Research on Potential Impacts from Hydraulic Fracturing on Drinking Water Resources

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Purpose of the EPA Study *

In its FY 2010 Appropriations Committee Conference Report, Congress directed EPA to study the relationship between hydraulic fracturing and drinking water, using:

- Best available science
- Independent sources of information
- Transparent, peer-reviewed process
- Consultation with others

*http://www.epa.gov/hfstudy/
Purpose of EPA’s Study

- To assess the potential impacts of hydraulic fracturing on drinking water resources
- To identify the driving factors that affect the severity and frequency of any impacts

*This study is not intended to determine or evaluate best management practices.*
Research Approaches

- Gather and analyze existing data
- Case studies
- Scenario evaluations
- Laboratory studies
- Toxicological assessments
What are the possible impacts of releases of flowback and produced water on drinking water resources?
Hydraulic Fracturing

Hydraulic fracturing often involves the injection of more than a million gallons of water, chemicals, and sand at high pressure down the well. The depth and length of the well varies depending on the characteristics of the hydrocarbon-bearing formation. The pressurized fluid mixture causes the formation to crack, allowing natural gas or oil to flow up the well.

Water Use in Hydraulic Fracturing Operations

- Water Acquisition - Large volumes of water are transported for the fracturing process.
- Chemical Mixing - Equipment mixes water, chemicals, and sand at the well site.
- Well Injection - The hydraulic fracturing fluid is pumped into the well at high injection rates.
- Flowback and Produced Water - Recovered water (called flowback and produced water) is stored on-site in open pits or storage tanks.
- Wastewater Treatment and Waste Disposal - The wastewater is then transported for treatment and/or disposal.

Aquifer

Hydrocarbon-bearing Formation

Induced Fractures
HF in Ohio

- **Marcellus Shale Horizontal Well Permits**
  - 13 horizontal well permits issued - 7 drilled from 2006-present

- **Utica Shale Horizontal Well Permits**
  - 137 horizontal well permits issued - 35 drilled from 2009-present

Research on WW and DW

• Research Questions
  • How effective are conventional and commercial treatment systems in removing organic and inorganic contaminants of concern in HFWW
  • What are the potential impacts from surface water disposal of treated hydraulic fracturing WW on DW treatment facilities
What is HFWW?

• “Flowback”
  • Injected fracturing fluid returning to the surface after a fracturing event

• “Produced”
  • Water extracted from the formation during gas production

• Storm water runoff?
Volumes of WW

• 56 M bbl/day from on-shore oil and gas production*
  • = 2.353 Bgal. Los Angeles Hyperion Treatment plant treats 340 MGD. Seven days to treat a days’ worth of wastewater (Detroit could treat the volume in 1.5 days)

• Shale Gas well
  • Rough average 500 bbl/day = 21,000 Gal/day
  • Varies greatly depending on location, stimulation methods, geology etc.
    • e.g. Barnett 3-4X “wetter” than Marcellus

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Duration of WW production

• Flowback
  • 2-8 MG/well for drilling/fracturing
  • 30-70% flowback*
  • 13.5% Susquehanna River Basin (131 Wells)**
  • Hours to weeks (14-30 days cutoff?)

• Produced
  • Greatly depends on formation
  • Generally less than 1000 gal/MMCF gas over lifetime***

**Hoffman, J. 2010. Susquehanna River Basin Commission
Natural Gas Development at http://www.srbc.net/programs/projreviewmarcellustier3.htm
***ERG Draft Pollutant Research Literature Review
Potential Contaminants

- TDS
- Anions
- Cations/elemental
- Organics
- Radionuclides (NORM)
  - Radium
  - Uranium
  - Thorium
WW Storage

• Lagoons, ponds, tanks
• Storage issues
  • Wildlife
  • Odor
  • Overflow/failure
• Regulations
  • States
    • Liners
    • Construction requirements
WW Treatment

- Direct discharge to surface
- Indirect discharge to surface water
  - Publically owned WW treatment plant (POTW)
    - Conventional WW treatment: Primary settling, aeration basin/activated sludge, secondary settling
  - Commercial Treatment
    - Evaporative/Distillation
- Underground injection
- Reuse
**DW Issues**

- **Direct contamination**
  - Subsurface migration
  - Faulty well construction

- **Discharge to surface water**
  - POTWs
  - Commercial facilities
  - spills
DW-Bromide

