Getting The Waters Tested
The Marcellus Shale Factor

Water Resources
Environment
Old Issues

New Issues

Presented by: Mr. Brian Oram, Professional Geologist (PG), Soil Scientist, Licensed Well Driller
B.F. Environmental Consultants Inc.
http://www.bfenvironmental.com
And
Water Research Center
http://www.water-research.net

Presented At
PA State Nursing Association Marcellus Shale: Unearthing Environmental Health Issues for Nurses – October 7, 2011

B.F. Environmental Consultants Inc.
"Professional Consulting Services"
"Baseline with Chain-of-Custody"
"Expert Testimony"
"Provide Continuing Education Programs for licensed professionals"
"Informational Water Testing and Public Education Programs"
http://www.bfenvironmental.com

Water-Research Center
Education and Outreach Program funded by B.F. Environmental Consultants Inc.
Outreach Programs
"Environmental and Professional Education and Training for Citizens and Local Municipalities"
"Water Quality Help Guides – Information Library"
"Community and Business Outreach Programs"
"Low Cost – Informational Water Testing Program with National Laboratory"
"Citizen Monitoring Programs"
Website: http://www.water-research.net

Target Audience
"Stakeholders"
"Community Advocates and Scientists"
"Health Related Professionals"
"Municipal and Local Officials"
"Water Supplies and State Regulators"

What is the Marcellus Shale Factor?

We have been educating private well owners for 20+ years but it was difficult to get citizens to test their well water. It looks clear – I am not sick – it is fine.

The Marcellus Shale Factor – Baseline Testing for Natural Gas Development is conducting testing and citizens are be told they have a Problem NOW.

Based on Private Well Construction and Placement - Some Private Wells may be the pathways for Contamination.

DO YOU Know that 30 to 50 % of Private Wells in PA produce water that does not meet the Drinking Water Standards??

WE Support the Citizen Groundwater Database at Wilkes University!
Goals

- Private Well Water Quality for the Region
- Existing Problems in Region
- Brief Introduction to Marcellus Shale and Importance of Proper Well Construction
- Review of Hydraulic Fracturing
- The Citizen Groundwater Database
- Well Monitoring and Purging
- Baseline Testing – What Parameters?
- Educating the Community

Private Wells/ Water Systems in Pennsylvania

<table>
<thead>
<tr>
<th>County</th>
<th>1980</th>
<th>1990</th>
<th>2000</th>
<th>Avg. Change in homes served by private water systems per year</th>
<th>% of all homes served by private water system</th>
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<td>180,209</td>
<td>242,020</td>
<td>+62,022</td>
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</tbody>
</table>

Our Groundwater is Pure and Regulated?

Information We Have Known Prior to Marcellus Shale Development

This is Drinking Water from Private Wells in PA?

- Iron / Manganese
- Sediment / Gases / Saline Water
- Corrosive Water
- Bacteria

50% Other 50%

Things I have found within 100 feet of a private well – Just a Few

Free Artesian Well Water

By the way – these two photos are only 200 feet apart. Groundwater is Safe and Pure. Really 53.
**Geological Sequence**

<table>
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<tr>
<th>Time</th>
<th>Period</th>
<th>Deposit or Rock Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 1.8 million years</td>
<td>Quaternary – Glaciation</td>
<td>sand, silt, clay, and gravel</td>
</tr>
<tr>
<td>1.8 to 2.9 million years</td>
<td>Tertiary to Permian</td>
<td>Not present (eroded and weathered)</td>
</tr>
<tr>
<td>290 – 320 million years</td>
<td>Pennsylvanian</td>
<td>Llewellin (coal) and Pattysville (minor coal)</td>
</tr>
<tr>
<td>320 – 354 million years</td>
<td>Mississippian</td>
<td>Catskill Formation</td>
</tr>
<tr>
<td>354 – 417 million years</td>
<td>Devonian</td>
<td>Trimmers Rock Formation, Mahantango Formation (Black Shale), Marcellus Formation (Black Shale), Onondaga Formation (calcareous sandy shale)</td>
</tr>
<tr>
<td>417 – 443 million years</td>
<td>Silurian</td>
<td></td>
</tr>
</tbody>
</table>

Based on the geology of the NEPA and my 20+ years experience, the common water quality problems are as follows:

- Corrosive Water (Low pH)
- Soft Water (low hardness) to Moderate Hardness
- Iron and Manganese
- Total Coliform Bacteria
- Sulfur Odor and Methane
- Biogenic/Thermogenic Gas (Tends to be < 10 mg/L)
- Radon Gas
- Arsenic

**Quick Questions?**

- Have I mentioned that these problems have nothing to do with Marcellus Shale?
- These background and baseline issues have nothing to do with Marcellus Shale – 50% of Private Wells DO not meet the drinking water standard.

