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May 1, 2007
Albuquerque, NM
2007 Ground Water Summit
National Ground Water Association
What is the Problem?

- Population growth in Texas and other southwestern states
- Need for development of alternative sources of water at low cost
- Disposal of concentrate is a barrier to implementation of inland desalination facilities
- Evaporation ponds are very cost-effective in Texas and other southwestern states for small communities (<1 MGD)
- Self-sealing ponds could be even more cost-effective
What is a Self-Sealing Pond?

• A pond where cracks, holes, and other defects of the clay/geomembrane liner would heal quickly with no local intervention of operator.

• Physics/chemistry of the system is so that either material identical to the liner will grow (clay liner case – not common) or precipitant will use clay/geomembrane liner as physical support only.

• Challenge is to make it cheaper than the simple, robust existing technology.
Presentation Outline

• What are the current regulatory requirements (Texas) and is there any barrier to the implementation of SSEP?
• Understanding favorable conditions for precipitating self-sealing compound(s)
• Perform a high-level cost/saving analysis
What is the Current Legislation? (1)

• Solely under State regulations
• Liquid wastes are either municipal or industrial
• Desalination concentrate is an industrial waste
• Could follow the prescriptive rules of municipal waste water:
  – 3-ft thick in-situ or constructed (compacted) clay liner with $K<10^{-7}$ cm/s
  – >30-mil geomembrane with leak monitoring or GW monitoring system
What is the Current Legislation? (2)

• Or could follow alternative liner options
• A waiver from prescriptive rules is possible when:
  – Shallow aquifer water quality will not be degraded by leaking pond (discharged water WQ > aquifer WQ)
  – Any containment system that would be equivalent to prescriptive rule containment
  – Monitoring of the ground water beneath the EP
Current Legislation- Conclusions

- Regulatory conclusions are clear: there is no regulatory obstacle to overcome to implement SSEP
- “Alternative liner” option is broad enough to include SS approach, however burden of proof is on the applicant
- Very similar requirements in neighboring states
- No reference to SSEP in any regulation
Desalination Facilities in Texas
(\geq 0.025 \text{ MGD as of 2005})
Disposal Methods

Disposal Method
- Evaporation Pond
- Land Application
- Surface Water Body
- Municipal Sewer

Disposal Methods

[Map of Texas showing disposal methods with different icons for each method]
A Few Examples across the State

- River Oaks Ranch (Hays Cty) – 0.14 MGD
- City of Brady (McCulloch Cty) – 1.5 MGD
- City of Abilene (Taylor Cty) – 8 MGD
- Horizon Regional MUD (El Paso Cty) – 2.2 MGD
River Oaks Ranch

GEOMEMBRANE + LEAK DETECTION SYSTEM
City of Brady

NO CLAY LINER
IN-SITU SILT + LOWER WQ
City of Abilene

IN-SITU CLAY LINER
Horizon Regional MUD

CONSTRUCTED CLAY LINER:
LOCAL CLAY + BENTONITE
Mineral Precipitation

• Common minerals in sampled evaporation ponds and saline lakes:
  – Calcite, gypsum/anhydrite, rare clays minerals
  – Dust (clay/silt size) and mostly detrital minerals (quartz and clays)

• Sepiolite has been observed in saline lakes and is a good candidate for self-sealing properties:
  – Clay-like mineral with no volume change characteristics
  – Relatively easy to generate from ions in aqueous solution
Net Annual Evaporation Rates
(low salinity water body)
Concentrate Composition

• To determine amount and nature of precipitant, need to know feedwater composition
• All samples from TWDB database with TDS>1,000ppm and <5,000ppm were sorted in 19 groups
• 20th group is surface water from TCEQ
• Concentrate ~4x feedwater ion concentration
Net average annual evaporation rates for the 20 sampling groups (90% of gross lake ER)
Groundwater Samples

- Approximately 13,000 brackish water samples with chemical analysis of sufficient quality to do geochemical modeling.
Surface Water Samples

- 49 stations with at least one complete sample > 1,000 ppm
- 496 samples
Surface Water Group

TDS (ppm)

- 1,000 - 2,000
- 2,000 - 3,000
- 3,000 - 4,000
- 4,000 - 5,000
- >5,000

Miles

Surface Water Group
Piper Plots

- Mixed Alluvium Group
- Brazos River Alluvium Group
- Rio Grande Alluvium Group
- Seymour Group
- Bolson Group
- Ogallala Group
- Pecos Valley Aquifer Group
- Gulf Coast Sandstone Group
- Eocene Group
- Cretaceous Limestone Group
- Cretaceous Sandstone Group
- Triassic Sandstone Group
- Permian Evaporite Group
- Permian Limestone Group
- Permian Sandstone Group
- Bone Spring – Victoria Peak
- Capitan Reef Group
- Pennsylvanian Group
- Llano Uplift Group
- Surface Water Group
Geochemical Simulations

