Temperature-Dependence of Biodegradation from Two Perspectives: Big-Data and Site-Specific

Poonam R. Kulkarni (prk@gsi-net.com), Thomas E. McHugh, David C. King, and Charles J. Newell (GSI Environmental Inc., Houston, Texas, USA)
Harley Hopkins (ExxonMobil Environmental Services Company, Spring, Texas, USA)

Background/Objectives. Natural source zone depletion (NSZD) is a key process that occurs at light non-aqueous phase liquids (LNAPL) sites, with measured degradation rates in the hundreds to thousands of gallons per acre per year. Several factors are expected to impact the microbial activity at these sites. In particular, microbial populations are sensitive to temperature (i.e., warmer subsurface temperatures result in faster biodegradation rates) and respond to natural seasonal patterns from the atmosphere. Additionally, thermal NSZD monitoring can be used to provide continuous (daily) measurements of subsurface temperature than can then be converted to NSZD rates based on the heat generated by LNAPL biodegradation.

Approach/Activities. Two key approaches to evaluate the temperature dependence of biodegradation were conducted:

i. Big-data approach: source attenuation rates of dissolved-phase groundwater constituents were evaluated using long-term monitoring well data and
ii. Site-specific approach: evaluation using continuous (daily for full year) thermal monitoring to quantify NSZD rates.

In the first approach (Big-Data), source attenuation rates (concentration versus time attenuation rates over many years) were calculated for benzene and toluene from >2000 LNAPL sites (Kulkarni et al., 2017) in the California Geotracker database. These rates were then compared with representative subsurface temperatures at each site to determine the correlation between temperature and dissolved phase attenuation rates.

In the second approach (Site-Specific), continuous (daily) temperature measurements were obtained for one year at an LNAPL site with six different thermal NSZD monitoring locations. These temperatures were then used to determine NSZD rates by applying the thermal monitoring method (Thermal NSZD, 2018; Karimi Askarani et al., 2018). Additionally, subsurface temperatures in clean areas were also recorded over time to evaluate the natural conditions at the site. The correlation of NSZD rates versus subsurface temperatures was then conducted using the daily measurements (365 data points).

Results/Lessons Learned. With the Big-Data approach, statistically significant and positive relationships between climatic temperature and source attenuation rates were determined for both benzene and toluene where sites in warmer climates exhibited higher NSZD rates. In particular, this relationship was stronger at sites with deeper water tables (>30 ft bgs) which are less susceptible to oxygen influx than sites with shallower water tables (<15 ft bgs). With the Site-Specific approach, NSZD rates at three of the four impacted locations exhibited a positive statistically-significant relationship with background subsurface temperature in the saturated zone (i.e., generally higher rates in warmer seasons). The slope of this relationship (NSZD rate versus subsurface temperature) also provides a measure of the potential increase in biodegradation rate with an increase in temperature at this site.