**Drinking Water Regulations**

The Safe Drinking Water Act (SDWA), passed in 1974 and amended in 1986 and 1996, gives the Environmental Protection Agency (EPA) the authority to set drinking water standards. These standards are divided into two broad categories: Primary Standards (NPDWR) and Secondary Standards (NSDWR).

**Primary Standards (NPDWR)**

National Primary Drinking Water Regulations

Primary standards protect drinking water quality by limiting the levels of specific contaminants that can adversely affect public health and are known or anticipated to occur in water. They take the form of Maximum Contaminant Levels or Treatment Techniques.

Examples: Arsenic, Lead, MTBE, total coliform, Giardia, Trihalomethanes, Asbestos, Copper, Benzene, Trichloroethylene, etc.

**Secondary Standards**

National Secondary Drinking Water Regulations

These standards were established more for cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor or color) in drinking water.

The secondary standards include: aluminum, chloride, color, corrosivity, fluoride, foaming agents, iron, manganese, odor, pH, silver, sulfate, total dissolved solids, and zinc.
Private Wells Not Regulated

- Private Wells Are Not Regulated under Safe Drinking Water Act
  - EPA – NO
  - PADEP – NO
- County – Very Few Counties in PA
- Townships – some have basic ordinance on placement- some have comprehensive requirements- but most have nothing.

Private Wells (They) - The Facts - Baseline Conditions

- Are they Regulated?
  - Not really – no state-wide construction standard
  - Not Classified as a Regulated Source
- Are they Permitted?
  - May be the Licensed Well Driller Submitted a Log
  - Maybe a permit issued at the local level
- Are they Tested?
  - Not required- Data not stored
  - Some contain elevated levels of bacteria, barium, salt, arsenic, etc – should we be concerned.
- Do we know where they are located?
  - Maybe +/- a few hundred feet
  - PaGWIS - PA Groundwater Information System

Before Marcellus Shale Development

What was the Quality of Private Well Water?

A USGS survey found that 70% of private wells were contaminated. This contamination could result in acute or chronic health concerns (1996).

Testing Conducted under my supervision at Wilkes University in through out the United States indicates that 30 to over 50 % may be contaminated – Mostly by Total Coliform Bacteria (1989 – 2011).

PSU - Master Well Owner Network suggests that 33 to 50 % of Private Well Owners in PA may have some Form of contamination.

Most Contamination appears to be associated with Total Coliform Bacteria

- Insects, Larvae and Nests / Egg Masses
- Mouse Colonies
- Snakes
- Beehives
- Mud - when casing to close to ground

Therefore – In some cases - the Private Wells are Facilitating Groundwater Contamination.

An Ungrouted Residential Well

A Properly Grouted Well

Radon (In Air)- PA -Recommend < 4 pCi/L

Bradford County – 38 % < 2 pCi/L, but 43 % > 4 pCi/L
Lackawanna County – 52 % < 2 pCi/L, but 27 % > 4 pCi/L
Luzerne County – 45 % < 2 pCi/L, but 23 % > 4 pCi/L
Susquehanna County – 48 % < 2 pCi/L, but 31 % > 4 pCi/L
Radon Exposure

http://pa-radon.info/

Radon in Water – no Standard, but proposed range 300 to 4000 pCi/L

Recent testing in Susquehanna/ Luzerne County at 577 to 2200 pCi/L – 100% over 300 pCi/L

Recommendations
1. Test indoor radon in air levels.
2. If radon in air > 2 pCi/L - test the radon level in the water.
3. Add to Community Baseline Testing Program

Metering in Water

- Methane has been a hidden issue in NEPA.
- The gas is colorless, tasteless, and odorless and there are no known health effects.
- Potential concerns relate to flammability/ explosiveness of gas.
- Background – appears to range from non-detect to over 20+ mg/L (highly variable) in Northeast Pennsylvania.
- I light my first well water sample in about 1989 – thanks to methane gas.

