US EPA Technical Workshop on Wastewater Treatment and Related Modeling For Hydraulic Fracturing

Treatment for Beneficial Use of Produced Water and Hydraulic Fracturing Flowback Water

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energywater SOLUTIONS

Introduction

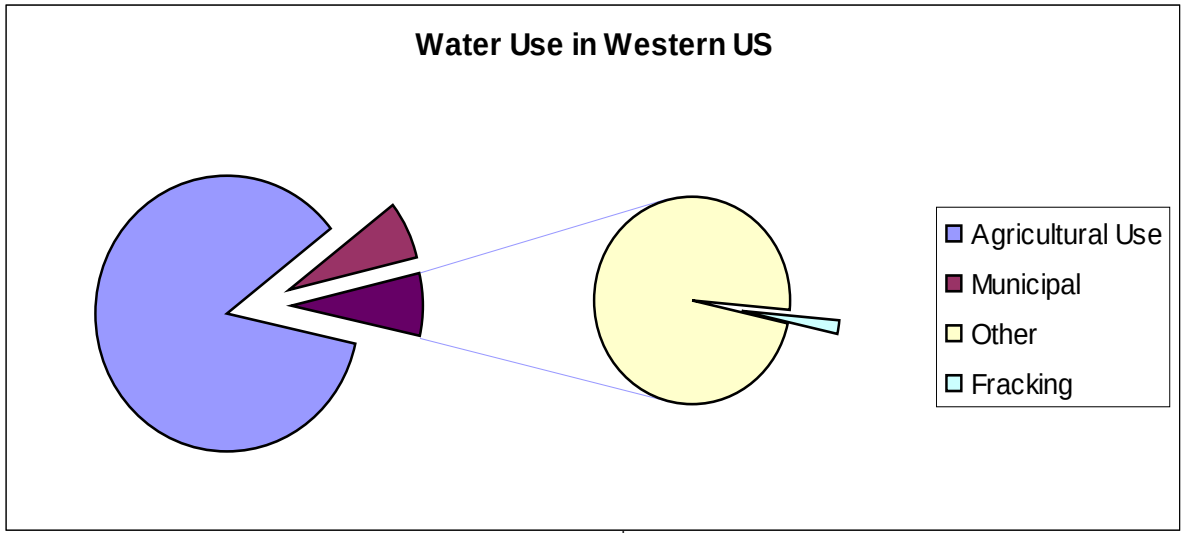
- Water reuse and recycling is a significant issue in the development of oil and gas shale plays in the United States
- Water use for E&P operations is significant in areas where the drought exists – low percentage number but total consumption
- Water reuse will be dependent on the interactions of water quality constituents as they relate to water reuse and recycling
- Beneficial reuse of produced water can be for hydraulic fracturing but also for agricultural reuse, municipal augmentation and environmental benefit

Water Quality Criteria for Reuse

- Constituents of concern for water reuse:
  - Total Dissolved Solids
  - Oil and Grease
  - Suspended solids
  - Dispersed oil
  - Dissolved and volatile organic compounds
  - Heavy metals
  - Radionuclides
  - Dissolved Gases and Bacteria
  - Chemical additives such as biocides, scale and corrosion inhibitors, guar gum and emulsion/ reverse-emulsion breakers

Water Use as a Function of Overall Water Management

- What is the percentage of total fracking and energy development = **0.14% of total** use in the US typical - (example is Colorado)
- Largest use is Agricultural at 85%
- Second highest use is Municipal and Industrial at 7%
- All others is 8%
- This 0.14% equals the amount of water used on an annual basis by the City of Denver.

