Water Quality Issues: Coal Bed Methane Development

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CBM Water Quality

- **Primary Water Quality Concerns**
  - **pH**
  - **Electrical Conductivity**
  - **SAR (Sodium Absorption Ratio)**
- **Impacts on:**
  - **Infiltration**
  - **Hydraulic conductivity**
    (soil and vegetation characteristics)

Definitions

- Infiltration: process by which water enters the soil surface
- Infiltration capacity: maximum rate at which water can enter the soil
- Soil Hydraulic Conductivity: movement of water through soil (saturated and unsaturated flow)
- Soil Water: water held in soil pores
  - Plant available water

Infiltration Capacity

Influenced by:

- Soil texture (pore size):
  - R = pore radius
  - Δp = pressure drop
  - η = viscosity

$$Q = \frac{\pi R^4 \Delta p}{8 \eta L}$$

- Rainfall or application rate
- Soil moisture content/matric potential

Very high spatial variability

Water Movement Through Soils

- Downward flow governed by most restrictive layer in the profile
- Redistribution within the profile:
  - Uptake by plants
  - Evaporation
- Continually redistributing
- High spatial variability

Salinity

- High concentration of dissolved salts, or Total Dissolved Solids (TDS)
- Salinity of water is referred to in terms of Total Dissolved Solids (TDS) or Electrical Conductivity (EC)
- Water with EC > 3.0 dS/m considered saline (USDA)
  - 3.0 dS/m = 3,000 umhos/cm
- Harmful to plants: alters the osmotic gradient

Salinity rules of thumb:

- Traditional thinking . . . The saltier the soil is, the wetter the soil must be kept to offset the salt effect on plants
  - minimize matric force to reduce combined effect of matric and osmotic stress
- Soil solution salinity will equilibrate at an EC value approximately 2-3 times the EC of the applied water
- Significant impacts of "salt" sensitive plants

Salt & Water Distribution

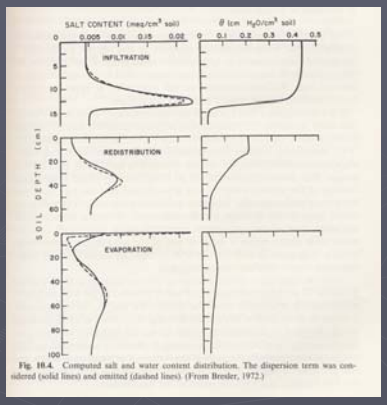


Fig. 10.4. Computed salt and water content distribution. The dispersion term was considered (solid lines) and omitted (dashed lines). (From Bresler, 1972.)

From: Hillel, D., Fundamentals of Soil Physics

Sodicity

- Caused by sodium salts: $NaHCO_3$, NaCl, $NaSO_4$, etc.
- Risky on soils having significant amounts of swelling clay:
  - changes soil physical properties: poor drainage, reduced infiltration, soil crusting
- Generally no crusting or poor drainage on sandy soils, but saline-sodic may affect crop growth and yield
- The sodicity of water is expressed as the Sodium Adsorption Ratio (SAR):

$$SAR = \mathrm{Na}/\sqrt{(\mathrm{Ca}+\mathrm{Mg})/2}$$ Meq/L

Why SAR Matters

- SAR 13 = Sodic Soil
- Calcium holds soil particles together, ensuring stability, root penetration, water infiltration and aeration.
- Poorly structured, dispersive, "sodic" soils contain high levels of exchangeable Sodium where there should be Calcium.

Sodic Soil

Photo: Courtesy Jim Bauder

Why SAR Matters

Decrease in Infiltration

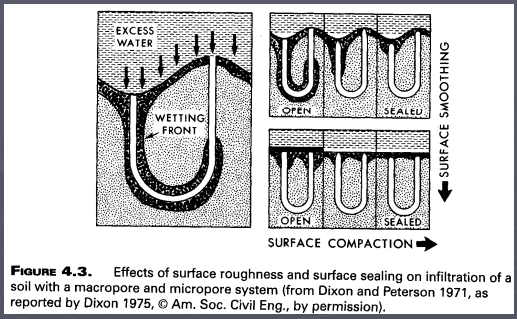
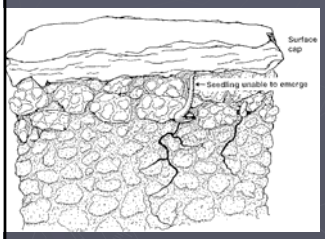


FIGURE 4.3. Effects of surface roughness and surface sealing on infiltration of a soil with a macropore and micropore system (from Dixon and Peterson 1971, as reported by Dixon 1975, © Am. Soc. Civil Eng., by permission).

Why SAR Matters

poor infiltration and root penetration.



Courtesy: www.biofarmag.com.au

CBM Water Quality

- Decrease of solution Ca^{2+} through precipitation process in disposal ponds - increases SAR (McBeth et al., 2003; Patz et al., 2004 and 2006; Jackson and Reddy, 2007)
- Increase in pH of produced water subsequently increases the availability and transport of trace elements (e.g., arsenic and selenium) in semi-arid ecosystems (McBeth et al., 2003; Reddy et al., 2005; Jackson and Reddy 2007; Milligan and Reddy, 2008)

Risks Associated with CBM water disposal

- Unmanaged system
- Lots of water
- Do not specifically control EC and SAR – only set upper limits
- Tier 1
  - EC limits are set based on most "sensitive" plant
  - SAR capped at 10

Issues with Tier 2

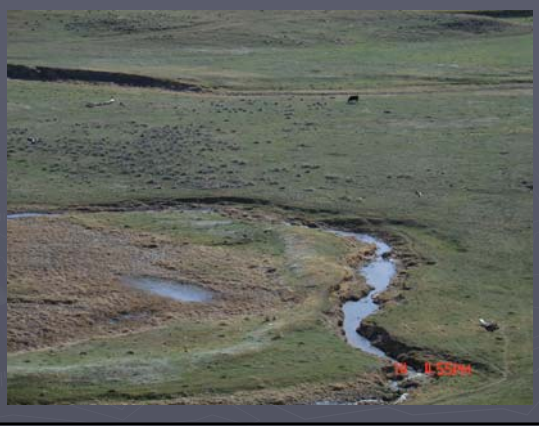
- Unmanaged system
- SAR ***is not*** capped at 10
- Concept:
  Set EC and SAR standards based on background water quality.

Issues with Tier 2

- Reality:
  - ***Very Difficult*** to determine background water quality in ephemeral drainages
  - ***Can not*** determine background water quality from measuring soil EC and SAR
    - Developed under "natural" rainfall and water movement through soils
    - Soil EC and SAR vary throughout soil profile (and over time)

High spatial variability of soil characteristics & hydrologic processes

Impacts on Ephemeral Drainages



Salt Build-up & Slumping

Slumping

Photo: Dr. Harold Stepphuhn, Agriculture and Agri-Food Canada
From the cover of: Daniel Hillel, 2000 Salinity Management for Sustainable Irrigation