Methane Gas Migration- Not Related to Marcellus Shale

Sanitary Well
Landfill
Wetland

Groundwater Flow

600 to 1200 ft
600 to 1200 ft

Gas Finger Printing

Upper Devonian

Coal Gas

Methane Gas- Natural Sources – Saline Seeps

Video from Salt Springs State Park – Fall 2010, by Brian Oram
http://www.friendsofsaltspringspark.org

“At the base of the gorge is a bubbling salt spring, traces of an 1850s woolen mill, and mid-19th century farmhouses and barns.”
Methane (a little more)

- The Coal regions and northern portion of NEPA, and areas associated with the Mahantango / Marcellus Shale may have elevated levels of methane.
- No drinking water limit, but Office of Surface Mines recommends monitoring for concentrations from 10 to < 28 mg/L and immediate action for concentrations > 28 mg/L.
- My Recommendations:
  - < 2 mg/L - Monitor annually with passive venting
  - > 2 mg/L - Real-Time Monitoring and Isotopic Analysis – “Like fingerprinting the source of the gas” with passive venting.
  - > 7 mg/L to < 10 mg/L - active venting
  - > 10 mg/L - Treatment with active venting

Marcellus Shale

This is Causing all the Concern?

Geological Sequence

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Looking Back 400 million Years

Source: http://www2.nau.edu/rcb7/nam.html

Barkley, 2009

DEVONIAN DEPOSITIONAL ENVIRONMENTS

Marcellus Shale or Other tight Black Shales

Source: http://www2.nau.edu/rcb7/nam.html
This is why the term – Fairway is being used to describe the play.

Marcellus Shale Development
- Drilling
- Casing
- Cement
- What are the weaknesses?
- What are the contaminants of concern?

Marcellus Shale Drilling Site
Total disturbed pads areas can be 5 acres – but one pad will support drilling multiple horizontal wells. Many drillers switching to Closed loop drilling and lining sites – Not a Regulation.

Types of Fluids  - Associated with Marcellus Shale
- Top hole fluids – typically the water from the freshwater aquifer. This water from the first 600 to 1200 feet.
- Bottom hole fluids – brine or connate water.
- Stimulation Fluids – fluid used to improve recovery (frac process)- includes biocides and other chemicals.
- Production Fluids – water produced along the natural gas release – similar to bottom hole fluid.

Properly Constructed Wells and Ideal Natural Gas Wells- How Long it May Take to See an Impact

Getting to The Natural Gas
- Freshwater Well
- Saline/Brine Water
- Stagnant Water – no to little flow

- 5000 to 7000 feet
- Up to a few thousand feet
General Geology - Northern Tier PA

Private Well

Water Table

Older

New Regulations

Younger

Brine Water

Protective Casing – Do it Right!

Typical Well

Additional Cementsed Zones

This Zone should be cemented

Even after new regulations, there may be a zone from 1500 to 2000 feet thick not cemented.

Problems with Gas Migration and Cement

Does not Bound

Migration Concepts - Non-Marcellus Shale - While Drilling - Proper Casement Placement

Private Well

Marcellus Shale

Shallow Gas

Confining Layer

Migration Concepts - Multiple Casements and Recreate Confining Layers - Need Good Cement Bonds - Cement up to Deepest Casement or Surface

Water Table

Private Well

Older
Migration Concepts- Multiple Casements and Recreate Confining Layers – No Uncemented Zones.

Older

Younger

Water Table

Private Well

Shallow Gas

Hydrofracturing

High Pressure Injection of Water, sand, and a mixture of chemicals in a series of stages to part formation. Note: Drilling Rig is not on the site – all drilling is done.

Injection Wells – Class II

Class II wells inject fluids associated with oil and natural gas production. Most of the injected fluid is salt water (brine), which is brought to the surface in the process of producing (extracting) oil and gas.

