Sublette™ CONSULTING, INC.

BASIC GUIDELINES FOR REMEDIATION OF BRINE SPILLS

First response to a brine spill

Routine inspections and preventative maintenance can help avoid equipment failures or line breaks. When a release occurs, first assess the situation. Always approach cautiously and resist the urge to rush in. Identify risks based your experience, observations, and senses. Isolate the source and stop the release; contain any fluids; and recover fluids for proper disposal. Once you've done that you can begin to work on restoring the soil conditions needed for revegetation. Start remediation as soon as possible and you'll save money.

Spills of produced water or brine on soil result in two types of damage

Start remediation of a brine spill as soon as possible to reduce costs!

- Excess salinity
  - ✓ Creates an osmotic imbalance that reduces water uptake by plant roots. Plants can go into drought stress even though there is plenty of water in the soil.
- Excess sodicity (an excess of sodium)
  - ✓ Destroys soil structure by dispersing clays
  - ✓ Produces a hardpan that will not transmit water
  - ✓ Enhances erosion
- Both salinity and sodicity must be addressed in any successful remediation of a brine impacted site

Soil analysis is necessary for successful remediation

When remediating a brine spill, it will be necessary to take soil samples and analyze them for salt content. Why? You need 1) to see how well you are doing overall and, 2) to identify hot spots that may need extra treatment. How should the samples be analyzed?

- The salt concentration or salinity in the soil is measured in terms of the chloride concentration or electrical conductivity (EC) of a soil extract. A field kit can be used to measure chlorides and a portable conductivity meter can be used to measure EC of a soil extract (usually one part soil and one part distilled water by weight)
- The sodicity of the soil is measured in terms of the sodium adsorption ratio (SAR). Send your soil samples to an agricultural extension lab for SAR analysis.

Soil sampling recommendations

The salt content of soil impacted by a brine or produced water spill is highly variable over the area of the spill and with depth. Mixing of the soil by tilling helps but no practical amount of tilling will evenly distribute the salt. This variability will exist throughout an entire remediation process. We have to keep this fact in mind when we take a soil sample for salt analysis.

Whenever we analyze brine-impacted soil for salt content, the sampling method is dependent on what you want to know.

- Grab sample – soil sample from a single spot in the impacted site
  - ✓ Analysis of this sample tells you only the characteristics of that sample point
  - ✓ Usually used to determine the distribution of a contaminant over a site or for screening
- Composite sample – composed of a mixture of equal volumes of grab samples from several individual spots in the impacted site
  - ✓ Analysis of this sample can tell you the average concentration of the salt over the area sampled
  - ✓ Statistically 20 grab sample per composite gives the best results
  - ✓ Sample from three depth intervals, 0-6 inches, 6-12 inches, and 12-24 inches; mix grab samples from like depths to form composites
  - ✓ Composite sampling reduces analytical costs
  - ✓ Sample only when the soil is relatively dry. Clumps should be easily broken and the soil easy mix.

Sampling recommendations:

- Make a sketch of the site
- Note easily recognizable features:
  - ✓ Clearly different soil types
  - ✓ Different slopes
  - ✓ Very rocky conditions
- Establish a permanent reference point for measurements and add dimensions to your sketch
- Take photos of the site which include your reference point
- Each different section of the spill site you noted on your sketch will likely respond differently to remediation efforts and should probably be sampled separately each time the site is sampled.

Brine/Produced Water Spills

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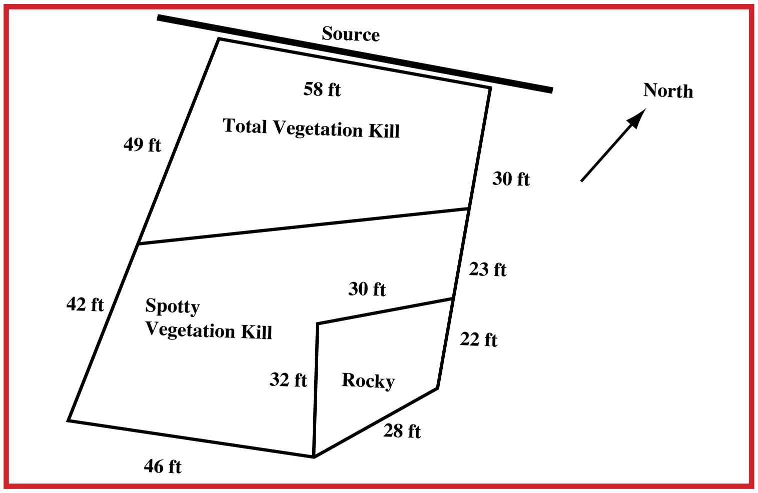
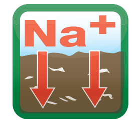
Brine/Produced Water Spills



