terms of a lease agreement entered into by the previous owners of their farm. It prohibits them from objecting to any drilling under any new property or residence they may own, and details the lifetime nondisclosure and nondisparagement clauses preventing them from speaking publicly about the settlement or protesting or challenging any gas development activity or lease by the operators.

Bottom 6 stressors

Stressor	Session 1 (n=33)
Desire to move	42%
Animals died/sickened	42%
Estrangement from community	39%
Intimidation/fear of retribution	27%
Odors	13%
Light pollution	9%

Ferrar, K. J., Kriesky, J. K., Christen, C. L., Marshall, L. P., Malone, S. L., Sharma, R. K., Michanowicz, D. R., Goldstein, B. D., (2013). Assessment and longitudinal analysis of health impacts and stressors perceived to result from unconventional shale gas development in the Marcellus Shale region. International J Occup Environ Health. DOI: 10.1179/2049396713Y.0000000024

Factors Affecting the Applicability of Sutton's Law to an Industrial Process

- Likelihood of failure
- Multiplicity of potential failure points
- Likelihood of detecting and reporting failure
- Past history and known stability of technical process
- Immediacy of observation of adverse impacts
- Seriousness of potential impact
- Extent of public concern
- Availability of valid biomarkers of exposure or effect

Sutton's Law: Directly Measure Exposures or Effects in Receptors of Concern

Sutton's Law may be violated if:

1. The time and locations of all significant releases can be reasonably identified.
2. All intermediate pathways can be reasonably identified and measured.
3. The chemical and physical agents of potential concern are known and can be measured

Usual Progression of Environmental and Occupational Issues Related to Human Health

1) Potentially harmful societal/industrial activities occur before all health and safety information is available
2) Report of adverse health and environmental outcomes potentially associated with activity
3) Major public concern
4) Inability to establish cause and effect relationship primarily because of inadequate exposure information and reluctance to support epidemiological study