Biosolids Disposal into Sedimentary Rocks

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**Biosolids Injection...**

- Slurried biosolids injected at depth (> 500 m)

- Anaerobic decomposition takes place...
  - $\text{CH}_4$ is generated – 12-15% of the mass
  - $\text{CO}_2$, $\text{H}_2\text{O}$ are additional “byproducts”
  - CO2 enters into solution in formation water
  - ...and, “elemental” carbon is sequestered (35%)

- Environmental risks are vanishingly low...

- Energy recycling is achieved ($\text{CH}_4$ recovery)

- Per year, up to 600 kg per person $\text{CO}_2$ eq

- ABSOLUTELY SECURE sequestration...
Waste Management Needs

- e.g.: India: Large population, growing
- Urbanization taking place quickly
- Development rate is high (up to 10%)

Water contamination and health problems from wastes...
How can we handle the wastes?
Areas Highly Ranked for Deep Waste Injection

Igneous rocks are not suitable
Biosolids Disposal Methodology...

- A slurry of granular biosolids and waste water is injected at depth
- Injection is by continuous hydraulic fracturing, \( p_{\text{inj}} \sim 1.2 \cdot \sigma_v \) to \( 1.3 \cdot \sigma_v \)
- Filtration of solids, water dissipates
- \([\Delta \sigma], \Delta(k, C_c)\) take place
- The reservoir “evolves” with injection
- Uplift occurs \( (\Delta V)\), etc.
- Decomposition, etc...
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Regional low-k stratum
Cemented steel casing
High-k saline DSI zone

Perforations
Packers, p-gauges

Surface casing protecting groundwater

Slurry injection into secure tubing

Data

Packer

High-k saline DSI zone

Low-k stratum

High-k zones for leak-off

400-3,000 m
Sand Field Case - Alberta - 1996

Produced Solids (oily contaminated sand)

Flowline to SFI well

Containment system (Cement pit)

SDU system
Oilfield Zero Discharge Injection

Oil Industry Solids Injection Facility

- SFI Well
- Water tank
- OVF tanks
- Pumping Unit
- Pit Material Storage
- Facility Entrance
Biosolids Injection
World’s first biosolids injection on a trial basis, Los Angeles, Aug 2008
Los Angeles O&G Fields

Sewage treatment sites

Injection began Jul-Aug 2008
The World’s First Biosolids Injection Site – Los Angeles

August 2008
Biosolids Injection Benefits...

- Risk reduction (no transport, etc...)
- GW protection (great injection depth)
- Soil protection from viruses, prions, chemicals, metals in the sludges...
- CH$_4$ generation at depth (14% of dry mass) for energy recovery
- C sequestration ($\approx$40% of dry mass) in a zero-risk solid form is achieved at 0 incremental $\$
- Less surface treatment, less transport...
Ganga R.

Cross-Section Across the Ganga Basin
Ganga Basin Hydrogeology

- Hydrogeological conditions seem ideal...

**Ganga Basin**

- **Deccan Plateau**
- **Nepal, Himalaya**
- **SSW**
- **NNE**

**Ganga River Plain**

- **Basement rocks** (Indian Shield)
- **Deep formation water flow paths**
- **Miocene and younger sediments**
Also... Coastal Cities in India

- Many coastal cities sit on sedimentary wedges with subsea groundwater discharge
- Chennai, Kolkata, Mangalore, Mumbai, Calicut are some examples
- In these cases, regional groundwater flow is down, out to the sea, with subsea discharge
- The hydrogeological security in such cases is tremendous
Mumbai General Groundwater Flow

West

Discharge subsea

High porosity sandstones

5000-10,000 year flow time

not to scale

East

Recharge area, high precipitation

Mumbai urban area

Deep slurry injection

Sediment wedge

shales
Some Conclusions and Comments

- We understand deep solids injection fairly well
- We can monitor it very well (displacements, pressures, stresses...)
- We understand site geological engineering
- Analysis tools for the actual biosolids injection process remain in need of improvement
- The important factors are a vast reduction of risk, improved surface conditions, and so on
- A geomechanics development has led to a novel waste disposal method
Environmental Rock Mechanics

NOT NOW!
CAN'T YOU SEE I'M TOO BUSY TO LOOK AT NEW TECHNOLOGY!