Optimization of Remediation of Salt-Affected Soils by Leaching

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Introduction

Petroleum reservoirs typically produce a mixture of hydrocarbons and saline water. Due to past operational practices, accidental spills, or pipeline breaks, salt-affected soils are perhaps the single most common environmental problem faced by the upstream petroleum industry. A three year study to optimize the remediation of salt-affected soils is being conducted for an existing tile drain salt-leachate collection system installed in central Alberta. The tile drains are installed at a depth of 2 m below ground near the base of fine-grained glaciolacustrine material, immediately above a dense glacial till layer. The objective of the remediation system is to lower salt concentratrions in the rooting zone to meet provincial salinity guidelines. Due to the semi-arid climate, water drainage into the leachate collection system has been intermittent and limited.

Methods and Analysis

Irrigation water was applied to a test plot during the summer of 2009 in order to conduct a salt-flushing experiment. A total of 240 m^3 of irrigation water was applied to a 20 m by 20 m test plot, corresponding to a water depth of 600 mm. A sump was constructed and tied into two tile drains beneath the irrigation plot to monitor the volume of captured water and the chemistry of the leachate. Due to an extended drought, the pre-irrigation water table was approximately 3.5 m below ground surface and the tile drains were not producing water until irrigation was applied. Time-lapse soil chloride profiles indicate significant leaching of salts from beneath the irrigated plot between sampling events in fall 2008 and fall 2009. Gypsum was added to the soil as a source of available calcium to mitigate the deleterious effects of elevated sodium concentrations. Time-lapse soil sulphate profiles collected beneath the irrigation plot indicate a lower rate of leaching than for chloride. This may indicate that gypsum solubility is limiting the mobilization of calcium. Small decreases in the sodium adsorption ratio (SAR) profiles are observed above the tiles drains in contrast to negligible decrease in SAR between the tiles.

The percentage of irrigated water recovered by the tile drains was relatively low, approximately 6% of that applied. The salt concentration of the leachate remained elevated during the experiment, ranging from 6000 to 8000 mg/L chloride. Comparison to the chloride concentration of the irrigation water (2 mg/L) indicates successful mobilization of salts from soil. The initial conceptual model for flow to the tile drains was one of vertical infiltration to the water table and lateral flow to the tile drains, with negligible vertical flow penetrating the dense basal till below. Laboratory hydraulic conductivity measurements on 5 cm diameter intact soil cores from the glaciolacustrine material indicate a matrix vertical hydraulic conductivity on the order of 10^{-9} to 10^{-10} m/s. Field hydraulic conductivity does not appear to be as low as that measured in the laboratory. Root casts have been observed in the shallow glaciolacustrine material above the tile drains, and oxidized fractures have been observed in glacial till below the tile drains. Two sand layers exist within the glacial till at depths of approximately 4 and 6 m, which may serve as lateral flow pathways. The effect of macropores and fractures on the flow system and the potential for leaching of salts to the sand layers is a primary component of this study. Due to low regional water table conditions, radial flow away from the irrigation plot is also being considered.

Conclusions

Understanding the flow paths is necessary for the optimal design of the tile drain system and optimal irrigation schedules. The flow paths also control the volume and concentration of leachate water recovered for potential water recycling and are a primary control on the risk to ecological receptors.

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