Addressing Impacts of Produced Water

- Effects on Soils, Plants, and Water
- Rules of Thumb: Potential for Impacts
- Soils: Remedy Selection and Implementation
- Groundwater: Simple Modeling Tool
- Site Investigation Guidelines
Addressing Impacts of Produced Water

Background on API Publication 4758

**GOAL**
Provide concise technical guidelines based on prior publications.

**SCOPE**
1) Will produced water release cause unacceptable impact?
2) Appropriate and effective response actions?

**WHERE**
www.api.org/produced_water

API 4758: “Strategies for Addressing Salt Impacts of Produced Water Releases to Plants, Soil, and Groundwater”
How: High TDS in soil pore water prevents osmotic uptake, causing desiccation. Most sensitive at germination stage.

What: Bare soils, stunted growth, deep blue-green foliage (not yellow), tip burn and cupping.

Source: API Publication 4663; from Donahue et al., 1983. Photo used with permission of www.laspilitas.com. TDS = Total Dissolved Solids
Salt Impacts to Plants: East Texas Site, 2001

Releases at PW Injection Facility

Timber loss over 5-acres; growth of salt tolerant brush (*willow baccharis*)

PW = Produced water
Salt Impacts to Soils

**Clay Soil Dispersion**

- **How:**
  - Sodium in PW exchanges with K, Ca, Mg in clay minerals.

- **What:**
  - Loss of soil cohesion
  - Loss of permeability, drainage
  - Increased erosion

- **When:**
  - Affected soil ESP > 15%

Source: API Publication 4663. ESP = Exchangeable Sodium Percentage. PW = Produced Water
High-sodium brine spill to lake causing dispersal and erosion of clay soils in dam.
Salt Impacts to Plants: Former Brine Pit

Former brine pit with vegetation loss and surface erosion.
Salt loading can impair beneficial use of surface water or groundwater.

<table>
<thead>
<tr>
<th>Use</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drinking Water:</td>
<td>Secondary MCLs for TDS (500 mg/L) and chloride (250 mg/L).</td>
</tr>
<tr>
<td>Aquatic Life:</td>
<td>USEPA acute (860 mg/L) and chronic (230 mg/L) criteria for Cl. State criteria for TDS: 250 - 2500 mg/L.</td>
</tr>
<tr>
<td>Irrigation:</td>
<td>Salinity hazards above ~1,500 mg/L TDS.</td>
</tr>
<tr>
<td>Livestock:</td>
<td>Useable with TDS up to 3,200 mg/L, with some effects.</td>
</tr>
</tbody>
</table>

SOURCE: API Publication 4663. CI = Chloride TDS = Total Dissolved Solids
( In-situ photo of affected groundwater )
**Rules of Thumb:**

**Will Soil be Impacted by PW Release?**

<table>
<thead>
<tr>
<th><strong>Nope</strong></th>
<th><strong>Yep</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>ESP &lt; 5%</td>
<td>ESP &gt; 22%</td>
</tr>
<tr>
<td>EC &lt; 4 mmhos/cm</td>
<td>EC &gt; 16 mmhos/cm</td>
</tr>
</tbody>
</table>

**Affected Soil Contains:**

- ESP < 5%
- EC < 4 mmhos/cm
- ESP > 22%
- EC > 16 mmhos/cm

**KEY POINT:**

For soil conditions between these extremes, must consider climate, drainage, vegetation, etc.

ESP = Exchangeable Sodium Percentage;    EC = Electrical Conductivity (saturated paste)
**Rules of Thumb:**
*Will Groundwater be Impacted by PW Release?*

<table>
<thead>
<tr>
<th>SPILL SITE CONDITIONS:</th>
<th>LESS LIKELY</th>
<th>MORE LIKELY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Release Volume</td>
<td>&lt; 100 bbls</td>
<td>&gt; 100 bbls</td>
</tr>
<tr>
<td>Chloride Content</td>
<td>&lt; 100,000 mg/L</td>
<td>&gt;100,000 mg/L</td>
</tr>
<tr>
<td>Depth to GW</td>
<td>&gt; 10 ft</td>
<td>&lt; 10 ft</td>
</tr>
<tr>
<td>Soil Type</td>
<td>clayey</td>
<td>sandy</td>
</tr>
<tr>
<td>Spill Area (volume/area)</td>
<td>&lt; 0.15 bbl/sq ft</td>
<td></td>
</tr>
</tbody>
</table>

**KEY POINT:**
Most important variables for predicting groundwater impact = chloride mass, climate, soil type, depth to GW, aquifer thickness and flow.

