Hydrofracturing Public Health Issues and Impacts: the PA Experience

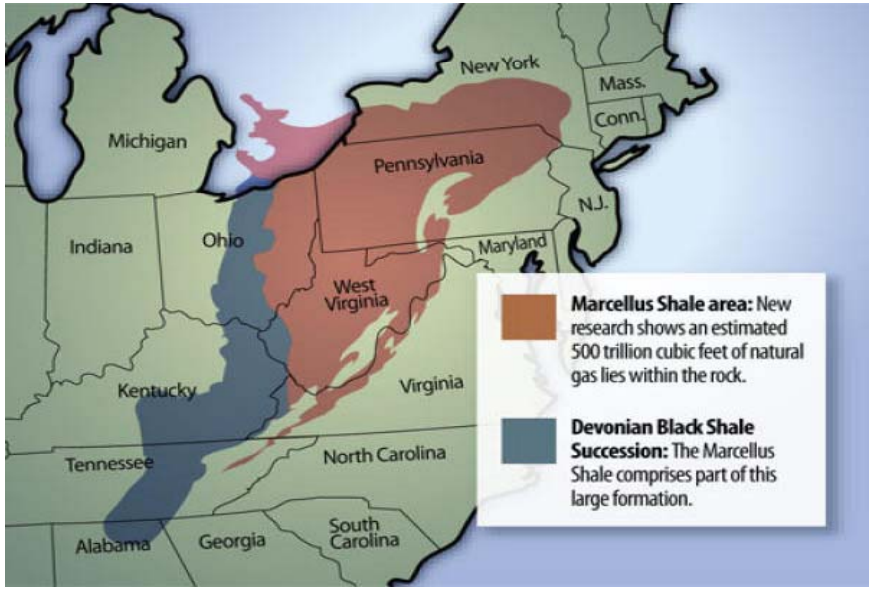
Reynold A. Panettieri, Jr., M.D.
Vice Chancellor, Translational Medicine and Science
Rutgers University
Former Deputy Director Center of Excellence in Environmental Toxicology, Perelman School of Medicine
www.med.upenn.edu/ceet

National Institute of Environmental Health Sciences

CEET

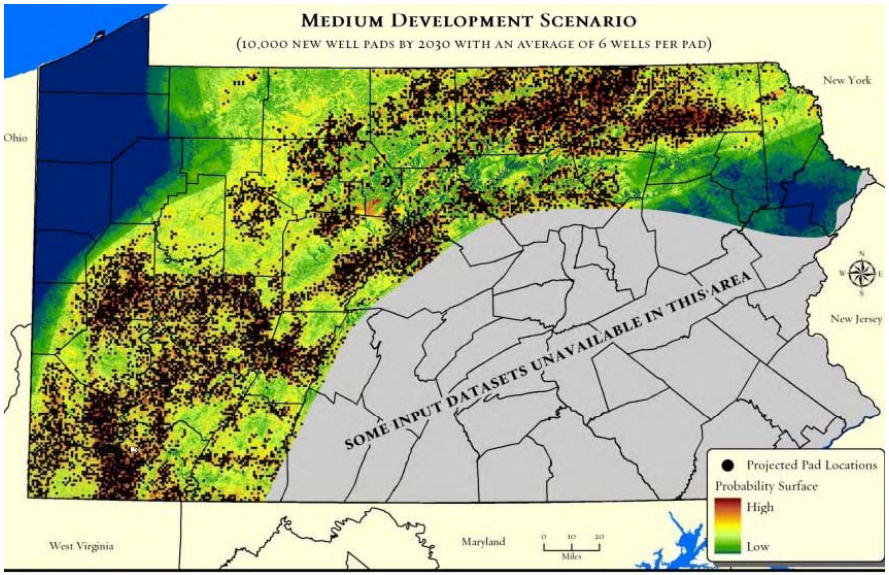
CENTER OF EXCELLENCE IN ENVIRONMENTAL TOXICOLOGY

What is the Marcellus Shale?



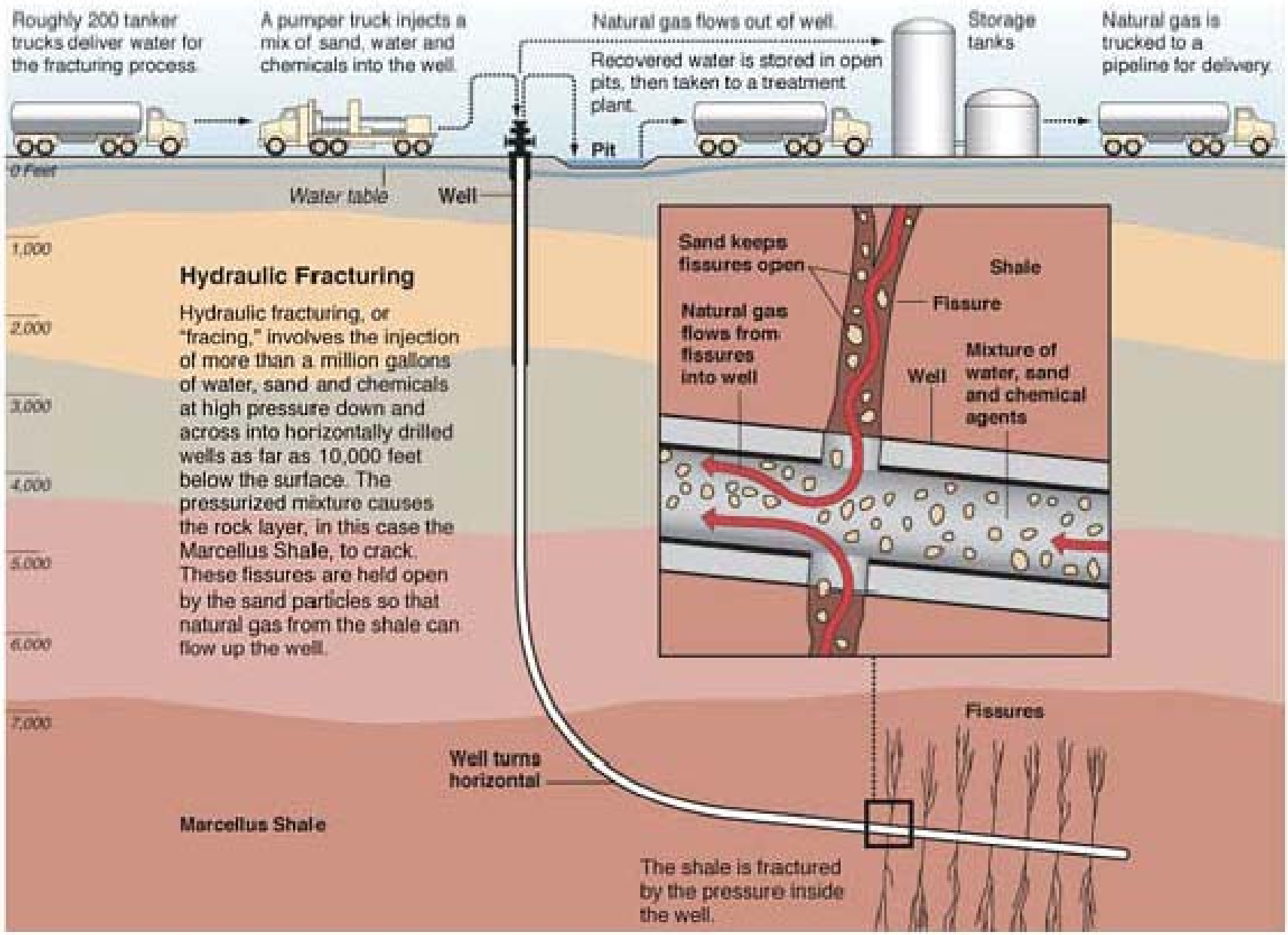
- Half the land mass of Pennsylvania
- 22,835 sq. miles
- 84 trillion cubic ft of natural gas
- Price is $2 - $14 per thousand cu. ft.
- Enough for the entire US population for 4 yrs
- Shale sedimentary rock
- Organic rich and porous
- Contains thermogenic methane