- Need to know nature and amount of precipitant minerals
- USGS code PHREEQC with Pitzer database
- Runs simulate evaporation pond with balanced steady input and evaporation (i.e., salinity increases through time)
- pH maintained at 8.5 – Temperature at 25°C
- Sepiolite is a Mg mineral – need to manage precipitation of other Mg minerals
- Al for clay precipitation controlled by diaspore (AlOOH)
- Addition of 0.01mol/L of sepiolite precursor (2Mg:3Si)
- Outfall only or outfall + Na metasilicate ($\text{Na}_2\text{SiO}_3$ hydrated or not) + MgCl$_2$
Examples of Runs (1)

Rio Grande Alluvium

Evaporation Progress

Accumulation (mol/L)

Non-engineered conditions

Capitan Reef

Evaporation Progress

Accumulation (mol/L)
Examples of Runs (2)

Rio Grande Alluvium

Non-engineered conditions

Capitan Reef
Examples of Runs (3)

Rio Grande Alluvium

Engineered conditions

Capitan Reef
Examples of Runs (4)

Rio Grande Alluvium

Comparison engineered / non-eng. conditions

Capitan Reef
Results of Geochemical Runs

Mineral Accumulation at 5 years (inch)

- Natural system
- Engineered system

Mixed All.
BZ All.
RG. Alluvium
Seymour
Bolson
Ogalala
Pecos Val.
GC. San
Eocene
Cret. Lim.
Cret. San
Trias.
Perm. Ev.
Perm. Lim.
Perm. San.
BS-VP
Capitan
Penn.
Llano
SW
Conclusions on Geochemical Runs

• Precipitation includes calcite, gypsum, a soluble Mg carbonate, clay mineral – typically
• Total amount precipitated is small (~1 inch or less)
• Engineer significant precipitation with additives could come at a prohibitive cost (>\$1/1,000 gal)
Containment Equivalence (1)

- Flow properties of precipitant to meet prescriptive rules: leakage rate should be no greater than prescriptive rate.
- Equivalence to clay liner:

\[ Q = K \frac{h + t}{t} \]
Containment Equivalence (2)

- Equivalence to geomembrane liner: leakage through defects

- Q much smaller than with defects and smaller than with clay liner (3 1-cm holes / acre)
Cost Analysis

• Capital Costs:
  – Cost for clay liner or geomembrane liner and leak detection system ~equivalent (~54k/acre)
  – Reduction of 17% if 20-mil geomembrane liner (more defects but better plugging by precipitant)
  – Reduction of 30% if 2-ft clay liner (+precipitant)
  – Reduction of 60% if 30-mil geomembrane with NO leak detection system
  – Reduction of 90% if simple excavation with equivalent containment

• Operating Costs:
  – Sepiolite precursors cheap but not cheap enough
Conclusions (1/3)

• There is no significant regulatory barriers, no changes need to be made to regs

• Prescriptive liners:
  – “Hole in the ground” – 3 ft with $K < 10^{-7}$ cm/s
  – Constructed clay liner – 3 ft with $K < 10^{-7}$ cm/s
  – Geomembrane with leak detection system

• TCEQ has the authority to approve alternative approaches (if well supported by data):
  – Over lower quality aquifer
  – Containment equivalence
  – Groundwater monitoring
Conclusions (2/3)

• Geochemical modeling:
  – Main minerals to precipitate are calcite and gypsum with some Mg mineral
  – System can be engineered to precipitate sepiolite

• Total sediment accumulation is too small to substitute for a clay liner
  – [Accumulation conductivity is not low enough to meet containment equivalence requirements]

• SSEP could help in eliminating the requirement for a leak detection system when a geomembrane is used:
  – Precipitant even with $K > 10^{-7} \text{ cm/s}$ could efficiently plug holes
Conclusions (3/3)

• High-level cost analysis suggests that self-sealing properties of the precipitant could significantly decrease capital cost.

• Operating costs are problematic if additives are needed. EP use a very simple technology, hard to overcome cost-wise.

• SSEP could bring an additional layer of safety to ponds located in environmentally sensitive areas.
QUESTIONS?