Soil Remediation Options: *Will They Work?*

**NATURAL RESTORATION**

Okay If …
- Soil EC < 16 mmhos/cm
- Soil fertile
- PEI > 4 in/yr
- Adequate drainage
- Halophytes will grow
- Active remedy could increase damage

If not, try **IN-SITU CHEMICAL AMENDMENT**

Okay If …
- Soils will leach salt naturally or leaching can be enhanced
- Erosion can be controlled

If not, try **MECHANICAL REMEDIATION**

- No technical restrictions, except collateral effects

SEE Decision Chart in API 4758

**KEY POINT:** If need rapid remedy, use chemical amendment or mechanical remediation.

Source: Adapted from API Publication 4663. PEI = Precipitation Evaporation Index
Soil Remediation: Natural Restoration

**Concept:** Use plants and natural water flushing to restore salt-impacted soil.

**Option A:** Monitor natural revegetation process for 1 to 3 years.
- **Mulch:** 2 to 4 inches
- **Fertilizer:** 28 lb per 1,000 sq ft of 13-13-13
- **Watering:** *Don’t water clay soils!*

**Option B:** Plant halophytic vegetation to restore affected area.

**Rules of Thumb:**
- **Mulch:** 2 to 4 inches
- **Fertilizer:** 28 lb per 1,000 sq ft of 13-13-13
- **Watering:** *Don’t water clay soils!*

Source: API Publication 4663. Photo courtesy of David Carty, Greenbridge Earthworks.
Soil Remediation: Natural Restoration

Source: Photos courtesy of David Carty, Greenbridge Earthworks.
Salt Remediation: *In-Situ Chemical Amendment*

**Concept:** Add calcium to replace sodium and restore clay soil structure.

- **Drainage:** Improve as needed to leach Na.
- **Gypsum:** 13 lb/100 sq ft (or calculate per ESP, CEC, Na).
- **Mix:** Focus = upper 2 ft of soil. Add fertilizer and mulch if needed.
- **Irrigation:** Pulse flooding can reduce water requirements 50%. Perimeter berms improve infiltration.

Source: API Publication 4663. Photo courtesy of David Carty, Greenbridge Earthworks.
API 4758: Addressing Impacts of Produced Water

Soil Remediation: *Chemical Amendment*

Source: Photos courtesy of David Carty, Greenbridge Earthworks.
Soil Remediation: Mechanical Remediation

**Concept:** Optional methods for mixing, spreading, or relocating salt-impacted soil.

- **Land-spreading:** Mix affected soil with unaffected soil to reduce soil EC.
- **Burial:** Construct burial vault with capillary barrier; and gypsum, clay cover, and topsoil layers atop affected soil.
- **Road spreading**
- **Other:** Soil washing; landfill disposal.

**BURIAL VAULT**

SOURCE: API Publication 4663. Photo courtesy of David Carty, Greenbridge Earthworks.
**API 4758: Addressing Impacts of Produced Water**

**Evaluating Groundwater Impacts: Simple Modeling Tool**

**KEY POINT:** All calcs based on simple nomographs ...no computer.

**Step 1:** Mass of chloride to soil

**Step 2:** Chloride infiltration to GW

**Step 3:** Chloride conc. in GW

**Step 4:** Chloride plume migration

API guide provides planning model to predict chloride impacts on GW
**Site Investigation: Data Needs**

- **Soil Tests:**
  - EC, ESP (or SAR), CEC, Na, cleanup goal.
- **Soil Properties:**
  - Hydr. cond., shrink-swell pot’l, slope, depth to GW, soil type (0-3 ft), unsat zone soil type.
- **Prod. Water:**
  - Vol. and area of release Na, TDS, Cl levels.
- **Climate:**
  - Annual rainfall, evaporation.
- **GW Data:**
  - Source width, GW velocity, aquifer thickness, nearest well, cleanup goal.

**Key Data Needs for Evaluation of Soil & GW Impacts**

**KEY POINT:**

API 4758 provides simple guidelines on data collection and field and lab analyses.

EC = Electrical Conductance (soil paste); ESP = Exchangeable Sodium Percentage; SAR = Sodium Absorption Ratio; CEC = Cation; Exchange Capacity; Na = Sodium; TDS = Total Dissolved Solids; GW = Groundwater.
API 4758: Addressing Impacts of Produced Water

Where to Learn More

API 4758

Download free or buy fancy printed version.

www.api.org/produced_water