The Drill Rig



- Drill head and pad 5-10 acre plot
- Ideally one per sq mile
- Saturating drilling 8 per square mile
- High density drilling in Susquehanna and Bradford Co, PA
- Pennsylvania would need 22,000 to 160,000 drill rigs
- In April 2013 > 16,000 permits

The "Fracking" Process



The Holding Ponds for Flow-Back Water

- Need 5M gallons water per well head
- Each truck carries 4,000 gallons water
- 1250 truck loads
- Proppant: 1.5 M pounds (silica/sand)
- Requires 750 truck loads
- X1 to x10 “frack” episodes per well
- <30% in the flow back water held in pits

Diesel Trucking

Diesel Trucks Deliver:

- **Drill-Rigs**
- **Proppant**
- **Fracking chemicals**
- **Compressor parts**
- **Gas line piping**

Diesel Trucks Remove:

- **Natural gas**
- **Waste water**

Night-Time Flaring

- Well is tested by flaring
- Release of methane: BETEX (benzene, ethylbenzene, toluene and xylene)
- Move towards marketing “wet-gas” a larger portion of methane is burned
- Release of hydrogen sulfide

Processing and Transport

- Dehydration and condensation to remove water and VOCs
- Liquefy hydrocarbon by-products (propane and butane)
- Compressor stations to pressurize natural gas for pipe-lines
- High-pressure gas lines navigate PA countryside
- Welding exempt from safety regulations in rural areas
- Pipes join national grid

Hazard Identification

- **Water Contamination**
- **Air pollution**

Additives in Fracking Fluid

Table 2: Fracturing Fluid Additives, Main Compounds and Common Uses.		
Additive Type	**Main Compound**	**Common Use of Main Compound**
Acid	Hydrochloric acid or muriatic acid	Swimming pool chemical and cleaner
Biocide	Glutaraldehyde	Cold sterilant in health care industry
Breaker	Sodium Chloride	Food preservative
Corrosion inhibitor	N,n-dimethyl formamide	Used as a crystallization medium in Pharmaceutical Industry
Friction Reducer	Petroleum distillate	Cosmetics including hair, make-up, nail and skin products
Gel	Guar gum or hydroxyethyl cellulose	Thickener used in cosmetics, sauces and salad dressings.
Iron Control	2-hydroxy-1,2,3-propanetricaboxylic acid	Citric Acid it is used to remove lime deposits Lemon Juice ~7% Citric Acid
Oxygen scavenger	Ammonium bisulfite	Used in cosmetics
Proppant	Silica, quartz sand	Play Sand
Scale inhibitor	Ethylene glycol	Automotive antifreeze and de-icing agent

Arthur et al., (2008) Hydraulic Fracturing Considerations for Natural gas
FracFocus.org Chemical Disclosure Registry- 12,000 disclosures

Potential for Water Pollution-Fracking Fluid

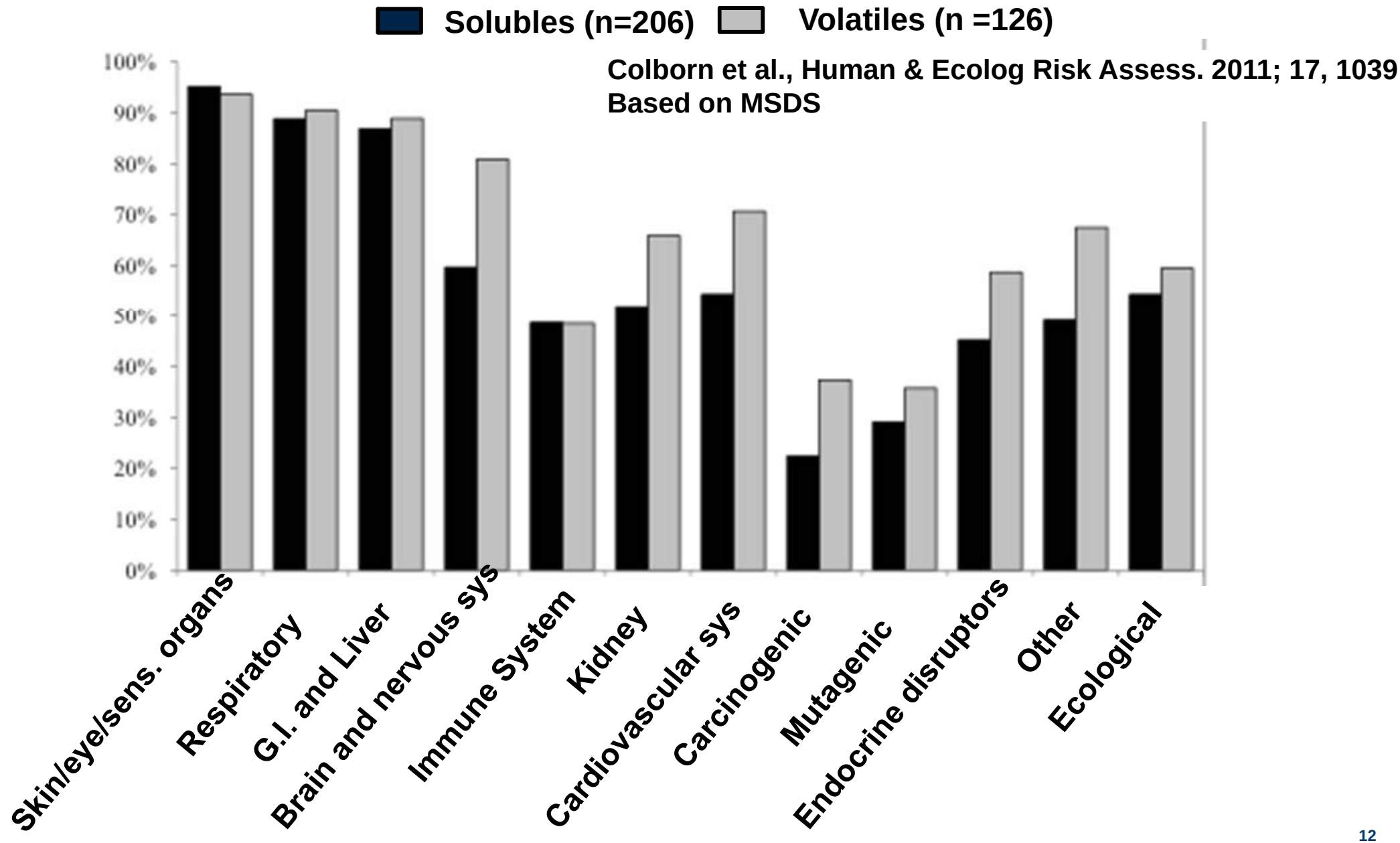
1,2,4-Trimethylbenzene	Glycol Ethers (includes 2BE)
1,3,5 Trimethylbenzene	Guar gum
2,2-Dibromo-3-Nitrilopropionamide	Hemicellulase Enzyme
2.2-Dibromo-3-Nitrilopropionamide	Hydrochloric Acid
2-butoxyethanol	Hydrotreated light distillate
2-Ethylhexanol	Hydrotreated Light Distilled
2-methyl-4-isothiazolin-3-one	Iron Oxide
5-chloro-2-methyl-4-isothiazotin-3-one	Isopropanol
Acetic Acid	Isopropyl Alcohol
Acetic Anhydride	Kerosine
Acie Pensurf	Magnesium Nitrate
Alchohol Ethoxylated	Mesh Sand (Crystalline Silica)
Alphatic Acid	Methanol
Alphatic Alcohol Polyglycol Ether	Mineral Spirits
Aluminum Oxide	Monoethanolamine
Ammonia Bifluoride	Naphthalene
Ammonia Bisulfite	Nitrilotriacetamide
Ammonium chloride	Oil Mist
Ammonium Salt	Petroleum Distallate Blend
Ammonia Persulfate	Petroleum Distillates
Aromatic Hydrocarbon	Petroleum Naphtha
Aromatic Ketones	Polyethoxylated Alkanol (1)
Boric Acid	Polyethoxylated Alkanol (2)
Boric Oxide	Polyethylene Glycol Mixture
Butan-1-01	Polysaccharide
Citric Acid	Potassium Carbonate
Crystalline Silica: Cristobalite	Potassium Chloride
Crystalline Silica: Quartz	Potassium Hydroxide
Dazomet	Prop-2-yn-1-01
Diatomaceus Earth	Propan-2-01
Diesel (use discontinued)	Propargyl Alcohol
Diethylbenzene	Propylene
Doclecylbenzene Sulfonic Acid	Sodium Ash
E B Butyl Cellosolve	Sodium Bicarbonate
Ethane-1,2-diol	Sodium Chloride
Ethoxlated Alcohol	Sodium Hydroxide
Ethoxylated Alcohol	Sucrose
Ethoxylated Octylphenol	Tetramethylammonium Chloride
Ethylbenzene	Titaniaum Oxide
Ethylene Glycol	Toluene
Ethylhexanol	Xylene
Ferrous Sulfate Heptahydrate	
Formaldehyde	
Glutaraldehyde	

