PIEDMONT GEOLOGIC

SMART EARTH SOLUTIONS

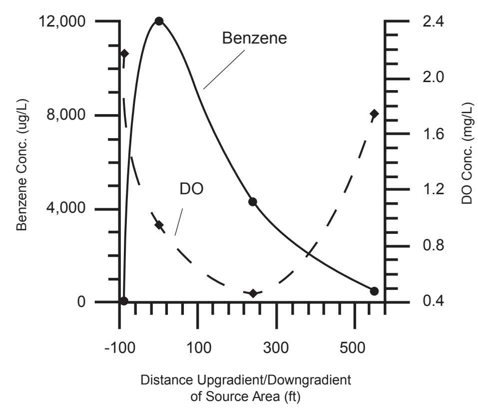
Effective Demonstrations of Groundwater Remediation by Natural Attenuation

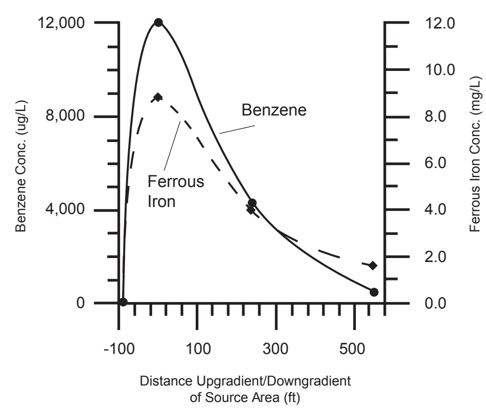
State/Federal environmental regulations allow for groundwater remediation by natural attenuation (RNA) to address groundwater contamination, relying on natural processes of biological degradation, dilution, dispersion, volatilization, hydrolysis, and sorption. An effective demonstration of groundwater RNA may be achieved using relatively inexpensive geochemical analyses and simple graphical and mathematical techniques.

Does Your Aquifer Have The Right Stuff?

Biodegradation of organic contaminants involves microbial metabolism, whereby naturally occurring elements or compounds are reduced by accepting electrons produced by the oxidation of organic contaminants through metabolism. Dissolved oxygen (DO) is the most readily utilized electron acceptor for metabolisis (i.e., aerobic degradation). Following the depletion of dissolved oxygen, the biodegradation process becomes anaerobic as nitrate, ferric iron, sulfate, and carbon dioxide are utilized, respectively, and converted to metabolic by-products, including ferrous iron, sulfide, and methane.

Aerobic and anaerobic biodegradation processes in groundwater may be demonstrated using simple graphical techniques, comparing contaminant versus geochemical parameter concentrations along a transect of the contaminant plume. Transects of contaminant concentration vs. DO, oxidation/reduction potential (ORP), nitrate, and sulfate should show inverse relationships (example right top), whereby transects of contaminant concentration vs. ferrous iron or methane should show parallel relationships (example bottom).





Just Eatin' and Breathin'

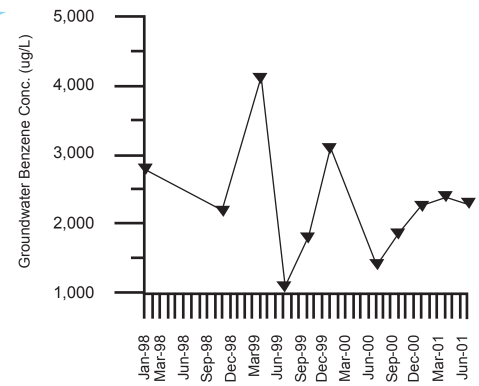
In aquifers contaminated with fuel hydrocarbons, naturally occurring microbes utilize native organic carbon as an electron donor (i.e., for "eating") and dissolved oxygen (DO) is utilized initially as an electron acceptor (i.e., for "breathing"). Once DO is depleted, the process becomes an-aerobic, and nitrate, ferric iron, sulfate, and carbon dioxide are used in order as electron acceptors.

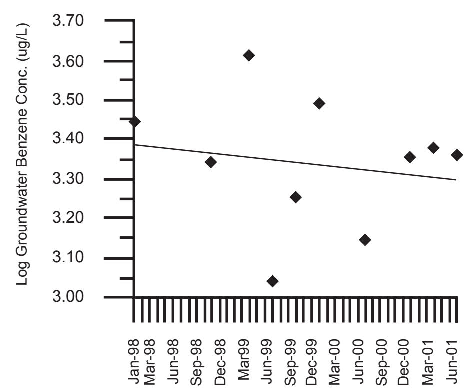
In aquifers contaminated with chlorinated hydrocarbons, biodegradation occurs through reductive dechlorination, whereby the chlorinated hydrocarbon is used as an electron acceptor, not as the source of carbon, and a chlorine atom is removed and replaced with a hydrogen atom, forming other compounds. Reductive dechlorination of chlorinated hydrocarbons is thereby accompanied by the accumulation of daughter compounds (generally other chlorinated hydrocarbons) and an increase in chloride ion concentrations.

