The long way home

Bringing slurry injection back to the US onshore market

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Slurry Injection: A Primer

Cuttings injection is standard practice

- Slurry injection is a standard practice for managing solid wastes in environmentally sensitive regions including offshore, tundra, marsh, and remote areas
- Injected waste would otherwise be discharged to ocean, left in reserve pits, or land-farmed
- Injection of slurry relies on hydraulic fracturing science to create subsurface voids in which solids are stored

Best practices are critical to success

- Proper feasibility studies, well construction, and zonal selection are all critical to achievement of waste disposal objectives

Safe operations require real-time monitoring

- Best practice uses well surveillance and control to continually monitor both surface pressure and subsurface fracture behavior to assure containment at all times







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Slurry Injection Benefits

- Disposal solution designed specifically to accommodate oilfield wastes (solids, liquids, TENORM, NORM) at a single location
- Provides an environmentally sound solution with proximity to oilfield activity
- Substantially reduces truck traffic by managing all phases of oilfield waste disposal at a single location operating 24/7
- Provides economical disposal for TENORM wastes without remote storage requirements, thereby reducing spill exposure
- Returns oilfield wastes to the geology from which they were generated and eliminates/minimizes potential exposure pathways that could negatively impact human health and the environment
- Eliminates disposal delays related to analytical processing times
- Avoids waste volume magnification needed to solidify oilfield wastes prior to disposal at traditional disposal facilities

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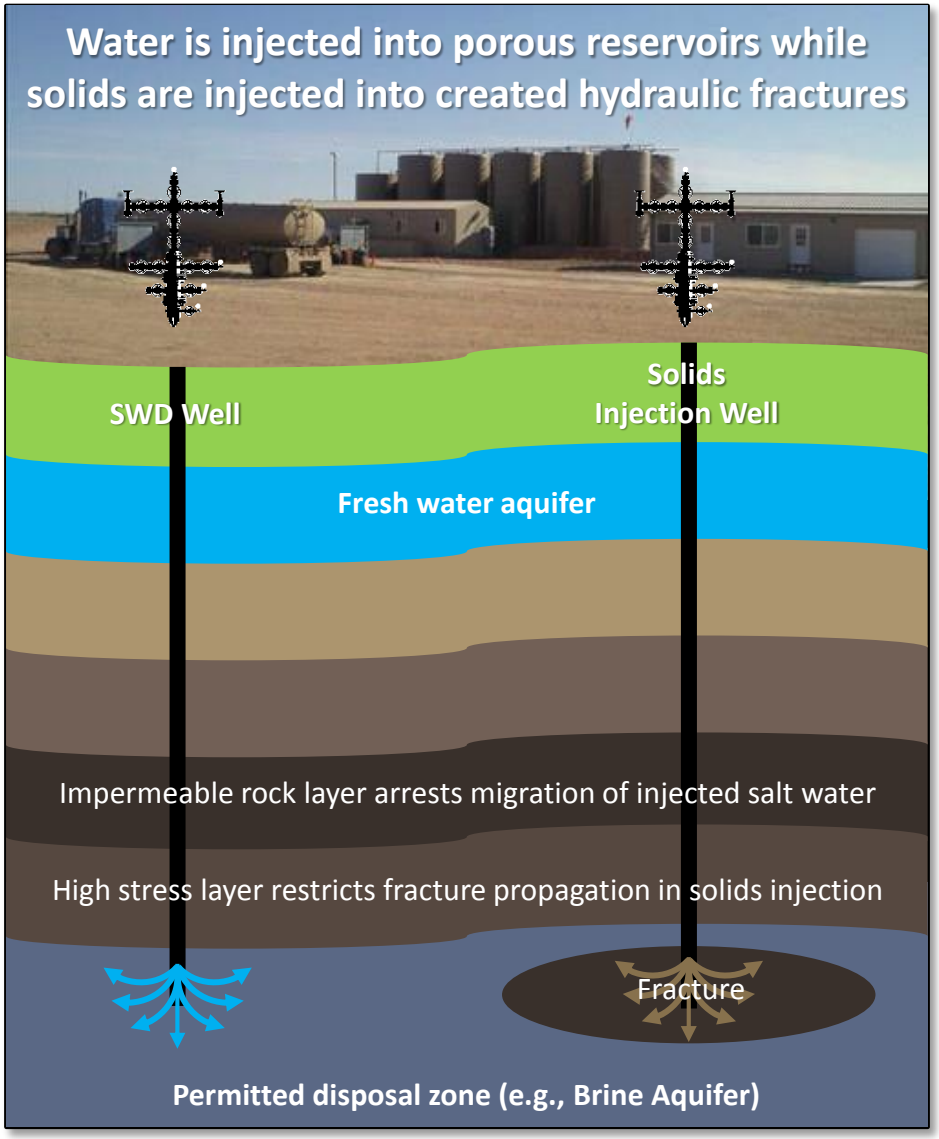
Technology Overview: Slurry vs Water Injection

Salt Water Disposal Wells:

- Typically inject water directly into the disposal zone's rock matrix
- Total capacity is determined by the volume of the disposal reservoir
- Disposal zones are selected based on isolation from freshwater sources

Slurry (Solids) Injection Wells:

- Inject solids by grinding them with water to create slurry and injecting the slurry into naturally occurring hydraulic fractures or those created during the injection process
- Capacity determined by the volume of the fractures accessed during injection
- Disposal zones are selected based on isolation from freshwater sources and stress barriers which prevent fracture propagation beyond the permit zone



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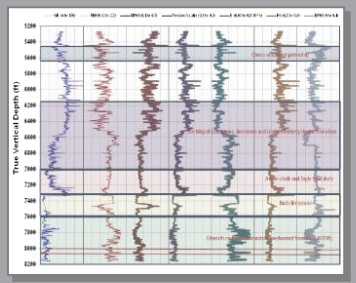
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Achieving best practice requires attention to three key activities



Feasibility, site selection, and permitting

Establishing that a target zone provides a safe operating window considering geological, geomechanical, and seismicity data requires sophisticated analysis.