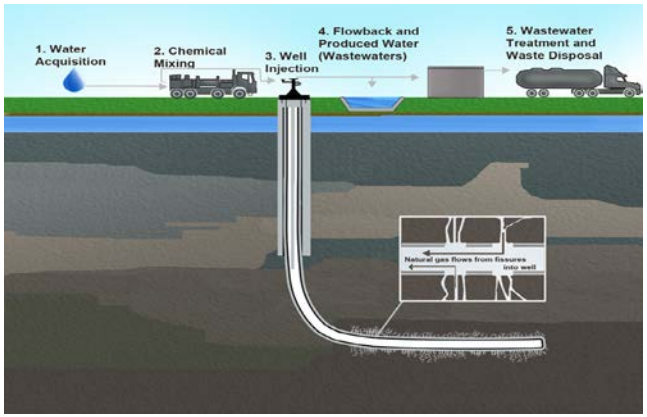


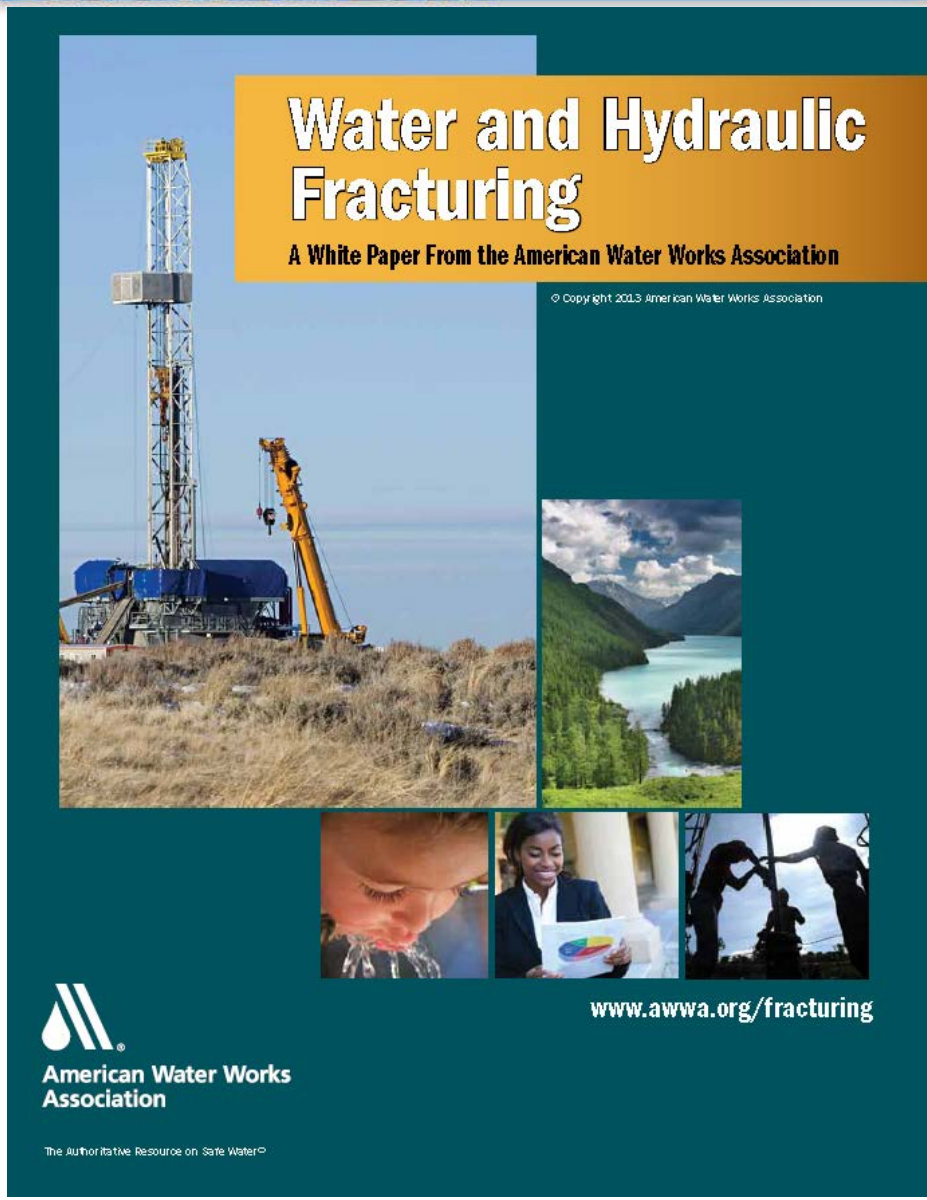
Experience in produced water treatment

- Experience in treatment of produced water for beneficial reuse
  - Wellington Colorado
    - 5,000 bbl/ day facility
    - Operational since 2006
    - Produced water uses
      - Makeup water for hydraulic fracturing
      - Agricultural irrigation
      - Municipal augmentation water for a drinking water supply
  - Utah facility of 5,000 bbl/ day
  - Texas facility of 1,500 bbl/ day
  - Wyoming facility 100,000 bbl/ day