Are Your Contaminant Levels Decreasing?

A primary line of evidence of groundwater remediation by natural attenuation is a shrinking or stable groundwater contaminant plume, as indicated by decreasing or steady contaminant concentrations over time. While this principle would appear simple to apply, actual groundwater-concentration trends may often be obscured by normal variability, due to factors such as fluctuating groundwater levels, seasonal effects, sample and laboratory variances, etc.

The arithmetic plot of site groundwater benzene concentrations vs. time (lower right) shows an apparently random pattern of fluctuating benzene concentrations over the 3½-year monitoring period, with both increasing trends and decreasing trends but no apparent dominant trend. By contrast, a simple linear-regression analysis of the same data plotted logarithmically indicates an overall decreasing trend in groundwater benzene concentration over time.





How Much for Nothing?

Background concentrations of geochemical parameters in groundwater can be used to predict the assimilative capacity of the contaminated aquifer–that is the mass of contaminant expected to be consumed through biodegradation. For instance, the oxidation of benzene to carbon dioxide and water is described by:

$C_6H_6 + 7.5O_2 \longrightarrow 6CO_2 + 3H_2O$.

By this reaction, 1 mg/L of benzene is consumed for each 3.1 mg/L of DO utilized in aerobic biodegradation.

The total aquifer assimilative capacity may be evaluated by analyzing uncontaminated (i.e., background) groundwater samples for DO, nitrate, sulfate, methane, and ferrous iron. The background concentrations of these parameters in conjunction with their respective assimilative capacities may be used to predict the total contaminant concentration reductions to be expected through RNA.

Case Study: Swamp Thing

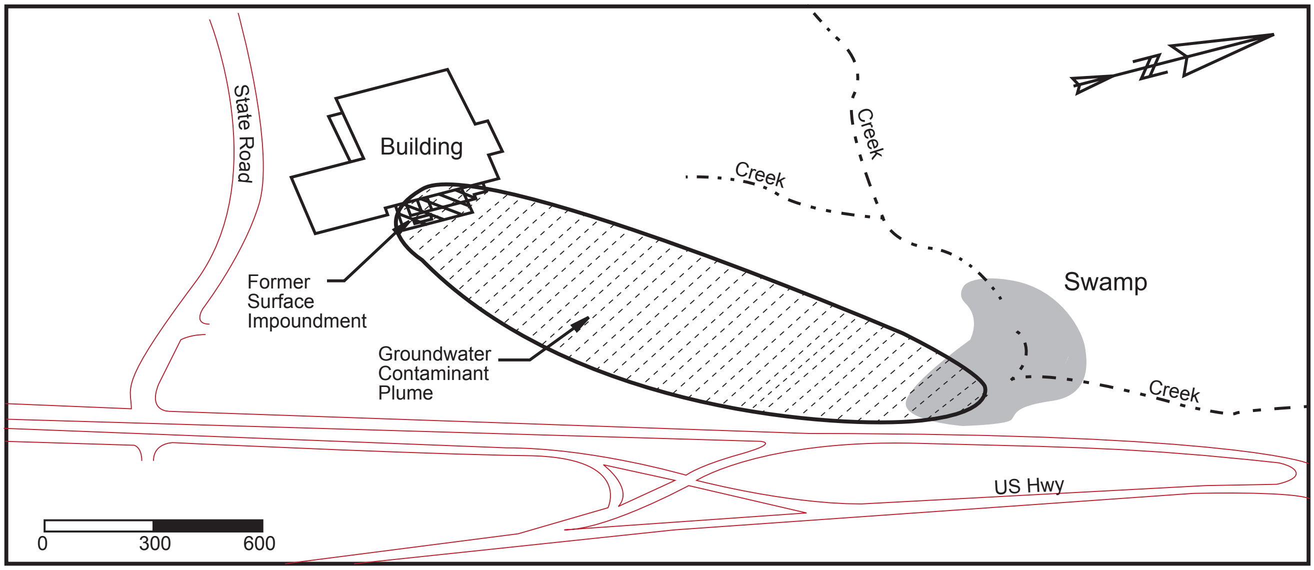
Piedmont Geologic developed a Corrective Measures Plan for a RCRA corrective action site in North Carolina, relying on groundwater remediation by natural attenuation (RNA) to address an extensive plume of chlorinated hydrocarbons in groundwater. Investigative efforts demonstrated that a man-made wetland swamp was serving as an organic “filter” at the groundwater contaminant discharge zone, reducing groundwater contaminant concentrations to below groundwater and surface water standards prior to discharge to the surface environment. The EPA-approved strategy represents a client cost savings of hundred’s of thousands of dollars.