Regulated by:

EPA - [Link](http://www.epa.gov/safewater/uic/wells_class2.html)

Does the UIC Program regulate hydraulic fracturing? Sometimes. The UIC Program regulates the following activities:

- Well injection of fluids into a formation to enhance oil and gas production (Class II wells).
- Fracturing in connection with Class II and Class V injection wells to "stimulate" (open pore space in a formation).
- Hydraulic fracturing to produce methane from coal beds in Alabama.
- Hydraulic fracturing that uses diesel in the mixture.

Note: Class V wells are shallow wells that inject water into or above a freshwater aquifer. [Link](http://www.epa.gov/ogwdw000/uic/)
Concerns Related to Marcellus Shale

Based on Location in Community Location – additional planning, education, and response plans are needed.

In general, the issues are related to the following:

- Erosion and Sedimentation
- Volume of Water Used in Hydrofracturing - 2 to 9 million gallons per well.
- Loss of Freshwater Aquifer or contamination by brine water and drilling fluids.
- Drilling fluids may contain environmental contaminations (metals and organics).
- Impacts to Roadways, Tourism, and Ecology
- Noise Levels - be at a Nuisance Level for the Public
- Air pollution – Partial Combustion, Methane Releases.

Active Marcellus Production Site – Frac Fluid Chemistry – I may concern is Surface Spills and Releases!

Typically Frac Water is comprised of clean or recycled water with a low probability for scale formation, but treated effluents and other sources being used. The components include:

- Friction Reducer – anionic polymer high molecular weight (hold frac sand and other particles)
- Wetting Agent - nonionic surfactant - reduce surface tension and improve frac water flowback.
- Biocides- control growth or regrowth of microorganisms.
- Scale Inhibitor – phosphate based chemicals to inhibit precipitate formation and scale formation.

Industry has released chemicals used – Great Website http://www.fracfocus.org

Flowback Water Chemistry

Flowback water is generated from drilling and it is what gets produced from the first 5% of water returned after a well is started.

May contain elevated levels of trace metals, nitrogen, bromide, uranium, and hydrocarbons. Most of the dissolved solids includes chloride and sodium.

Source: http://www.prochemtech.com/

Production Water

Produced water is wasted water that accompanies oil extraction and is high in saline. Typically, separated stored on site and then hauled to treatment/disposal facility.

May contain elevated levels of trace metals, nitrogen, bromide, uranium, and hydrocarbons. Most of the dissolved solids includes chloride and sodium.

Source: http://www.prochemtech.com/
Concerns Related to Marcellus Shale

In general, the concerns are related to the following:
- Surface Spills and Releases Near Surface
- Methane Gas Migration
- Pushes and Slugs associated with Improper Cementing and not Properly Sealing the Existing Confining Layers
- Improper Disposal of Brines
- Freshwater Aquifer Contamination by brine water and drilling fluids/muds.
- Drilling fluids does contain environmental contaminations (metals and organics).

Frac Water Chemical Disclosures

- FracFocus - http://fracfocus.org - the hydraulic fracturing chemical registry website.
- Information is also in the well permit and on-site.
- This website is a joint project of the Ground Water Protection Council Interstate Oil and Gas Compact.

Citizen Database

Please spread the word – Private Well Owner and Watershed Group Survey – Data will be used to update a Free Guidebook – Go to http://www.surveymonkey.com/s/NMG6RQ3

Goal of the Database

- Provide a Central Location to Store Baseline Pre-Drilling and/or Post-Drilling Water Quality Data for the Region
- Document Quality by Geological Formation
- Identify Existing Regional Issues or Concerns
- Provide an Un-Biased Community Resource
- Provide a Mechanism to Track Temporal, Spatial, and other Geospatial Variation in Water Quality.

Recent Baseline Testing in Luzerne County, PA
320 Private Wells

Image Source: Luzernecounty.org

Tested Conducted by Certified Laboratories
Third Party Samplers
Not Wilkes University
Connate water is water that was trapped in formation when material was deposited.

Percent Exceeded

Total Coliform

pH

< 6.5

Lead

Manganese

Iron

e. coli

Phthalates

Arsenic

TDS

Sodium

Chloride

Gross Alpha

About 49% - Do NOT Meet Drinking Water Standards!

What are Phthalates?
- Used as Plasticizers - a substance which when added to a material, usually a plastic, makes it flexible and easier to handle.
- Bis(2ethylhexylphthalate) (DEHP) – DW Standard – 6 ppb – GI problems, possible endocrine disruptor and carcinogen.
- Recent Testing – Highest Value was 60 ppb.
- How did this get in the aquifer?