- Bromide + NOM + chlorination = Br disinfection by-products (DBPs)
  - Total Trihalomethanes (THMs)- 80 µg/L
    - Chloroform (aka trichloromethane) - CHCl$_3$
    - Bromodichloromethane - CHClBr$_2$
    - Dibromochloromethane - CHCl$_2$Br
    - Bromoform (aka tribromomethane) – CHBr$_3$
  - High source water bromide concentrations
    - Tend to shift THMs toward Br forms
    - Br is heavier thus 80 µg/L reg is exceeded
• **Marcellus**
  
  • Bromide ranges from non detect to 1600 mg/L in HFWW (PADEP 26R Forms-Annual Report by Generator)
  
  • Min: 0.14 mg/L Max: 1990 mg/L Avg.: 410 mg/L Median: 180.5 mg/L
DW-Bromide in SW

• Possible Sources
  • Coal fired power plants
  • Surface/Mountain Top Mining Valley Fill
  • Hydraulic Fracturing
    • Runoff/overflow/spills
    • Treated discharge
      • Commercial Trtmt. Facilities
      • POTWs
DW-Bromide in SW

PWSA Bromide Samples, July 2011
Research-Bromide

• Phase I: THM formation potential from Br containing compounds
  • Typically used as biocides in HF fluids
    • Bronopol: 2-bromo-2-nitro-1,3, propanediol
    • DBNBA: 2,2-dibromo-3-nitrilopropionamide
  • Do these Br compound contribute to Br-DBP formation?
  • Can they potentially form Br-DBPs in storage if shock chlorination is used (odor control in open lagoons)?
  • Can they be “ruled out” relative to naturally occurring bromide?
  • Longevity
• Phase II: THM formation potential from Br in HFWW

  • Proposed methodology
    • Dilute actual HFWW (1%)
    • Account for, by estimation, receiving water dilution factor
      • Use actual PA numbers as a basis
    • Add NOM (e.g. Suwanee River Humic/Fulvic Acid)
      • 0, 1, 5, and 10 mg/L
    • Chlorinate (1-2 mg/L)
    • Chloraminate (1-2 mg/L)
    • Analyze for THMs, Haloacetic acids, and nitrosamines as a function of time
Phase I: Fate and transport of priority contaminants in WW treatment

- Proposed methodology
  - Utilize target contaminant list (Brian’s list-under development)
    - Elements: Ba, Sr, Fe, Mg, Na, Ca
    - Organics: Ethylene glycol, acrylamide, glutaraldehyde, formaldehyde, alkylphenols, benzene/toluene/ethylbenzene/xylenes (BTEX), ethylene glycol monobutyl ether (aka 2-butoxyethanol)
    - Anions: Br, Cl, NO₃, PO₄, SO₄, F
  - Fate/transport studies (benchtop)
    - 10 L temperature controlled stainless steel reactors
Research-Wastewater

Benchtop Reactor
Research-Wastewater

• Phase I: Fate and transport of priority contaminants in WW treatment
  • Proposed methodology
    • Fate/transport studies (benchtop, pilot-scale)
      • Blend HFWW with synthetic WW
        • 0, 1, 5, 10% HFWW
      • Hydraulic Residence Time
        • 6-8 hours
        • 1-2 hours primary settling
  • Concurrent Studies on effects on activated sludge process
    • Monitor biological oxygen demand, chemical oxygen demand, nitrogen (in/out) and phosphorous (in/out)
Phase II: Partitioning of contaminants in residuals

Proposed methodology

- Analyze residuals from bench-top studies and actual HFWW residuals
  - Elemental
    - Bulk digestions, ICP-OES, ICP-MS
    - Elemental chemical speciation
    - Bonding/sorption characteristics (X-ray absorption spectroscopy)
  - Organics
    - Accelerated solvent extraction
    - LC-triple quadrupole mass spectrometry
Current Status

- QAPPs and HASPs in place
- Work has commenced on Br compounds/DBP formation
- Contract support for DBP work in place
- Contract support for WW work is in progress
- ORISE Post-doc expected on-board in March
Immediate Future

- Help to finalize(?) chemical contaminant priority list (end of March)
- Develop/optimize IC/MS procedure for Br analysis in high TDS matrix (end of March)
- Procure HFWW samples for benchtop DBP studies (by end of April)
- Begin setting up benchtop WW systems (May)
Questions?