Basic principles in the remediation of brine spills



- ➢ Salt concentrations in the plant root zone must be reduced to acceptable levels in the long term to allow growth of desired plants
  - ✓ It's easy to flush salts from soil in the short term – the challenge is in making sure it doesn't come back!
- ➢ Soluble salts are transported by water
  - ✓ Therefore, remediation requires contact of water with salt and drainage to convey salt away from the root zone
  - ✓ Both the quantity and quality (EC and SAR) of irrigation water are important to the outcome of any remediation effort
- ➢ The rate of movement of water through the soil and, therefore, the rate at which salts can be carried out of the root zone is determined by the permeability of the soil
  - ✓ Permeability must be addressed in the short term and the long term
    - ■ In the short term we must mechanically open the soil and prop it open with bulking agents to maintain a porous structure to allow the transport of water
    - ■ In the long term we must rebuild soil structure by generating the natural glue that holds soil particles together and reverse sodicity.
- ➢ The concentration of soluble salts in the soil solution is increased as water is removed by evaporation
  - ✓ Drying of surface soil by evaporation creates a suction gradient (capillary suction) that produces upward movement of salt and water.
  - ✓ The finer is the soil texture (higher silt and clay content) the farther salt can be transported vertically upward.
- ➢ All soluble salts are affected by leaching
  - ✓ Leaching to remove produced water salts also removes beneficial nutrients (particularly nitrogen) – this can affect revegetation
- ➢ Once salinity and sodicity damages have been alleviated revegetation is required to prevent erosion and restore productivity
  - ✓ Successful revegetation is dependent on: preparation of a proper seedbed, choosing the right plants (seeds) for the climate, addressing any nutrient deficiencies in the soil, and maintaining proper moisture conditions while new plants get established – see Sublette Consulting, Inc. guidelines for revegetation

Basic elements in the remediation of brine spills

- ➢ Water (irrigation and/or rainfall)
  - ✓ How much water will be required?
    - ■ Rule of thumb: A unit depth of irrigation water or rainfall will remove about 80% of the salts from a unit depth of impacted soil
      - ○ For example, 24 inches of water will remove about 80% of the salts from a 24 inch thick layer of contaminated soil
- ➢ Minimizing runoff and maximizing infiltration – making the most of the water we have!
  - ✓ Avoid watering under conditions which produce high rates of evaporation (sunny and hot, low humidity, windy).
  - ✓ A surface cover of organic mulch reduces runoff and evaporation.
  - ✓ Pulsed irrigation works better than soaking.
- ➢ Swelling clays?
  - ✓ Certain clays swell in contact with fresh water like rainfall or irrigation water. When clays swell they can effectively seal the soil surface and prevent water infiltration which is required for remediation of a brine spill. Prevent clay swelling with the surface application of InfiltratioNhance™.

InfiltratioNhance™ Hydrocarbon or Brine Remediation in Clay Soils

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- **Drainage, drainage, drainage: Any attempt to leach salt without adequate drainage is not only doomed to failure but will actually make things worse! Throughout the remediation process you must have good drainage from the site. The salt has to have somewhere to go!**
  - ✓ Where can the salt go? What are the options?
    - Vertical drainage
      - Is there an impermeable layer in the soil that will prevent vertical drainage?
        - If yes, can it be penetrated by soil profile modification (ripping)?
      - Will it go deep enough? Will it impact groundwater? How deep is deep enough?
        - Rule of thumb: Salt must be pushed down at least 6 ft to prevent capillary suction from drawing the salt back up into the root zone
  - ✓ Lateral drainage, taking advantage of natural drainage patterns
    - When using natural drainage patterns "dilution is the solution to brine pollution".
    - The objective with this approach is to cause salts to leach from the impacted site slowly enough and over a long enough period of time that salt concentrations in down slope receptors (pristine soils, surface waters, groundwater) are never high enough to create environmental problems (vegetation stress, measurable effects on aquatic life, degradation of drinking water quality, etc.)
    - Will lateral drainage cause additional damage? There must be a commitment to monitor down slope!
      - Soil profile from the surface to any impermeable layer
      - Surface water
      - Signs of vegetation stress
    - Retain rainwater on your site as much as possible. Use soil berms to control water retention.
    - Insufficient natural drainage ? Use a tile drainage system
- Leaching of salts and restoring soil structure – getting the salt to move and keeping it moving
  - ✓ Increase the permeability of the soil to water with mechanical loosening of the soil: tilling, ripping
  - ✓ Add soil amendments (hay and fertilizer) to prop open the soil
    - Biodegradation of hay improves soil structure by enhancing aggregate formation which in turn improvessoil permeability
    - Cultivate in about five 50-lb bales of hay per 1000 ft^2
    - Repeat as necessary to maintain good soil structure
    - A top dressing of hay can help protect the soil surface from dispersing during a rainfall or watering event
    - Add fertilizer like 13-13-13 along with the hay or other organic matter, about 20 lbs per 1000 ft^2

Hint: Think about hiring the landowner to do this work!