Impacts on Water Market

- Impacts on the water market
  - Water Availability
  - Truck Traffic
  - Surface Spills and leaks
  - Air pollution





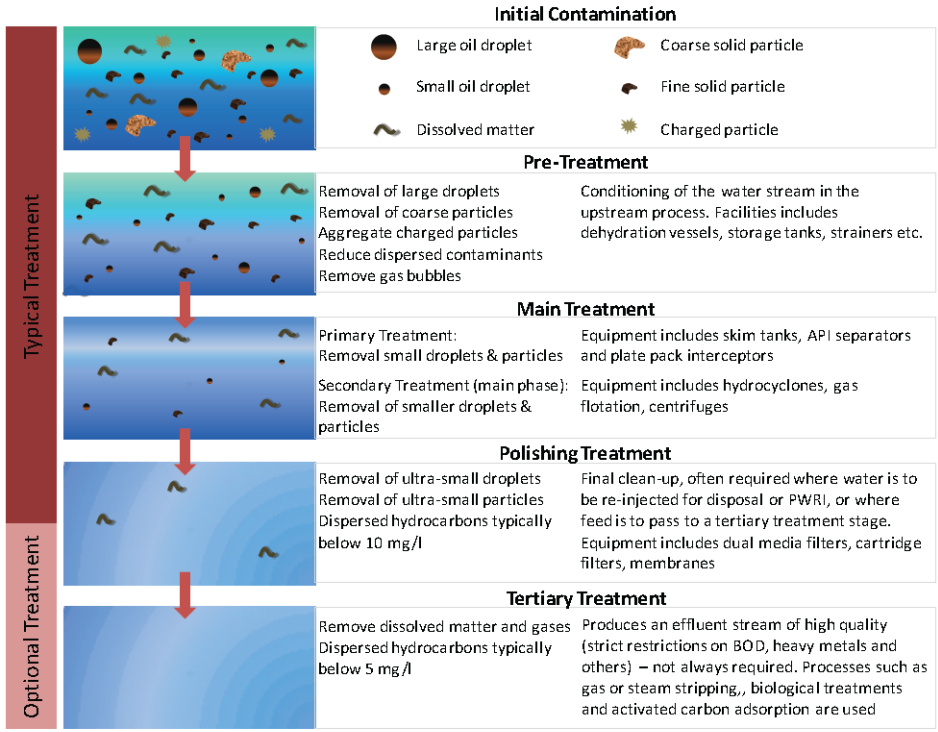
Flowback Chemistry

- Note the following
  - Barium levels
  - Iron levels
  - TOC
  - TSS
- These will be issues in treatment resulting in issues for reuse or recycling

Parameter	Feed Water	Flowback
pH	8.5	4.5 to 6.5
Calcium	22	22,200
Magnesium	6	1,940
Sodium	57	32,300
Iron	4	539
Barium	0.22	228
Strontium	0.45	4,030
Manganese	1	4
Sulfate	5	32
Chloride	20	121,000
Methanol	Neglible	2,280
TOC	Neglible	5,690
TSS	Neglible	1,211

Treatment Issues

- Treatment to what standard?
  - Frack water makeup?
  - Discharge to a surface water or tributary groundwater – 40 CFR 435
  - Disposal is Class II injection well
  - Disposal is surface water pond