- **0.49% of fracking fluid contains a mixture of chemicals**
- **95 tons of chemicals are used per well base**
- **Composition is a trade-secret**
- **Some chemicals listed by class and not by CAS registry number**
- **Classes of chemicals used include:**

-BETEX
-Substituted benzenes
-Ethylene glycol
-Petroleum distillate
-Silica
-Sodium and potassium salts
-Ammonium salts

(Source DEP-PA)

Possible Health Effects of Chemicals with CAS Registry



Potential for Water Pollution- Flow-Back Fluid

Typical Concentrations of "Flow Back" Constituents in Gas Well Water in Marcellus Shale based on Limited Samples from PA and WV Wells [14]

Chemical	Min	Median	Max	Units	MCL[15]	Max Excess
Arsenic	0.09	0.1065	0.123	mg/L	.010	12.3 x
Barium	0.553	661.5	15700	mg/L	2	7,850 x
Benzene	15.7	479.5	1950	ug/L	5	390 x
Cadmium	0.009	0.032	1.2	mg/L	.005	340 x
Chromium	0.122	5.0	5.9	mg/L	0.1	59 x
Ethyl benzene	3.3	53.6	164	ug/L	0.7	234 x
Fluoride	5.23	392.615	780	mg/L	4	195 x
Lead	0.02	0.24	0.46	mg/L	0.015	31 x
Toluene	2.3	833	3190	ug/L	1	3,190 x
Xylene	16	487	2670	ug/L	10	267 x

MCL = maximum contaminant level ppm

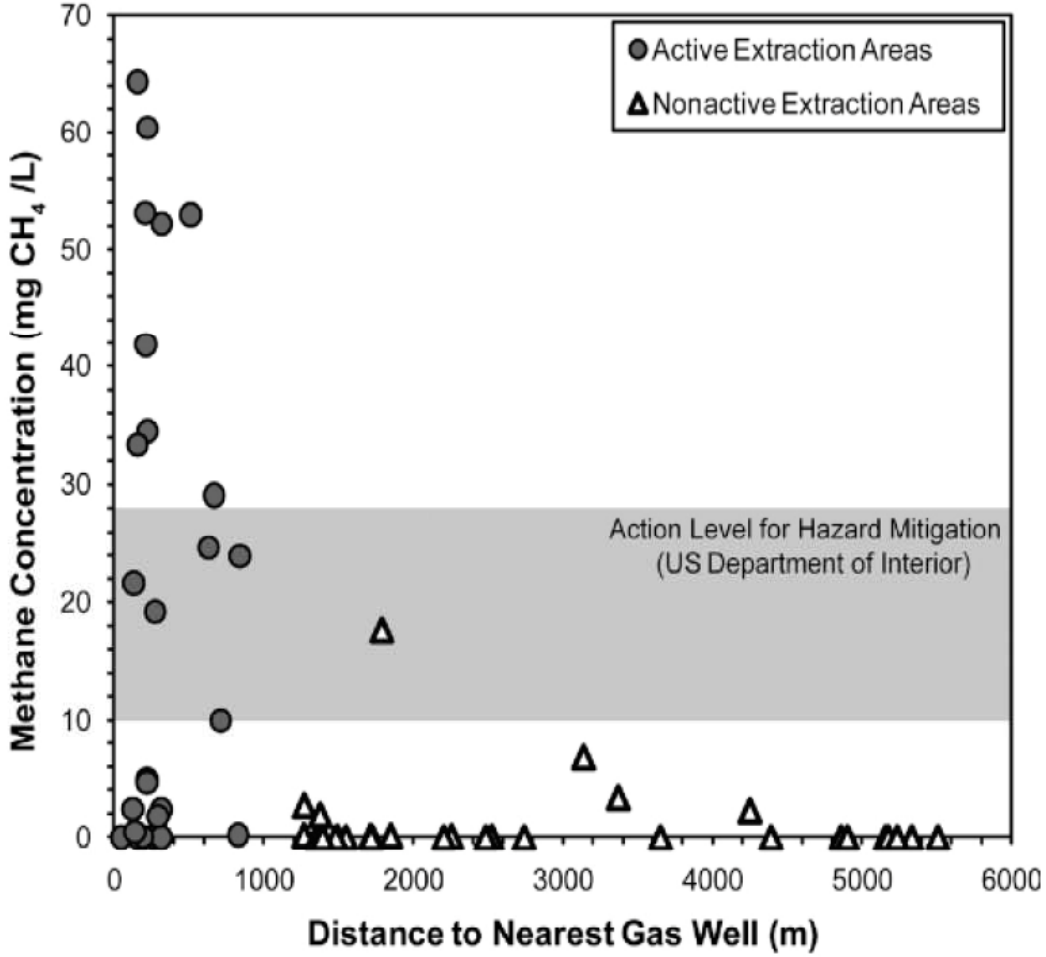
Potential for Water Pollution- Flow-Back Fluid

Concentrations of NORM Constituents Based on Limited Samples from Pennsylvania and West Virginia Marcellus Shale[17]