What Parameters
- Baseline Testing

The Marcellus Shale Factor- The Truth about Private Wells
- In 1996 – we knew 50% of Private Wells in PA were contaminated – But What Did We DO?
- The Marcellus Shale Factor or the Development of this resource is NOW bringing this problem to the surface.
- Baseline Testing is being conducted and more problems with groundwater quality are being identified.
- What do we do now? What is the Risk? What are the pathways to Contamination/Impact? How should Risk be Managed?
- What to Test For as Part of Baseline Testing?

Suggested Baseline- For Citizens
- Testing Package # 1 Recommendations
  - Total Coliform with e. coli confirmation, chlorine, sodium, bromide, barium, pH, total dissolved solids, MBAS, iron, manganese, and methane/ethane.
- Testing Package # 2 Recommendations
  - Package #1: pH, Eh, T. Hardness, Magnesium, Selenium, Strontium, Conductivity, Calcium, Zinc, Alkalinity, Arsenic, Nutrate, Total Suspended Solids, Sulfate, Oil & Grease, and 21-VOCs/MTBE.
- Testing Package # 3 Recommendations
  - Package #1 and #2 - plus Potassium, Sulfide, Ammonia, Acidity, Nickel, Grom, Alpha/Beta, Lead, and Uranium.

It may be advisable to add Glycols, Radon in water, and other organics and inorganics. Depending on surrounding land-use, use of geothermal wells, and past history.

http://www.wilkes.edu/water (Fact Sheet - Recommended Baseline)
II. Guidelines for Data Submission

1. Third Party Samplers following chain-of-custody to certified laboratory.
2. Submit detailed reports from certified laboratory with a GPS position for the well.
3. The water sample must be collected ahead of any water treatment system.
4. Other conditions – Learn More at the Wilkes University Website.

Learn More –
http://www.wilkes.edu/water

What Professionals Can Do?

- Get Educated and Informed. Where does your water come from?
- Be active in Proposed Legislation.
- Push for Local Zoning/ Subdivision Ordinances
- Encourage Private Well Construction and Siting Standards
- Getting all Marcellus Shale related infrastructure added to deeds for parcels.
- Determine the information you may need to baseline a patient.
- Self-Monitoring- Drinking Water- Encourage others to “Test the Waters”
  - Baseline Testing- Certified, Chain-of-Custody
  - Post Testing Using Informational Water Test Services – http://www.water-testing-kits.com
  - Self Monitoring – Easy to Use Monitoring Equipment and Citizen Monitoring Programs http://www.bfenvironmental.com

Get the Facts Not the SPIN !- There is SPIN on Both Sides

Recent Site Tour – Towanda, PA

I took both photos – First Time on the Drilling Platform

Suggestions for Baseline Testing

- Bacterial Series
- General Water Quality (pH, alkalinity, hardness, turbidity)
- Secondary Drinking Water Standards
- Oil/Grease
- Volatile Organics and regulated SOC’s (Maybe MTBE)
- Radionuclides (Alpha/Beta – Maybe Uranium),
- Gases – Methane/ Ethane/ Propane – Add Radon !
- Major Cations / Anions
  - Plus Bromide, Sulfide, Potassium, Sodium, Aluminum,
  - Selenium, Strontium, Arsenic, Lithium (?), Lead (?), Mercury (?), Silver (?)

Companies need to take a few extra steps – they are assumed responsible.
500 to 1000 feet 4000 ft

Mud/ Methane Migration (up to 1000 ft)
Methane Pushes (2500 feet)
Area Above Lateral
1000 ft Buffer

This is More Opinion/ Judgment- not fact.

In general – I could see a radius from 3000 ft to 1 mile

My Primary Concern with Respect to Radius and Assumed Liable is “Who is Responsible”

Company A  Company B
Private Well

May Zones for Testing should match drilling pad.

Presented by:
Mr. Brian Oram, Professional Geologist (PG), Soil Scientist, Licensed Well Driller, IGSHPA
B.F. Environmental Consultants Inc.
http://www.bfenvironmental.com

And
Water Research Center
http://www.water-research.net

Marcellus Shale Photo
Outcrops Along the Southeastern Border of Pike County Along Route 209

Main Fracture Orientation

This is why the term – Fairway is being used to describe the play.