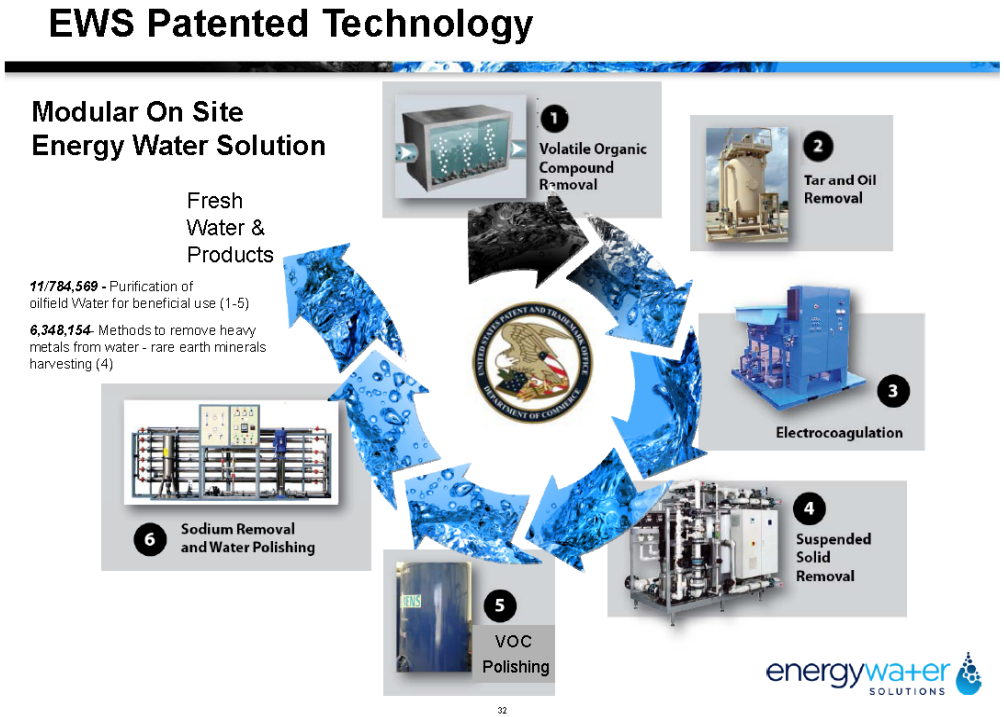


Treatment Requirements

- Two areas of concern
  - Organic treatment
  - Inorganic treatment
- Organic
  - Heavy Oils
  - Asphaltines/ Parrafins
  - VOC's
    - BTEX – benzene
    - Air stripping
    - GAC
  - Guar gum
  - Micro-organisiums
- Inorganic Treatment
  - Ion exchange
    - Higgins Loop
  - Precipitation chemistry
  - Electro-coagulation
  - CMF
  - NF/ RO

Treatment Process

- Treatment Steps
  - Aeration - removal of VOC's
  - WSF – heavy oils and asphaltines/ parafins
  - EC – precipitation of multi-valent ions
  - CMF – removal of precipitants and micro-organisiums
  - GAC – VOC removal
  - NF/ RO – control of salts



Scale Formation & Chemical Interference Issues for Water Reuse

- Constituents of concern:
  - Barium sulfate formation
  - Hardness (Calcium and Magnesium) interactions
  - Silicate formations
  - Boron issues
  - Salt removal
  - Radionuclides

Table 3 – An Example of Water Quality Goals for Hydraulic Fracturing Fluids

Bacteria	100,000 per 100 ml
Barium (mg/l)	< 2
Bicarbonates (mg/l)	250 to 100,000
Calcium (mg/l)	300
Chlorides (mg/l)	2,000 to 40,000
Iron (mg/l)	10
Hydrogen Sulfide (mg/l)	ND
Magnesium (mg/l)	100
pH	6.5 to 8.0
Phosphates (mg/l)	10
Radionuclides (pCi/l)	<15
Reducing agents (mg/l)	ND
Silica (mg/l)	<20
Strontium (mg/l)	<10
Sulfate (mg/l)	400 to 1,000
Total Dissolved Solids (mg/l)	500 to 5,000

Brine Control and Disposal

- Control of brine is the most difficult issue in recycling/ reuse of produced water and hydraulic flowback water
  - Brine stream can be 50,000 to 300,000 mg/ l TDS
  - Potential uses
    - 10 Pound Brine for drilling operations
    - Chlor-Alkali process for the manufacture of HCl or NaOCl and NaOH
  - By product capture
    - Lithium example

Conclusions

- Recycling and Reuse of produced water and flowback water will become a significant issue for the development of oil and gas shale plays in the United States
- Development of criteria for reuse and recycling needs to be developed
- Treatment technologies that fit the final reuse and recycling criteria will need to be deployed economically
- Economics is the driver for recycling and reuse
- Companies are committing to higher recycling and reuse rates but will need to implement more complicated treatment technologies
- Brine harvesting will need to be researched and perfected in the future