AAPG HEDBERG CONFERENCE
"Near-Surface Hydrocarbon Migration: Mechanisms and Seepage Rates"
SEPTEMBER 16-19, 2001, VANCOUVER, BC, CANADA

Computer Modeling of Regional Groundwater Flow and BTEX Migration in Sedimentary Basins of the Colorado Plateau Region

Ye Zhang[1], Michael Szpakiewic[2], and Mark Person[1]

[1] Indiana University, Department of Geological Sciences, Bloomington, IN
2 Idaho National Engineering and Environmental Laboratory, Idaho Falls, ID

Aromatic hydrocarbons such as benzene, toluene, and xylene (BTEX) can be found in high concentrations in basinal brines (up to 18.6 mg/l) adjacent to petroleum reservoirs. BTEX has been used as geochemical indicators in exploration. However, BTEX compounds dissolved in groundwater attenuate in the subsurface due to retardation and biodegradation. To date, the mechanism of aqueous BTEX transport from oil reservoir to the land surface is poorly understood. In this study, the long term transport and fate of BTEX components within the oil-prolific Uinta Basin has been assessed. BTEX concentrations were analyzed from both oil-field brines and springs located hydro-dynamically down gradient from relevant oil field. The springs sampled were situated within regional discharge area sof the Uinta Basin. BTEX concentrations measured in oil field brines have a concentration range of between 0.1 to 9.5 mg/l but were undetectable in most springs.

Mathematical models were constructed along a northwest-east cross-section across the Uinta Basin through the Altmount-Bluebell field following the regional groundwater flow direction. The models represent advective-dispersive BTEX transport by regional groundwater and BTEX diffusion within the oil reservoir. Rates of biodegradation and retardation estimated from shallow aquifer systems were also represented in the model. Model results indicated that BTEX concentrations in the basinal brines ranged from 0.0 to 17.0 mg/l. Significant concentrations (above detection: 0.01mg/l) were not detected in the surface discharge areas. Models which represent biodegradation predicted BTEX concentrations in oil field brines and springs that are consistent with field measurements. Models without biodegradation produced concentrations two to three orders of magnitude too high.

A suite of generic models were also constructed using an idealized basin-scale cross section (60km) to evaluate the influence of aquifer and geochemical parameters on BTEX transport. This cross section has three lithological units – aquifer in the middle, an overlying confining unit and an underlying confining unit. A single oil reservoir is located in a stratigraphic trap within the aquifer. Results indicated that hydraulic conductivity of the cap rock (overlying confining unit) greatly influenced the direction of transport and location of BTEX discharge. Interestingly, BTEX transport was not sensitive to the mass-transfer coefficients and saturation profiles assigned to the oil-water interface. Model results also demonstrated that biodegradation controlled the fate of BTEX transport and magnitude of their concentrations in groundwater. In simulations without biodegradation, BTEX concentrations in the basin dropped to below 0.01 mg/l at a distance up to 47km down gradient from the oil reservoir. With biodegradation, BTEX concentrations dropped below detection limit at 15km (λ^{*}=0.0001) and 3km (λ=0.001) and concentrations in springs were mostly undetectable. We conclude that BTEX concentrations detected in exploration wells may provide a useful indicator of a nearby, hydro-dynamically, up-gradient oil reservoir. However, surface geochemical sampling of soluble BTEX compounds in springs is probably not a useful exploration tool due to the effects of biodegradation.

$*$ λ is the biodegradation rate assigned to the model.