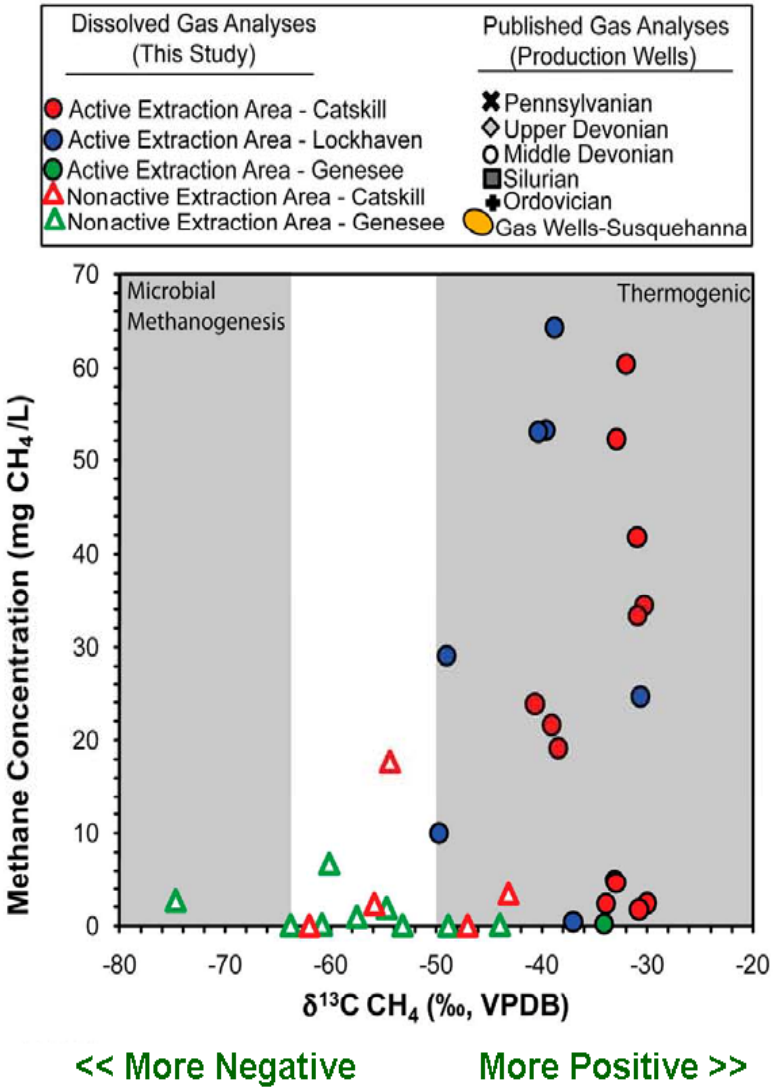
Radioisotope	Minimum	Maximum	Units	USEPA PRG [18,19]	Max Excess
Gross alpha	22.41	18.950	pCi/L	15	1,263 x
Total alpha radium	3.8	7.445	pCi/L	5	362 x
Radium-226	2.58	33	pCi/L	0.000833	40,097 x
Radium-228	1.15	18.41	pCi/L	0.0458	402 x

(NORM = Naturally Occurring Radioactive Material)

