Deep Well Injection for Concentrate Disposal

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Why use injection wells for concentrate disposal?

- Often more cost-effective than other disposal options.
- Permanent removal of concentrate from the environment.
- Minimal surface footprint.
- Aesthetically not objectionable.
- May be the only viable option for regulatory or technical reasons.
- Operationally simple.
Deep injection well negatives

- Expensive ($1,000,000s).
- Risk – no guarantee that system will satisfactorily perform, particularly in areas without deep injection well history.
- Public (environmental advocacy group) objections.
- Tightly regulated.
Injection well regulations

- USEPA Underground Injection Control (UIC) Program.
- States can apply for primary enforcement authority (primacy).
- Primacy states follow USEPA rules and can add additional state regulatory requirements.

Goal of Federal UIC regulations

- Prevent endangerment of Underground Sources of Drinking Water (USDWs).
- USDW - aquifer containing < 10,000 mg/L of total dissolved solids.
- Endangerment – result in the presence of any contaminant, such that it results in non-compliance with any national primary drinking water regulation.
- Endangerment concerns do not apply to non-USDW aquifers (> 10,000 mg/L)
Types of injection wells used for concentrate disposal

- **Class I** – inject waste below the lowermost formation containing a USDW within one quarter mile of a wellbore.
- **Class V** – well other than a Class I well. May inject into or above a USDW.
- **Key point** – in Class V wells injectate (concentrate) must meet applicable groundwater standards (i.e., no endangerment of a USDW).

Basis technical requirements for permitting new injection wells systems

- **Mechanical integrity testing requirements.** Well must be constructed so that it does not leak or there is no migration behind casing.
- **Area of review requirements.** Provide evidence for absence of vertical migration avenues from injection zone.
UIC Permitting Information

- Geological/hydrogeological investigation.
- Structural integrity of the well (design information and proposed testing program).
- Proposed operational information.
- Proposed monitoring plans

Hydrogeologic issues

- **Deep injection wells are not a viable option everywhere as hydrogeology may be unfavorable.**

Basis hydrogeologic requirements for Class I Injection wells:
- An aquifer below the deepest USDW with a transmissivity sufficient to efficiently accept design concentrate flow.
- Effective confinement between injection zone and bottom the deepest USDWs.
‘Boulder Zone’, South Florida

Injection well

USDW

Injection zone
Water Quality Issues

- Corrosivity: Injected fluids should not adversely impact injection well mechanical integrity.
- Scaling: Minimize precipitation of minerals within casing and formation.
- Other adverse fluid-rock interactions (e.g., clay minerals and redox reactions) that could clog pores.

Water Quality Issues: Scaling

- Groundwater typically is in approximate chemical equilibrium with aquifer rock.
- Concentrate has a tendency to be supersaturated with some minerals (e.g., calcite, barite, quartz).
- Saturation state can be evaluated using geochemical speciation/mineral saturation programs (e.g., PHREEQC).
- Bench-top experiments.
- Need to look at fluid-rock interaction under injection zone rather surface conditions.
Water Quality Issues: Kinetics

- Kinetics – study of reaction rates.
- Chemical reactions may be thermodynamically favorable but occur at too slow a rate to impact injection well systems (e.g., quartz precipitation).

Pretreatment

- Prevent precipitation of minerals within casing of formation, particularly near borehole.
- Strategy used is very system specific.
- Adjust chemistry so injectate no longer saturated with respect to mineral in question (e.g., pH adjustment to prevent carbonate mineral precipitation).
- Crystallization inhibitors.
- Pretreatment may not be need if precipitation is very slow (kinetics).
Injection Well System Costs: Capital

- Main cost items are the injection well, associated monitor well(s), wellhead, hydropneumatic systems, and instrumentation.
- Costs vary greatly depending upon diameter and depth of well, local driller market, and testing requirements.
- Clewiston, Florida injection well system
  - $4,900,000 bid price (12/2005)
  - One injection well & one dual-zone monitor well
  - 4.05 MGD design capacity
  - 10.72” I.D. fiberglass tubing to 2,900 ft.
  - To be completed with open hole to 3,400 ft.