Source- Cabot - Marcellus Shale Thickness Map
3.4 mmcf/day
$12,400/day
$23,900/day (25%)
2.3 to 6.3 mmcf/day
$3000/day (25%)
1 MMcf = 1000 MMBtu
$3.64 per MMBtu

Source: DUG Conference Presentation

Flowback Water Chemistry
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Source: http://www.prochemtech.com/

Multiple Grouted Casing Used in Drilling Process

Typical Well
Additional Cemented Zones
This Zone should be cemented
Even after new regulations
There may be a zone from 1500 to 2000 feet thick not cemented.
**Available Frac Water (Includes Recycled) Chemistry**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Concentration</th>
<th>PWS Standard</th>
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<tr>
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<td>0.2</td>
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<tr>
<td>Barium</td>
<td>mg/L</td>
<td>0.35</td>
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<tr>
<td>Iron</td>
<td>mg/L</td>
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<td>Manganese</td>
<td>mg/L</td>
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<td>0.05</td>
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<td>Hardness</td>
<td>mg/L</td>
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<td>500</td>
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<td>T. Dissolved Solids</td>
<td>mg/L</td>
<td>31324</td>
<td>500</td>
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<tr>
<td>Nitrates</td>
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<td>NH₃</td>
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<td>Bromide</td>
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<tr>
<td>Gross Alpha</td>
<td>pCi/L</td>
<td>221.5</td>
<td>15</td>
</tr>
<tr>
<td>Gross Beta</td>
<td>mcg/L</td>
<td>38.65</td>
<td>4</td>
</tr>
<tr>
<td>Radium 226</td>
<td>pCi/L</td>
<td>38.56</td>
<td>5</td>
</tr>
<tr>
<td>Radium 228</td>
<td>pCi/L</td>
<td>88.63</td>
<td>5</td>
</tr>
</tbody>
</table>

All parameters are below the PWS Standard.

**Photo Document Sampling Site, Purging, and Monitoring Process**

**Suggestions for Baseline Testing**
- Bacterial Series
- General Water Quality (pH, alkalinity, hardness, turbidity)
- Secondary Drinking Water Standards
- Oil/Grease
- Volatile Organics and regulated SOCs (Maybe MTBE)
- Radionuclides (Alpha/Beta – Maybe Uranium), Gases – Methane/ Ethane/ Propane – Add Radon!
- Major Cations / Anions
  - Plus Bromide, Sulfide, Potassium, Sodium, Aluminum, Selenium, Strontium, Arsenic, Lithium (?), Lead (?), Mercury (?), Silver (?)

Companies need to take a few extra steps – they are assumed responsible.

**Most Townships Only Requirement**
- Well is 100 feet from septic disposal area
- Well is 50 feet from septic tank
- Well is 10 feet from property
- That is ALL Folks!
- No Water Testing
- No Construction Requirements
- No Real Siting Requirements

**Just for the Record**

<table>
<thead>
<tr>
<th>Methane emissions per animal/human per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>120kg</td>
</tr>
<tr>
<td>60kg</td>
</tr>
<tr>
<td>1.5kg</td>
</tr>
<tr>
<td>0.13kg</td>
</tr>
</tbody>
</table>

Note: For Humans - Some higher than others.
How Contaminants Can Get In to the Aquifer (Surface)

- Ungrouted Well Pit
- Sanitary Well

How? Not Sure – Here are Some Ideas

- Trace Level or near Detection Limit may be related to contamination during field sampling or laboratory testing, but this does not appear to account for levels at or above the drinking water standard.

Other Sources:

- Private Wells Not Regulated and there are no plumbing codes.
- Sources – PVC plastic piping used in the home.
- Sources – Drop Pipe and Delivery Piping used in the well.

This is only a hypothesis.

Sometimes we also see hits for Vinyl Chloride and Toluene

(What the electric Tape ?!!!)

Baseline Testing

- Baseline Testing
  - Proper Well Purging, Field Monitoring, and Sampling
  - Documenting Existing Conditions and Well or Water Source Information
  - Chain-of-Custody Protocols
  - Using a Certified Lab / Using Certified Methods
  - Picking Water Quality Parameters