Methane in Drinking Water Comes From Natural Gas Drilling



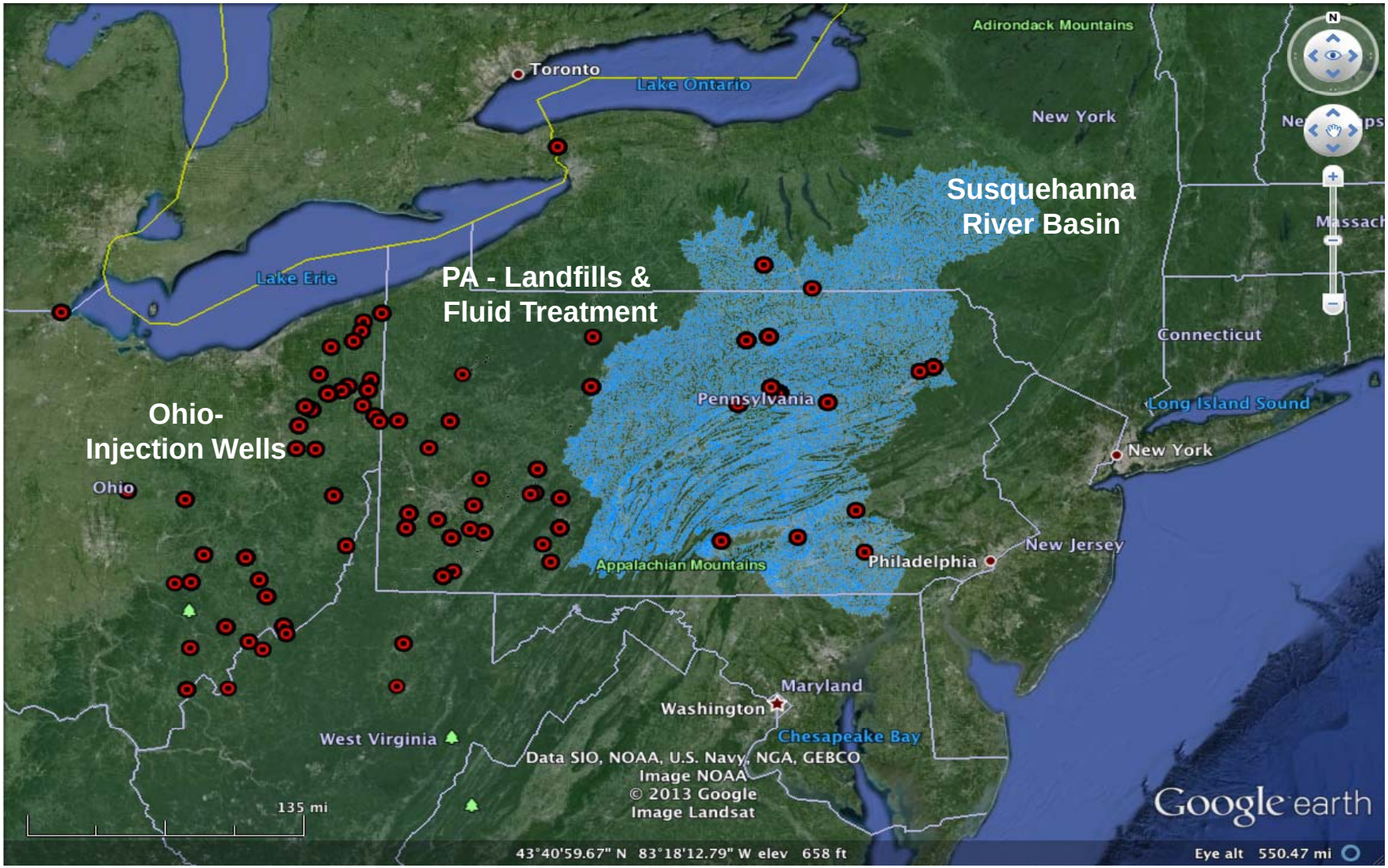
A



51/60 drinking wells tested + ive

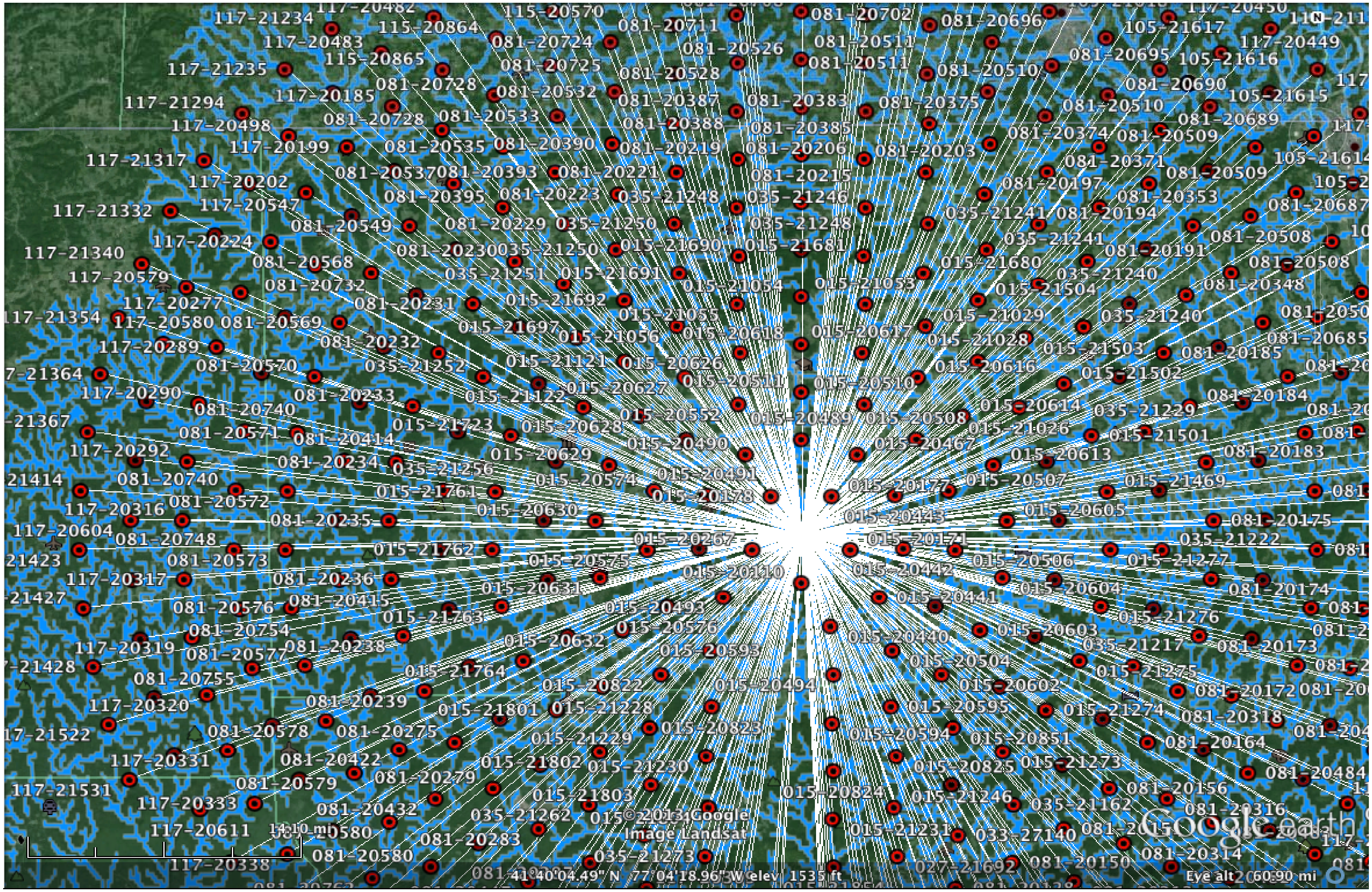
(Osborn et al., PNAS 2011, 108: 8172)

Waste Handling Facilities Jan 2012 – June 2012



Tioga County: Fluid Treatment

(each red dot is a well disposing of fluid waste at a single site)



Potential for Air Pollution –VOCs and PM 2.5

- **Photochemistry between VOCs and nitrogen oxides generate ground level ozone**

- **Ground level ozone exacerbates underlying asthma and COPD and causes lung injury**

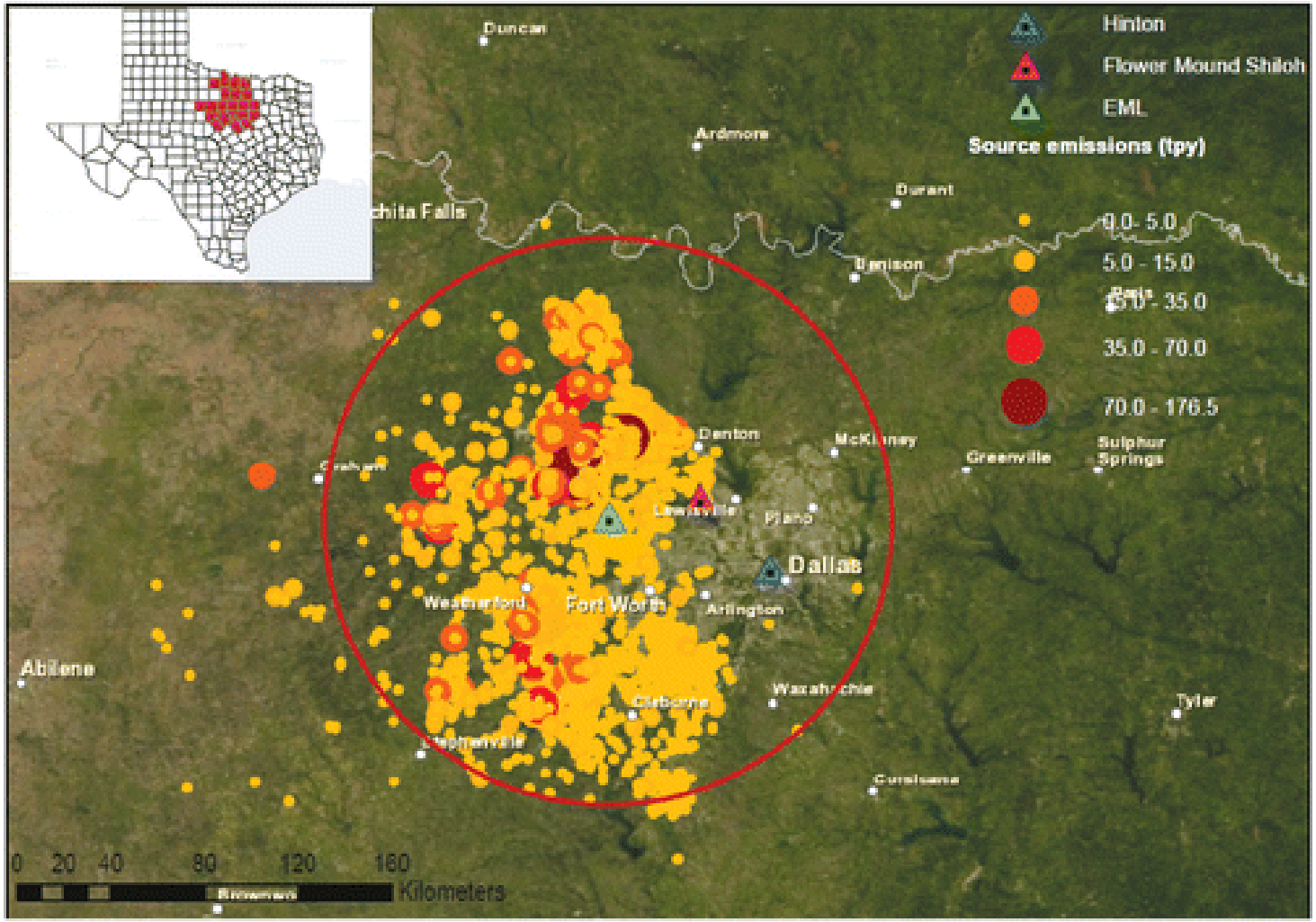
- **Diesel Exhaust – Transportation and Compressor Stations**
  - **-VOCs**
  - **-Butadiene, acrolein, formaldehyde**
  - **-PM2.5: carbonaceous core adsorbs PAH, nitro-PAH and metals**
  - **-PM2.5: lodge in the deep lung (bronchioles and alveoli)**
  - **-PM2.5: invoke an inflammatory response exacerbate lung disease**
  - **-Diesel exhaust: Group 1: carcinogenic in humans (IARC)**

- **Fugitive methane emissions > 9% of production**

What does the science tell us about air quality?

