Type them into questions box!

“Why am I muted?”
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Moderator: Kali Mihale, ACS Publications

What You Will Learn:
- What editors look for when reviewing submissions
- Tips for responding to reviewer reports
- Qualifications to become a reviewer and strategies to evaluate a manuscript
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ACS Green Chemistry Institute

Engaging you to reimagine chemistry and engineering for a sustainable future!

We believe sustainable and green chemistry innovation holds the key to solving most environmental and human health issues facing our world today.

- Advancing Science
- Advocating for Education
- Accelerating Industry

ACS GCI convenes companies in the chemical industries to advance the implementation of sustainable and green chemistry and engineering.
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To integrate GC&E principles into the chemical supply chain for the oilfield industry.

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Save the Date...ACS GCI Webinar Next Week!

Thursday. September 17, 2-3pm ET

“Beyond Organic Solvents: Synthesis of a 5-HT4 Receptor Agonist in Water”

Dan Bailey
Process Chemist, Takeda Pharmaceuticals

2020 Peter J. Dunn Award Winner for Green Chemistry and Engineering Impact in the Pharmaceutical Industry
This ACS webinar is co-produced with ACS Green Chemistry Institute.

Grand Challenges and Opportunities for Greener Alternatives within the Oil and Gas Industry

**Brian Price**
Vice President of Technology & Completions Business Line, Rockwater Energy Solutions and Member, ACS GCI Oilfield Chemistry Roundtable

**Dave Horton**
Chief Technology Officer, CES Energy Solutions and Co-Chair, ACS GCI Oilfield Chemistry Roundtable

**David Constable**
Science Director, ACS Green Chemistry Institute, American Chemical Society

Presentation slides available now! The edited recording will be made available as soon as possible.

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This ACS Webinar is co-produced with ACS Green Chemistry Institute.
Common ground: To fulfill today’s energy needs minimizing environmental impact.

Pre-competitive scientific collaboration within a non-profit organization, where research innovations could be driven and all companies could benefit.

Working together, brainstorming new ideas, creating tools and sharing best practices.

Why? Green chemistry & engineering is a driver to sustainability.
ACS GCIOR Mission & Strategic Priorities

To systematically integrate GC&E principles into the chemical supply chain for the oilfield industry.

- Develop scientific information.
- Provide a scientific framework and tools.
- Identify, assess and prioritize chemicals to find sustainable alternatives.
- Promote effective communication and collaboration.
- Advocate for scientific approaches & innovative additive technology.

Recent ACS GCIOR Perspective Publication!

Energy Fuels 2020, 34 (7), 7837-7846

Grand Challenges and Opportunities for Greener Chemical Alternatives in Hydraulic Fracturing: A Perspective from the ACS Green Chemistry Institute Oilfield Chemistry Roundtable

David Harry, David Horton, Danny Durham, David J. C. Constable,* Simon Gaffney, Joseph Moore, Bridget Todd, and Isamir Martinez

DOI: 10.1021/acs.energyfuels.0c00933
Fracturing Process Overview

- “Frac,” term used for hydraulic fracturing.
- After an oil and gas well is drilled in a shale reservoir, this stimulation method is used to create fracture networks in the shale that allow for the flow of oil and gas from the reservoir.
  - Fracs allow for release of oil and gas and improve harvest from the shale.
  - Frac fluid is pumped at high rates and high pressure to fracture the shale.
- Frac Fluid is a combination of water, proppant and additives specifically formulated for application in a specific shale.
- Shale reservoirs, isolated from the surface.
- Frac fluids are contained within the reservoir and associated well infrastructure.

Frac methods and frac fluid recipes vary depending on the shale basin.

Each region can have different characteristics that require unique pumping and fluid designs.

This depiction is from the Marcellus Shale in the U.S.
Global Shale Basins

Figure 1. Map of basins with assessed shale oil and shale gas formations, as of May 2013

Shale basins across the globe account for a significant portion of harvestable oil and gas reserves.

Legend
- Assessed basin with resource estimate
- Assessed basin without resource estimate

Source: USGS Shale gas from U.S. Energy Information Administration and United States Geological Survey; other basins from AIREE based on data from various published studies.

Audience Survey Question

ANSWER THE QUESTION ON BLUE SCREEN IN ONE MOMENT

Approximately what portion of the world’s technically recoverable oil and gas lies in oil shale?