Well logging, testing and process design review

Initial analysis using offset well data must be reviewed once the well has been drilled to target and the true formation properties tested.



Ongoing, real-time operational monitoring

Monitoring is crucial for the long term assurance of waste containment and well integrity, as well as the safe maximization of disposed volumes.

Successful operations must focus on all three areas

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Historical and Current Applications

Nuclear Waste (1960's-1987)

- Frist applied at Oak Ridge National Laboratory from the 1960's – 1987, low level radioactive water was used to make a cement which would set in the subsurface, binding the radioactive isotopes in place

Oil and Gas Wastes (1987-Present)

- First large scale project was in Alaska North Slope. Widespread adoption in offshore followed along with some major onshore facilites

BioSolids (~2009-Present)

- Recent Class V project in Los Angeles (biosolids)
- Obviates land-farming + long distance hauls and sequesters CO_2 and CH_4

Other Applicable Wastes

- Technique applicable for many other wastes (food, mining, petrochem, etc.)

From a 1998 EPA report: "The deep injection of waste [enabled by slurry injection] is the only disposal option that effectively removes waste from the biosphere."

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Deep Well Injection of Nuclear Wastes using Hydraulic Fractures



Oil Industry Helps Solve Radioactive Waste Problem

disposing of dangerous radioactive waste such as strontium 90 is shown in diagram. Waste originates at nuclear site (upper), is mixed with cement slurry (center) and is then pumped down a drilled hole (bottom) to fracture and enter an impermeable formation. Hallibburton engineer Mack Stogner, left reviews the project with Harry P. Conroy, senior vice president and general manager of the oil field service firm, and W. D. Owsley, senior vice president

A Halliburton engineer reviews Oak Ridge nuclear waste disposal project

USA

- Disposing of nuclear waste into fractures had been going on since 1960 using a cement slurry technique developed by Halliburton
- First applied at Oak Ridge National Laboratory
- Pre-1964, wastes pumped into shallow shale formations (500 ft); later, 1000 ft to 5000 ft
- The U.S. Government disposes of ~250,000 gallons of intermediate-level nuclear wastes each year through injection
- Injection into or under layers with near zero perm traps the radioactive wastes while radioactivity slowly decays over millions of years -- unless leakage into an overlying aquifer occurs

Russia

- Deep borehole injection of liquid radioactive waste was established since at least 1963
- The liquid is injected into sandy or other high porosity formations that are isolated by impermeable strata

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Slurry Injection in the Oilfield: From onshore to offshore and back again



1980's	1990'	2000's	2010's	Present
Onshore	Offshore	Offshore	Offshore	Both
Alaska	+ GoM, North Sea, California	+ Central Asia, Russia	+ West Africa, Latin America, MENA	+ US Shale, Onshore Africa
Arco, BP	Multi-nationals (e.g., BP, Statoil)	Super Majors, NOC's, Service Co's		Specialty Waste Management Co's
Fixed and Project based	Project Based	Project based	Fixed and Project Based	Fixed Facilities
Legal action forces Arco and BP to end practice of leaving drilling wastes in reserve pits at wellsites. Arco files a series of patents on Slurry Injection. Excavation and reinjection of 20+ years of wastes commences	JIP (Mounds Drill-Cuttings Injection Field Experiment) undertaken to validate the impact on fracture geometry on disposal capacity. Annular (small volume) injection used for offshore deepwater disposal	Cuttings injection promulgated across geographies into remote and harsh environments worldwide led by fluid service companies and specialty consulting firms	Cuttings injection and thermal desorption are now the standard methods for managing hydrocarbon contaminated drilling wastes in sensitive environments	Emergence of specialty waste management co's in US shale basins funded by private equity renews interest in cuttings injection due to inherent speed, cost, and scope advantages over other methods

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Slurry Injection: Worldwide Waste Management Practice (2003)

Location	Number of records in database
Alaska	136 (North Slope, 129; other 7)
Gulf of Mexico	66
California	18
Other U.S. onshore	28 (Louisiana, 20; Texas, 6; Oklahoma, 1; North Carolina, 1)
North Sea	35
Canada	9 (Alberta, 4; Saskatchewan, 3; Nova Scotia offshore, 2)
Latin America	4 (Argentina, 1, Mexico, 2, Venezuela, 1)
Asia	20 (India, 17; Indonesia, 1; Russia/Sakhalin, 1; Thailand, 1)
Africa	17 (Tunisia, 14; Egypt, 2; Chad, 1)
U.K. onshore	1
Total	334

- If Alaska is not counted, more than 50% injection jobs were done offshore; The areas with the most representation in the database are the GOM and North Sea (101 out of 198, 51%).
- Ten large multinational companies (Arco, BP, Chevron, ExxonMobil, Conoco, Marathon, Mobil, Phillips, Shell, and Unocal or their pre- or post-merger versions) account for 236 (70%) of the records. However, service companies were critical enablers of the technology deployment in many of these jobs
- Most of the injection jobs used annular injection (296, more than 88%), while 36 (11%) of jobs used dedicated injection wells with tubing and packer.

* Data summarized here is from Veil and Dusseault (2003)

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Thank You

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