- Natural gas drilling in the Barnett Shale since 2002
- Barnett Shale close to Dallas-Fort Worth Metropolitan Area
- Texas Commission on Environmental Quality - Air monitoring
- Measured NOx, VOCs (benzene) source of ozone
- Helicopter flyovers with GasFind IR cameras/ handmonitors for VOC/ mobile GC/ SUMMA-sampling canisters
- Monitored between 2009-2010; 560 sites
- LOC for benzene 180 ppb (acute) and 1.4 ppb (chronic exposure)
- Field deployed automated GCs for continuous monitoring at 2 sites
- Only two incidences where LOC was exceeded
- Results posted on Barnett Shale Geological Area

VOC Emissions Affecting Ambient Air-Quality in the Barnett Shale



Allen DT. 2014.
Annu. Rev. Chem. Biomol. Eng. 5:55–75

State of Affairs in Pennsylvania

- **Gov. Tom Corbett (R) assumed office Jan 2011**
  -no impact fee was placed on the natural gas industry

- **PA-DEP Secretary Krancer placed moratorium on waste water treatment-May 2011**

- **Delaware Basin Water Commission postpones decision on hydrofracturing indefinitely-Nov 21, 2011**

- **Act 13 – Feb 14, 2012 : Impact fee introduced**
  - **state takes back zoning authority**
  - **imposes CDA for health care professionals to treat patients**

- **PA-DEP Sec. Christopher Abbruzzo appointed Dec 10, 2013**

- **Zoning portions of Act 13 held unconstitutional by PA-Supreme Court- Dec 19, 2013**

- **Provisions of Chapter 78-Act 13 codify regulations for the industry -open for public comment Mar 14, 2014**

- **SB-790-Calls for health registry/training & research**

State of Affairs in Pennsylvania

- **State Auditor General Hon. Eugene DePasqual Report, July 2013:Found PA-DEP woefully under-resourced and 230 cases of drinking well contamination had not been adequately investigated**

- **Gov. Tom Corbett: *" I will direct the DEP to… return to its core mission of protecting the environment based on sound science"***

History of inter-EHSCC Working Group

- **NIEHS Annual EHSCC Meeting-March 2012**
  "Hydrofracking and Public Health Issues and Impacts"-Dr. Penning

- **Ten of twenty EHSCC indicated a desire to interact: bi-monthly teleconferences**

- **Sixteen Centers and COEC representatives are now in the group**

-Columbia University
-Johns Hopkins School of Public Health
-MD-Anderson
-Oregon State University
-University of Iowa
-University of Pennsylvania
-University of Rochester
- University of Wisconsin –Milwaukee
-Harvard School of Public Health
-New York University
-MIT
-University of Cincinnati
-UNC-Chapel Hill
-USC and UCLA
-University of Texas Medical Branch
-Rutgers University

- **Mobilization of Center resources to tackle emerging environmental health challenges**

Inter-Center Pilot Project

Inter-Center Pilot Project:

"Groundwater quality and health outcomes in adjacent areas with and without hydro-fracturing"

Columbia Investigators: Beizhan Yan, PhD; Martin Stute, PhD; Brian Mailloux, PhD; Matt Neidell, PhD; Steven Chillrud, PhD

PENN Investigators: Reynold A. Panettieri, Jr. MD; Poune Saberi, MD, MPH; Marilyn Howarth, MD

Hypothesis: Increases in health care utilization are associated with well density and well water quality in Pennsylvania counties and zip codes.

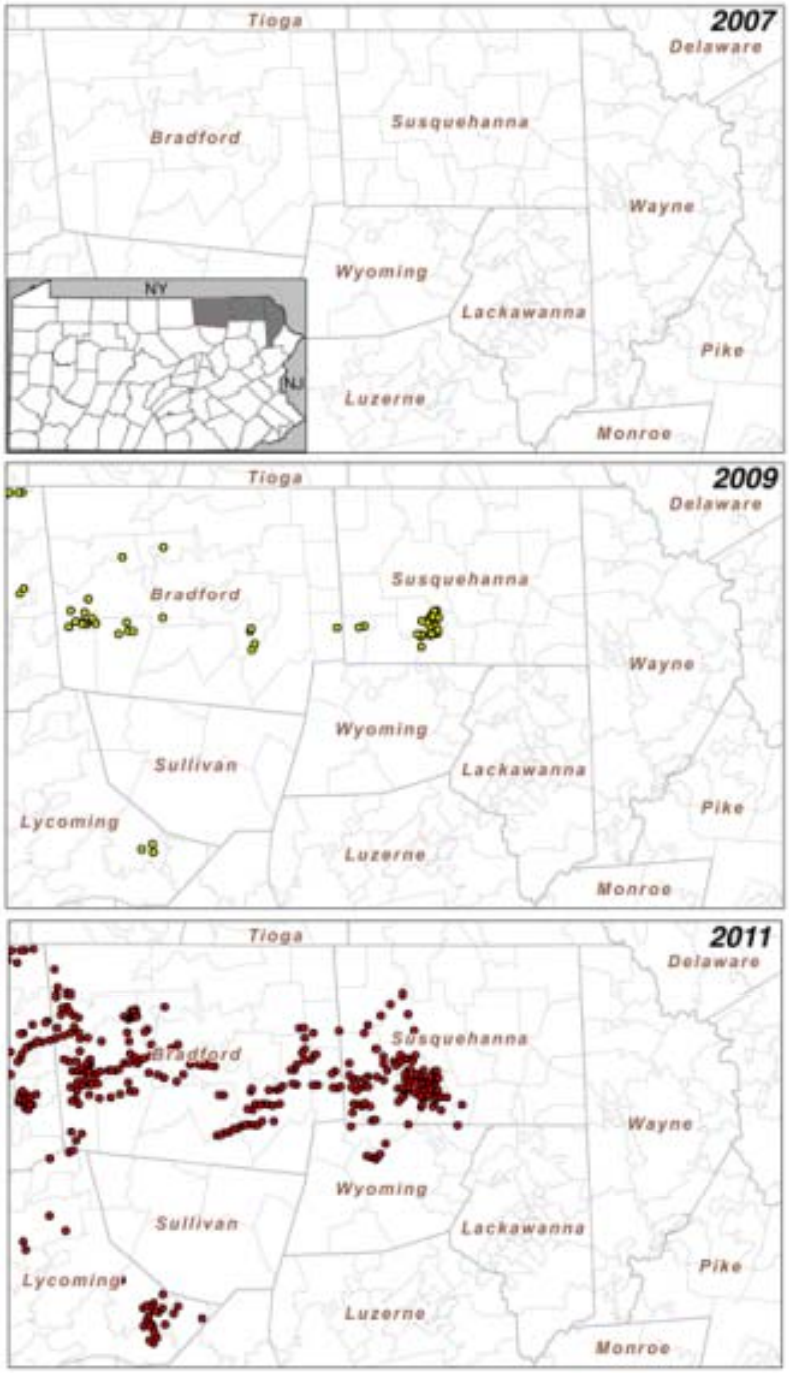
Study Design

1. **Characterize health care utilization in 2 counties in north eastern PA where natural gas drilling is occurring > 1300 wells vs adjacent Wayne Co where no drilling is occurring.**

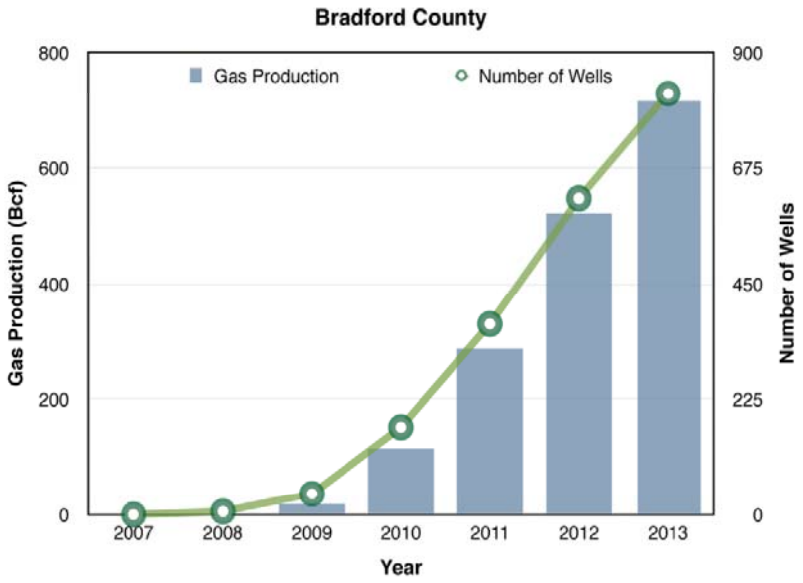
2. **From 2007-2011 obtained from Truven Health Analytics the UB92/UB04 inpatient discharge data sets from PA-Health Care Cost Containment Council. All lives covered by seven different insurance providers examined in the three counties**