- Less than 10 percent
- Less than 30 percent, but greater than 10 percent
- Between 40 to 70 percent
- Other (tell us more in the chat)

* If your answer differs greatly from the choices above tell us in the chat!
Average U.S. Shale Frac Fluid Composition

Composition:
- Water: 85.02%
- Proppant: 14.2%
- Additives: 0.78%


Water- Challenges and Opportunities

- Finding a suitable source of water
- Suitability of the water for use in a frac fluid
- Reuse and recycling of water
Creating a Frac Fluid

Composition, determined from detailed analysis and application of engineering principles:

- Shale composition
- Source water composition
- Proppant loading requirement
- Stimulation design
- Productivity Results

Examples of Frac Fluid Additives Components in Society

<table>
<thead>
<tr>
<th>Compound</th>
<th>Purpose</th>
<th>Common Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acids</td>
<td>Helps dissolve minerals and initiate fissure in rock (pre-fracture)</td>
<td>Swimming pool cleaner</td>
</tr>
<tr>
<td>Ammonium bisulfite</td>
<td>Removes oxygen from the water to protect the pipe from corrosion</td>
<td>Cosmetics, food and beverage processing, water treatment</td>
</tr>
<tr>
<td>Polyacrylamide</td>
<td>Minimizes the friction between fluid and pipe</td>
<td>Water treatment, soil conditioner</td>
</tr>
<tr>
<td>Borate Salts</td>
<td>Maintains fluid viscosity as temperature increases</td>
<td>Laundry detergent, hand soap, cosmetics</td>
</tr>
<tr>
<td>Sodium/Potassium Carbonate</td>
<td>Maintains effectiveness of other components, such as crosslinkers</td>
<td>Washing soda, detergent, soap, water softener, glass, ceramics</td>
</tr>
<tr>
<td>Glutaraldehyde</td>
<td>Eliminates bacteria in the water</td>
<td>Disinfectant, sterilization of medical and dental equipment</td>
</tr>
<tr>
<td>Guar Gum</td>
<td>Thickens the water to suspend the sand</td>
<td>Thicken in cosmetics, baked goods, ice cream, toothpaste, sauces</td>
</tr>
<tr>
<td>Citric Acid</td>
<td>Prevents precipitation of metal oxides</td>
<td>Additive in food and beverages</td>
</tr>
</tbody>
</table>

Green Frac Fluid Initiatives

• Increased activity and volumes have placed focus on chemistries used
  – Oil & Gas companies are incentivized to reduce chemical usage and meet ESG objectives
  – Suppliers of frac additives have been challenged to provide green alternatives
• Frac fluids optimization has been a primary driver in reducing chemical usage in frac fluids.
• New chemistries from a broader supply chain have found their way into oil and gas.

Type of Chemicals Used in Hydraulic Fracturing

- Friction Reducers (FRs)
- Surfactants
- Scale Inhibitors
- High Viscosity FRs (HVFRs)
- Solvents
- Biocides
- Acid Additives
- pH Adjusting Agents
- Breakers
- Chelating Agents
- Guar Slurries
- Clay Control Additives & Formation Stabilizers

- Each chemical has a specific purpose.
- We will review current chemistry being used in these areas and opportunities for improvement.
Audience Survey Question

**Answer the question on blue screen in one moment**

**Fluids used in Fracturing Fluids typically display?**
(Select all that apply)

- Shear thickening behavior
- Shear thinning behavior
- Newtonian behavior
- Other (tell us more in the chat)

*If your answer differs greatly from the choices above tell us in the chat!*

---

**Friction Reducers & High Viscosity Friction Reducers**
(FR and HVFR)

- Added to water to make "slickwater"

- Current technology: acrylamide co-polymers
  - Supplied in three polymeric forms
    - dry, emulsion, slurried
  - Anionic, cationic and zwitterionic polymers

- Compatibility with the water source is paramount in selection of the chemistry.
FR & HVFR: Chemistries

CAS 64742-47-8 Distillates (petroleum), hydrotreated light
- Complex combination of hydrocarbons
- Obtained by treating a petroleum fraction with hydrogen in the presence of a catalyst.
- Consists of hydrocarbons in the range of C9 through C16 and boiling in the range of approximately 150°C to 290°C (302°F to 554°F).

FR and HVFR: Challenges & Opportunities

- Monomers from non-renewable feedstocks
  - renewable feedstocks / high molecular weight biopolymers?
- HVFR’s are sensitive to ionic strength.
  - Higher usage required in high TDS brines.
    - Can chemistry solve this?
- Dry polymers require hydration units prior to application.
  - Dry HVFR can be challenging to hydrate on the fly.
    - Improvements to the powdered polymer to enhance dispersibility.
Guar Gum

- Until early 2010's most common viscosifier
  - displaced by FR and HVFR
  - Guar gum, hydroxypropyl guar (HPG) and carboxymethyl hydroxypropyl guar (CMHPG) are materials of commerce in fracturing
- Provide little friction reduction, mainly used due to sand transport / suspension characteristics.
- Cross-linked with a variety of inorganic compounds
- Viscosities in range of $10^2$ cP (@ 100/sec shear rate)
- Two forms: powder form or slurried in mineral oil for ease of application

Guar Gum:Chemistries

CAS 64742-47-8
Distillates (petroleum), hydrotreated light

- Increases viscosity making high-pressure pumping and fracturing process more efficient
Guar Gum: Challenges & Opportunities