Would You ”Buy” This Groundwater Remediation System?

You wouldn’t need to—this “system” came free with a highway project in the 1960s that resulted in the expansion of a wetland/swamp. Years later, this swamp serves to filter dissolved chlorinated solvents in groundwater from a nearby RCRA corrective action site, eliminating the need for installation of any engineered remediation system to address groundwater contamination.

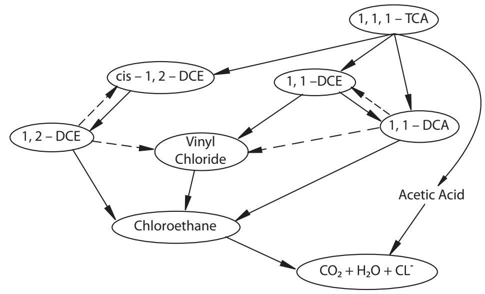
Site Layout

A former surface impoundment for electroplating sludge resulted in an elongated plume of dissolved chlorinated hydrocarbon compounds, including 1,1,1-TCA, 1,1-DCA, and 1,1-DCE, extending from the former surface impoundment to a downgradient swamp. The swamp represents the discharge zone of groundwater flowing from the site, and serves as a reservoir of water that trickles into a series of receiving creeks/streams.



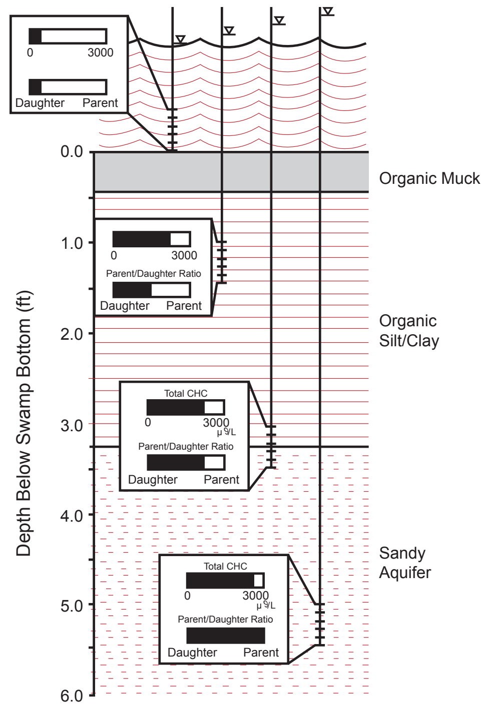
Reductive Dechlorination At Work

The reductive dechlorination for 1,1,1-trichloroethane (1,1,1-TCA), the primary site contaminant, is shown below. The reductive dechlorination process for 1,1,1-TCA ultimately leads to the complete mineralization of contaminants to carbon dioxide, water, and chlorine ion. Reductive dechlorination is favored under conditions of high groundwater organic content and low groundwater DO.



Swamp-Assisted Groundwater Remediation

Buildup of organic detritus and sediment over the years has resulted in a swamp-bed of dark muck , rich in organic matter but depleted in dissolved oxygen (DO). Discharge of contaminated groundwater into the swamp from the surficial sandy aquifer is channeled by an underlying clay aquitard. The diagram at right illustrates the process of reductive dechlorination of chlorinated hydrocarbons (CHCs) in groundwater through the swamp sediments, as determined through a multi-level well-point system installed by Piedmont Geologic. With increasing vertical travel distance through the swamp bed, ratios of parent to daughter compounds steadily decrease, with a final dramatic decrease in both parent/daughter ratio and total CHC concentrations through the organic muck swamp-bed layer. By this matter, the swamp muck serves as a "filter" for removal of CHCs from groundwater.



Protect Your Assets, Investments and Reputation

Demands for environmental compliance are high. But so is the pressure to protect your bottom line. At Piedmont Geologic, we are scientists and engineers who understand your business needs to comply with rapidly changing regulations using cost-effective methods.

For More Information

Call 919.854.9700 or

Visit www.piedmontgeologic.com