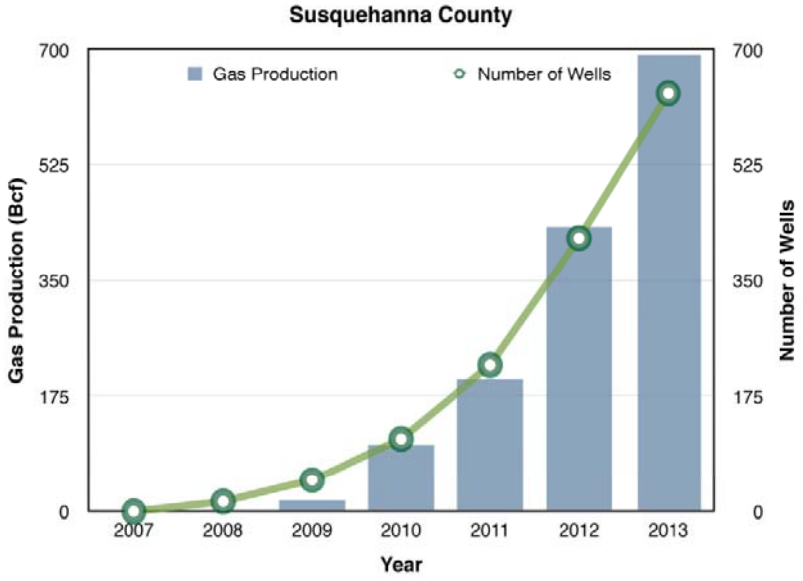
3. **Of the 67 zip-codes examined across the three counties there were 92,850 hospitalizations analyzed by 25 specific medical categories.**

4. **Well density and inpatient health records were matched by zip-code and normalized to population density to determine whether increased hospitalization had occurred by medical category.**



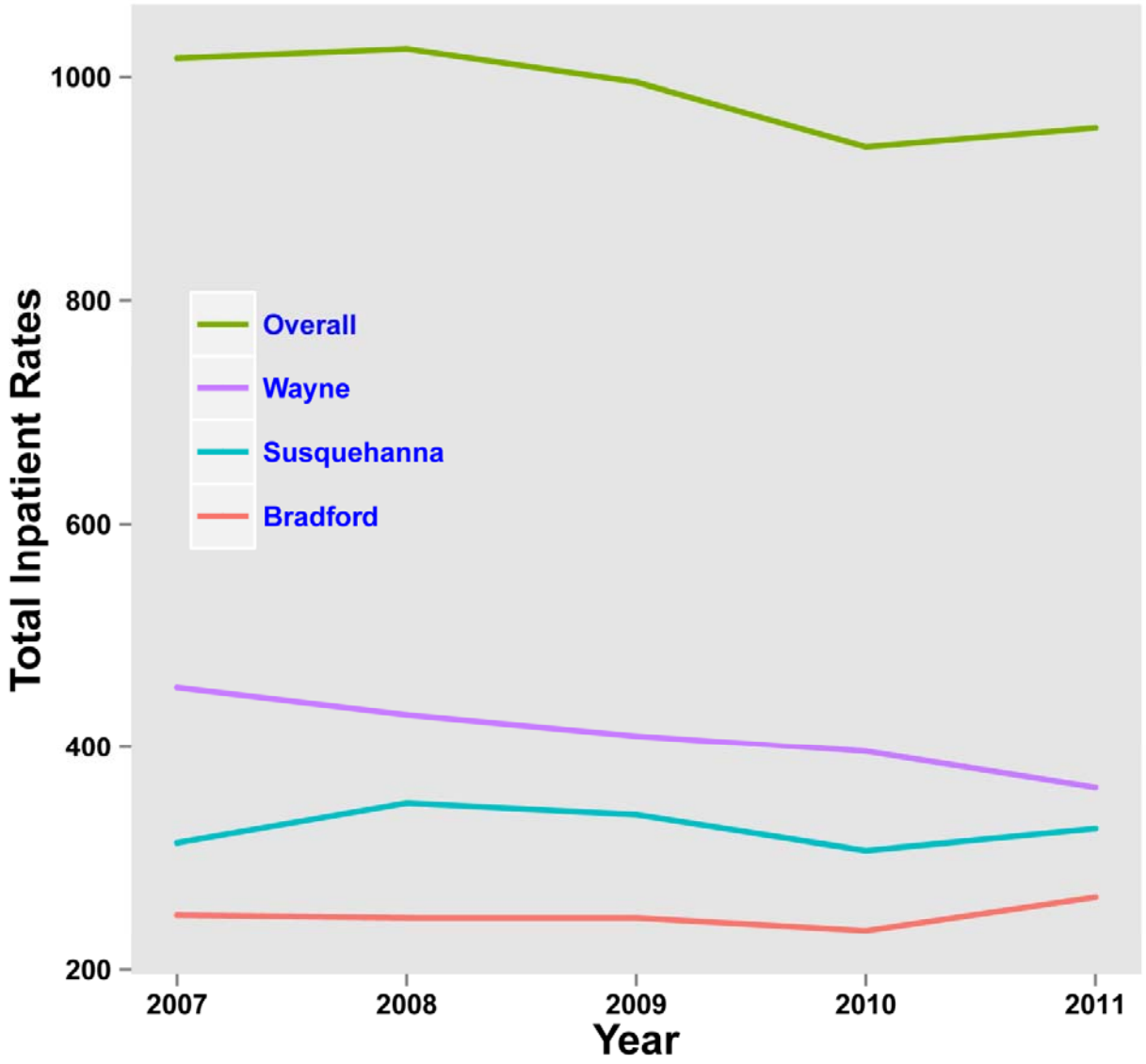
Increased Drilling-Well Activity In Bradford & Susquehanna Counties From 2007 - 2011





Increased natural gas production in Bradford and Susquehanna Co From 2007 -2013

Increased Hospitalizations Associated with Drilling Well Activity



Poisson Fixed Effects Models: Quantile Analysis of Wells/km2.