- Renewable solvent sources
- Mechanical Improvements

Breakers

- To reduce viscosity and clean viscosifier off formation face

- Examples:
  - Oxidizers (e.g. ammonium persulfate, peroxide etc.)
    - randomly attack backbone of polysaccharides – degradation products may have lower viscosity but may not be water soluble.
  - Enzymes, to break guar systems (e.g. hemi cellulase and mannanase)
    - Fragments from hydrolysis are water soluble.
    - Sensitive/specific to temperature and pH
    - Higher temperature and/or higher pH range enzymes present the greatest need / opportunity
Clay Stabilizers

- Swelling / dispersion will impair rock permeability
- Osmotic swelling occurs due to potential differences of the water in the clay interstitial spaces
- Hydrocarbon bearing formations frequently contain inclusion of swellable / migratable clays – e.g. illites and smectites

- Imperfections in the crystal lattice where Mg substitutes for Al, and Al substitutes for Si.
- In clay interstitial spaces, labile ions are coulombically bound to the surface of the platelet.
- If these labile ions are sodium, then swelling can occur due to ion hydration

Clay Stabilizers Chemistries – Ion Exchange

\[
\text{Al}_2\text{Si}_4\text{O}_{10}(\text{OH})_2
\]

\[
\text{M}^{+} (x+y) \text{Mg}_x\text{Al}_{2-x}y\text{Si}_{4-y}\text{O}_{10}(\text{OH})_2
\]

- Prevent migration or swelling

Choline Chloride
Vitamin B4

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Stabilizers: Challenges & Opportunities

- Currents chemistries relies in Vitamin B4
  - Manufacturing methods from petrochemicals feedstocks
  - Potential Biosource (e.g. biochemical reaction pathway)

Biocides

- Designed to:
  - Control populations of bacteria and other microorganisms.
  - To eliminate
    - sulfate reducing bacteria – formation souring / corrosion
    - acid producing bacteria – corrosion
    - slime forming bacteria – microbially induced corrosion
  - For these chemistries to work they need to be inherently toxic
    - amount vs. toxicity considerations
Biocides: Challenges & Opportunities

- Potential for synergy with enzymes that disrupt biofilms
  - ACS GCIOCR engaged a collaboration with MSU to use enzymes to reduce the biofilm formation

- Potency – does reduced toxicity require increased dosage?

- Regulatory – will require EPA registration.
Scale Inhibitors

- **Prevent scaling** from incompatible waters (e.g. sulfate / barium)
  
  - Chemistries are crystal modifiers, not chelants
  
  - Work at sub stoichiometric concentrations
  
  - Must be compatible with other additives, typically the friction reducer

Scale Inhibitors Chemistries

![Chemical structures of scale inhibitors](image)
Surfactants

**Major Uses for Surfactants in Hydraulic Fracturing**

- Assist in FR inversion via surface tension reduction
- Sacrificial water wetting of sand w/ friction reducer adsorption
- Reduction of relative permeability damage due to ingestion of frac fluids into pore spaces
- Non-emulsifying properties for fluids entering perforation of the wellbore at high shear rates
- Lower surface tension to aid in fluid traveling through sand pack

**Surfactant Chemistries**

**Non-emulsifiers**

- \( \text{H}_3\text{N} \quad \text{NH}_3 \)
- \( \text{O} \)
- \( \text{O} \)

**Surfactant Gels**

- Reduce the surface tension, detergent effect

**Emulsifiers**

- \( \quad \text{Na} \)

**IFTR**

**Inverting Surfactants**

**Prevent emulsion formation**
- Reduce interfacial tension
- Clean up the proppant pack
- Disperse slurries
- Invert FR emulsions
Surfactants: Challenges & Opportunities

- Non-renewable resource
- Biodegradable – e.g. branched alkylbenzene sulphonates
- Biosource

Other Areas of Interests

- **Solvents**
  - Replacements:
    - Useful solvent interactive tool (free to use):
      
      https://www.acsgcipr.org/tools-for-innovation-in-chemistry/solvent-tool
    - Biobased, Cost-effective

- **Acid Additives** – corrosion inhibitors

- **Chelating Agents** – Citric / acetic, THP

- **pH Adjusting Agents** – sodium / potassium hydroxides, sodium / potassium carbonates, organic acids
Chemical Reduction Strategies in HF

- To adopt strategies to enable a reduction in each area.
  - To reduce environmental, safety, and health impact.

Energy Fuels 2020, 34, 7, 7837-7846

Summary

- Efforts to provide greener alternatives in hydraulic fracturing are ongoing.
  - Chemistries’ environmental footprint have been improved; more could be done.
  - Finding new alternatives/replacements
  - collaboration among academia, chemical manufacturers, end users, and nonindustrial members is imperative.
- Innovation is essential for green chemistry, a driver for sustainability!
- ACS GCI OCR, pre-competitive scientific collaboration has been established to accelerate greener alternatives.
Thank you to our Members! Questions?

Join our ACS GCI OCR mission: [www.acs.org/oilfield-chemistry](http://www.acs.org/oilfield-chemistry)
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