The Potential for Natural Source Zone Depletion of Petroleum Hydrocarbons in Tropical Environments

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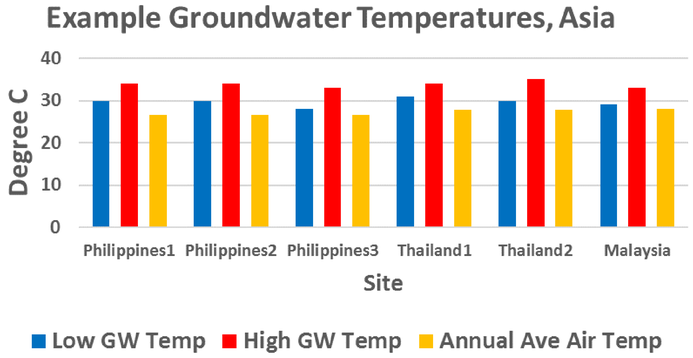
Abstract

- Natural Source Zone Depletion (NSZD) of petroleum hydrocarbons is gaining significant interest in North America with numerous research and case studies available demonstrating that that rates of NSZD can be significant.
- Petroleum hydrocarbon impacted soil and groundwater also exist in tropical climates such as South-East Asia.
- Little is known about the NSZD rates that might be expected in these tropic climates and the potential impacts on management of these sites.

Background Information



- Groundwater temperatures at a number of sites in South-East Asia ranged from 29°C to 34°C (see figure above)
- Annual average air temperatures ranged from 26.6 °C to 28 °C.
- Annual average air temperatures in US used by Kulkarni (2017) ranged from 5 °C to 24.9 °C

References

- Garg, S., et al., 2017. Overview of natural source zone depletion: Processes, controlling factors, and composition change. Groundwater Monitoring & Remediation .
- Kulkarni, P.R., et al., 2017. Impact of Temperature on Groundwater source Attenuation Rates at Hydrocarbon Sites. Groundwater Monitoring and Remediation, 37, no. 3/Summer 2017
- Siddique, T., et al., 2008. A first approximation of kinetic model to predict methane generation from an oil sands tailings settling basin. Chemosphere. 72:1573-1580.
- Zeman, N.R.,et al. 2014. Temperature impacts on anaerobic biotransformation of LNAPL and concurrent shifts in microbial community structure. Biodegradation. 25:569-585.

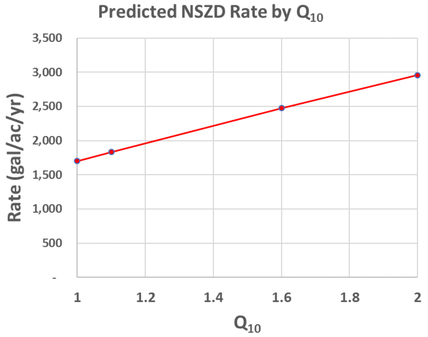
Potential Temperature Impacts on NSZD Rates

NSZD Rates:

- Reported NSZD rates for North America range from 700 and 2800 gal/ac/yr, with a median of 1,700 gal/ac/yr (Garg, 2017). Median temperature at these sites is unknown, but assumed to be 22o C.

.Temperature Impacts: Q_{10}

- Impacts of Temperature described by Q_{10} (magnitude of rate increase for a 10 °C temperature increase).
- Q_{10} of 2 (rate doubles) often assumed for biochemical processes (Kulkarni, 2017).
- Kulkarni (2017) observed a Q_{10} of 1.1 to 1.6 for dissolved hydrocarbon attenuation rates from >2000

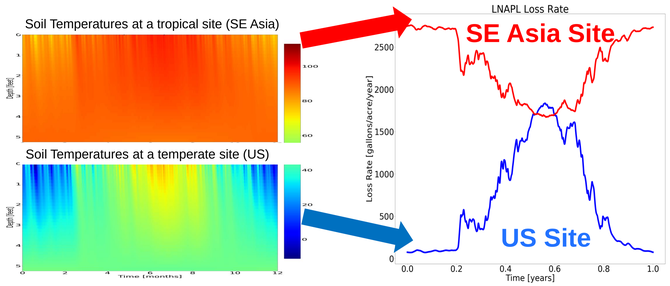


Temperature Impacts: Bio-Therm Model

- Using ambient and groundwater temperatures as inputs, Bio-Therm predicts local soil temperatures versus depth.
- Bio-Therm uses Monod kinetics for rates vs concentration and temperature corrections to it (Siddiqui et al, 2008; Zeman et al, 2014).

Bio-Therm predicted NSZD rates:

Additional info at www.BiogenicHeat.com

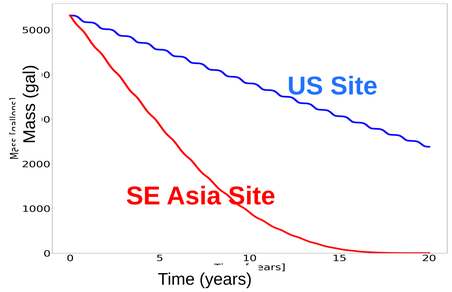


Implications

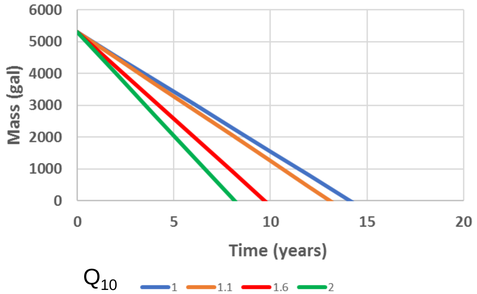
Assume service station fuel release:

- 5,300 gal (20,000 liters), one UST
- Area: 120 ft by 80 ft = 0.22 ac (38m by 25m)

Bio-Therm: Predicted Mass Losses vs Time



Q_{10}: Predicted Mass Losses vs Time



Conclusions

- Differences in mass loss vs time due primary to the base rate (US sites) assumed in the models
- Both approaches suggest that NSZD rates should be significantly greater at the elevated temperatures in SE Asia
- Consequently, the time for NSZD reductions to achieve significant mass reduction should lower, and may suggest active remediation is not need

Uncertainties

- Site specific data from SE Asia is currently not available.
- Rate vs temperature relationship may not hold across microbial classes (i.e. from psychrophiles (optimum temp of 10 oC to 15 oC) to mesophiles (optimum of 30 oC to 40 oC))
- Service stations are typically paved, so that NSZD rates observed at unpaved sites may not be representative.