Injection Well System Costs: Capital

- Back-up capacity. May need to have 100% redundant injection well capacity if there is no alternative disposal method (≈ double costs)
- Should design injection well system for maximum conceivable capacity, as it may be much less expensive to construct a larger well than an additional well.
Operational Requirements

- Continuous monitoring of injection pressure, flow rate, volume, and annulus pressure.
- Monitoring of injectate chemistry.
- Specific injectivity and pressure fall-off testing.
- Monitoring of water quality in monitoring zones.
- Monitoring of water levels in monitoring zones.
- Mechanical integrity test (every 5 years).

- Estimated annual cost $40,000 to $100,000, not including labor, electrical, and pre-treatment.

El Paso Joint Desalination Facility Design Information

- Source wells: 18 mgd
- RO production: 15 MGD
- Blended with 12.5 MGD of high TDS groundwater
- Total blended supply to distribution: 27.5 MGD
- 82.5% design recovery
- Pilot studies have shown potential for 90% recovery
- Concentrate production 1.8 – 3.2 MGD depending on recovery
Concentrate Disposal Alternatives Are Limited

- Evaporative disposal
  - Passive
  - Enhanced
- Deep well injection
- Mechanical evaporation/crystallization
- Lime softening to reduce concentrate volume

Injection Well Northeast Area

- Target zone salinity – 6,500 ppm
- Transmissivity up to 300,000 gpd/ft
- Estimated travel – 4,100 ft after 30 years
- 100’s of feet of shale overlaying injection zone will prevent upward migration of injection water
View of Proposed Injection Site

Projected Costs for Deep Well Disposal

- Three wells constructed to Class I standards
- Depth – approximately 4,300 ft
- Capital cost – $6.5M
- Annual operating cost – $0.75M
- Present worth – $24.5M
Deep Well Injection is Most Cost Effective

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<th>Method</th>
<th>Capital Cost</th>
<th>Annual O&amp;M Cost</th>
<th>Present Worth</th>
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Concentrate Water Quality

- Calcite Saturation Index (SI) 0.5 to 1.2
- Barite SI: 0.9 to 1.0
- Si: 150 mg/L to 200 mg/L
- pH: around 7.4 to 7.8
- Pilot testing completed at UTEP to determine precipitation potential

Denver Injection Well Issues

- **Uncertainties:**
  - Rocky Mountain Arsenal seismic issues (technical and perceived).
    Injection of ≈ 165 MG from 1962-1966 triggered seismic activity; what would ECCV 1 to 4 MGD do?
  - Permitting challenges.
    Likely public (environmental advocacy group) opposition.
    Any induced seismic activity might force abandonment of system after capital investment.
  - Uncertainties over hydrogeology of Injection zone (transmissivity & water quality).
  - Oil wells could necessitate corrective actions.
Denver Area Injection Well Issues

- **Oil and Gas Well Options:**
  - Use existing, abandoned, and/or plugged oil and gas wells for disposal of waste concentrates.
  - Regulatory Issue: Would the USEPA allow an existing oil and gas well, constructed outside of the UIC program and to different standards, to be used for industrial waste disposal?
  - Regulatory Issue: Water quality in proposed injection zone and permitting implications (Class I vs. Class V).
  - Capacity issue: oil and gas wells are typically not designed for high capacities. There is a big difference between producing 100 barrels per day vs. injecting 1 MGD.

Conclusions

- Where the hydrogeology is favorable, deep injection well systems are a very attractive means of concentrate disposal, in terms of costs (capital and operational), environmental and aesthetic impacts, and space requirements.
- Requires some sophistication on the part of operators because of regulatory requirements.
- Risk element where there is no injection well experience and limited hydrogeological data – no guarantee system will meet performance expectations.