- Restoring the proper exchangeable cation status (reducing sodicity)
  - ✓ Reductions in sodicity and restoration of soil structure require soluble calcium ion (Ca^{+2})
    - Most common sources are gypsum (calcium sulfate) and limestone (calcium carbonate)
      - The problem with gypsum
        - It takes lots of water to produce soluble calcium ion from gypsum
        - The low solubility of gypsum results in gypsum being effective only within the depth it is incorperated in the soil
        - Elevated concentrations of gypsum in soil have been shown to increase the leaching and loss of essential plant nutrients.
    - Limestone may already be present in the soil in sufficient amounts to fight sodicity but it must chemically react with a mild acid to liberate the calcium ion. An example of an ecologically acceptable mild acid is Ca^{++}Nhance™ (application rate 50 lb/1250 ft^2)

Ca^{++}Nhance™ Brine Remediation

      - Ca^{++}Nhance™ is 520 times more soluble than gypsum, therefore Ca^{++}Nhance™ penetrates deeply in the soil profile
      - Ca^{++}Nhance™ also stimulates microbial growth in the soil immobilizing soil nutrients preventing loss by leaching and building soil nutrient pools that will aid eventual revegetation
      - How can you tell if there is an abundance of limestone in your soil?
        - Add 2-3 drops of muriatic acid to dry soil (crush to break up any aggregates). If it fizzes you have limestone in the soil. If you don't have limestone in your soil it is an inexpensive amendment (about 50 lb/1000 ft^2)
    - If you choose to use gypsum consult your local agricultural extension agent for application rates

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- Site maintenance
  - ✓ Check irrigation system for coverage; monitor quantity of irrigation water applied or rainfall received
  - ✓ Look for signs of reduced drainage (ponding, excessive runoff); correct as required
  - ✓ Monitor EC and SAR every quarter in the first year
    - 0-6 inches
    - 6-12 inches
    - 12-24 inches
  - ✓ Till the site every 3 months to maintain permeability; reapply top dressing of organic matter after each tilling
  - ✓ Till in more organic matter and fertilizer if there are obvious changes in permeability or if EC reduction slows significantly
  - ✓ Reapply calcium source and/or a mild acid if SAR reduction slows significantly
  - ✓ If any part of the site begins to naturally revegetate do not disturb the vegetation; this applies to any stand of vegetation with a percent coverage of > 70%
    - Stops loss of topsoil
    - Stimulates soil biota
    - Root systems increases infiltration
    - Roots also release acids which solubilizes calcium (from natural or amended limestone) and further reduces sodicity.

Some common problems to watch for

Sometimes you might see new vegetation wither and die in dry weather when vegetation in unimpacted areas still looks okay! This is caused by upward migration of salt during dry weather by capillary suction. You might even see white salt crystals on the soil surface. What can you do when this happens? Keep applying the remediation protocol described above until vegetation returns to the site and remains healthy. A bare spot that does not revegetate but has acceptable EC and SAR probably needs nutrients.

Costs of remediation

- Costs are highly variable depending on
  - ✓ Size of spill
  - ✓ Salt mass loading
  - ✓ Depth of contamination
  - ✓ Soil types
  - ✓ Drainage requirements
  - ✓ Water availability
  - ✓ Etc., etc.
- Compare to dig and haul at about $50/yd^3
  - ✓ 0.5 acres excavated to 2 ft, disposal and replacement with clean soil, about $85,000
  - ✓ You still have to revegetate!

Everyone needs to be patient. Remediation of brine spills can take 1-2 years for some sort of vegetation to take hold. The time required for remediation ultimately depends on the availability of water and permeability of the soil.

Need help? Contact Kerry Sublette of Sublette Consulting, Inc. at (918)691-0639 or ksublette@microbe.com.

For more detailed guidance on soil remediation and information on **Ca^{++}Nhance™** and **InfiltratioNhance™**, as well as other products to support remediation of hydrocarbon-impacted soils and revegetation, go to **www.bovairdsupply.com**.

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Version 6-4-2010