	Q1 Wells RR (p-value)	Q2 Wells RR (p-value)	Q3 Wells RR (p-value)	Wald Test of all Q Wells = 0	Year RR (p-value)
Inpatient total	0.979 (0.475)	1.069 (0.044)	1.169 (0.041)	P = 0.0058	0.977 (0.013)
Cardiology	**1.021 (0.667)**	**1.142 (0.018)**	**1.27 (0.001)**	**P = 0.0008**	**0.957 (0.004)**
Dermatology	1.051 (0.572)	1.108 (0.429)	1.454 (0.013)	P = 0.0329	0.972 (0.329)
Endocrine	0.975 (0.862)	1.228 (0.045)	1.391 (0.029)	P = 0.0068	0.942 (0.039)
Gastroenterology	0.943 (0.369)	1.12 (0.168)	1.105 (0.364)	P = 0.1101	0.98 (0.406)
General medicine	0.911 (0.234)	0.993 (0.931)	0.985 (0.872)	P = 0.6373	1.037 (0.006)
Generals surgery	0.875 (0.011)	0.921 (0.228)	0.944 (0.424)	P = 0.0669	1.015 (0.157)
Gynecology	0.887 (0.300)	0.938 (0.606)	0.967 (0.849)	P = 0.7549	0.865 (<0.0001)
Hematology	1.202 (0.365)	1.21 (0.320)	1.221 (0.429)	P = 0.7145	0.993 (0.868)
Neonatology	0.994 (0.975)	1.301 (0.152)	1.527 (0.100)	P = 0.0745	0.95 (0.052)
Nephrology	1.115 (0.203)	1.143 (0.227)	1.151 (0.211)	P = 0.5566	1.004 (0.871)
Neurology	**0.922 (0.344)**	**1.157 (0.048)**	**1.188 (0.062)**	**P = 0.0003**	**0.99 (0.542)**
Normal newborns	0.949 (0.481)	0.978 (0.764)	0.964 (0.731)	P = 0.8980	0.965 (0.064)
Ob/delivery	0.958 (0.524)	1.028 (0.670)	1.029 (0.749)	P = 0.4219	0.956 (0.002)
Oncology	1.217 (0.144)	1.415 (0.028)	1.815 (0.002)	P = 0.0166	0.938 (0.022)
Ophthalmology	0.717 (0.381)	1.014 (0.976)	1.116 (0.836)	P = 0.5215	1.099 (0.263)
Orthopedics	0.996 (0.940)	0.981 (0.740)	0.875 (0.130)	P = 0.3591	0.963 (<0.0001)
Other/ob	0.966 (0.885)	1.176 (0.451)	1.264 (0.502)	P = 0.7209	0.879 (0.001)
Otolaryngology	1.052 (0.744)	1.194 (0.412)	1.004 (0.988)	P = 0.5564	0.966 (0.527)
Psych/drug abuse	0.944 (0.307)	0.927 (0.293)	1.13 (0.145)	P = 0.0535	1.039 (0.008)
Pulmonary	1.05 (0.267)	1.097 (0.202)	1.067 (0.572)	P = 0.3050	0.981 (0.306)
Rheumatology	1.091 (0.601)	1.432 (0.159)	1.866 (0.034)	P = 0.0774	0.94 (0.067)
Thoracic surgery	0.872 (0.391)	1.151 (0.470)	1.13 (0.654)	P = 0.0903	0.987 (0.751)
Trauma	0.997 (0.987)	1.057 (0.761)	1.265 (0.222)	P = 0.4373	1.02 (0.562)
Urology	0.827 (0.117)	1.105 (0.462)	1.24 (0.215)	P = 0.0334	0.977 (0.339)
Vascular surgery	1.103 (0.488)	1.052 (0.788)	0.966 (0.857)	P = 0.8116	0.946 (0.030)

Note: RR = Risk ratio

doi:10.1371/journal.pone.0131093.t005

Jemielita T, Gerton GL, Neidell M, Chillrud S, Yan B, et al. (2015) Unconventional Gas and Oil Drilling Is Associated with Increased Hospital Utilization Rates. PLoS ONE 10(7): e0131093. doi:10.1371/journal.pone.0131093
http://journals.plos.org/plosone/article?id=info:doi/10.1371/journal.pone.0131093

Summary

- There was a significant increase in hospitalizations associated with well density in counties where drilling activity was occurring
- The hospitalizations occurred in some but not all 25 medical categories
- These trends were observed between years 2007-2011; but the drilling activity has tripled since that time and this needs to be related to health utilization data when it becomes available
- The economic benefit of natural gas drilling has to be compared with the health economics of delivering more services in affected regions
- We have yet to analyze outpatient data from 2007-2011
- We have yet to analyze all patient data from 2011-2013
- We have yet to analyze health data based on episodic gas production cycles

ehp ENVIRONMENTAL HEALTH PERSPECTIVES
http://www.ehponline.org

Environmental Health Research Recommendations from the Inter-Environmental Health Sciences Core Center Working Group on Unconventional Natural Gas Drilling Operations

Trevor M. Penning, Patrick N. Breysse, Kathleen Gray, Marilyn Howarth, and Beizhan Yan

http://dx.doi.org/10.1289/ehp.1408207
Received: 31 January 2014
Accepted: 16 July 2014
Advance Publication: 18 July 2014

NIH National Institute of Environmental Health Sciences

Research Recommendations—Water Contamination

1. ***base-line ground water quality data should be taken before drilling begins and monitored over the life-time of the gas-producing well.***

2. ***full disclosure of the HF chemicals must take place so that they can be correlated with measurements of ground and surface water pollution: composition of the HF and produced water must be determined for hazard identification.***

3. ***a validated specific and sensitive indicator of early ground water contamination should be identified for site management and mitigation.***

4. ***fate and transport of ground and surface water pollutants should be elucidated under HF conditions.***

5. ***the effluent from waste-water treatment plants should be monitored to determine their effectiveness***

6. ***fundamental research on the toxicology of the HF and produced water must be performed for risk characterization***

Research Recommendations—Air Pollution

National Institute of Environmental Health Sciences

1. ***ambient and occupational air-quality should be measured at active drilling sites and be compared with base-line measurements in adjacent regions without UNGDO.***

2. ***the impact of diesel emissions on local air quality should be determined.***

3. ***residential indoor air quality data for homes potentially impacted by UNGDOs should be compared with those homes not impacted.***

4. ***determine spatial and temporal relationship between emissions from multiple point sources with their impact on air quality.***

5. ***the impact on air pollution by a field of gas producing wells should be compared to emissions produced by coal-fired power plants.***

Research Recommendations-Epidemiology

1. ***Health utilization in communities with and without hydrofracturing should be performed to identify health outcomes that may have changed.***

2. ***An environmental epidemiology study should be performed to determine whether an association exists between health outcomes data and water-quality in private drinking wells in communities with and without hydrofracturing.***

3. ***An environmental epidemiological study should be performed to determine whether air pollution associated with unconventional natural gas drilling increases the incidence of respiratory illness and cardiovascular disease.***

4. ***Epidemiological data must be accompanied with exposure data: proximity mapping, biomonitoring, and biomarkers of exposure and effect.***

Recommendations- Community Outreach

Towanda Twp Bradford Co, PA

Total Pop: 1,097
Median Family Income: $40K
Median Housing Value: $77K
Pop Density: 75 per sq. mile

1. ***Embrace CBPR principles in designing studies on environmental and public health impacts of UNGDO so that the right studies are performed. All stakeholders should be engaged to foster multi-directional communication and accountability.***

2. ***Communities should help determine how best to disseminate research findings and there should be timely and transparent dissemination of data.***

3. ***The sources of funding for research should be openly disclosed to communities.***

4. ***Determine whether rapid "industrialization" overwhelms health and public services and the social fabric of communities.***

5. ***Determine how existing regulations impact the reporting of environmental health effects of UNGDO.***

6. ***Conduct research on risk perception, including the impacts on community polarization.***

Conclusions

- Research recommendations are similar to those published by Union of Concerned Scientists & SOT
- Important difference is advocacy for CBPR
- Funding of needed research must avoid COI
- Implementation of recommendations would provide a risk assessment for affected communities
- Results of research would inform decision makers
- This would protect the public and improve public health

Ackowledgements

Members of the inter-EHSCC working group
-Leslie Reinlib, PhD Program Officer
-Liam O'Fallon, MA Program Analyst
-Sara Mishamandani

Inter-Center Pilot Project-Penn and Columbia
-Trevor Penning, PhD (Penn)
-Kathleen Propert, PhD (Penn)
-Marilyn Howarth, MD (Penn)
-Poune Saberi, MD (Penn)
-Beizhan Yan, PhD (Columbia)
-Steven Chillrud (Columbia)
-Martin Stute (Columbia)