DRAGUN CORPORATION'S

ENVIRONMENTAL MINUTE

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Conceptual Site Models (Part 8 of 8)

A Primer on Contaminant Transport

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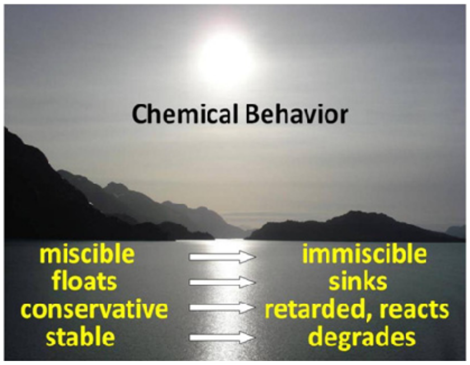
Mike is a hydrogeologist with a passion for getting things right the first time. He also isn't afraid to buck conventional thought, when necessary. Mike brings these two characteristics to every environmental project he touches. Mike has a deep and broad background in hydrogeology, formed from a demanding geological engineering undergraduate degree, followed by a Ph.D. from the world-class hydrogeology program at the University of Waterloo. Mike's 15-year academic career prior to consulting served to further broaden his knowledge and hone his communication skills.

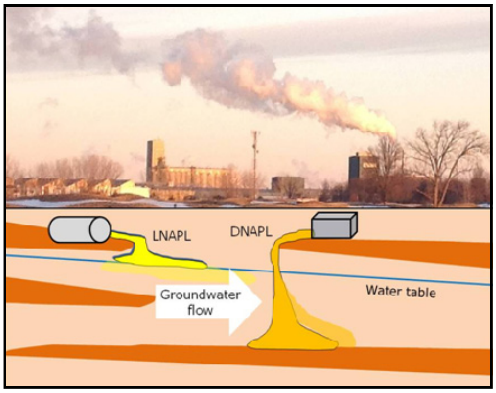
The Basics of Chemical Behavior

How a chemical behaves will play a large part in selecting a remediation approach. Several questions must be answered during the site characterization process so you are ready for remediation, including the following:



1. Does the chemical dissolve in groundwater or not?
2. If immiscible, does it tend to float or sink?
3. Does it react or have an affinity for the soil, or is it conservative (i.e., travel at the groundwater velocity)?
4. Does it breakdown into other compounds that might create other remediation challenges?
5. Is it a volatile chemical compound?

Many chemicals we commonly encounter are immiscible in water and can occur as a separate phase distinct from the groundwater.



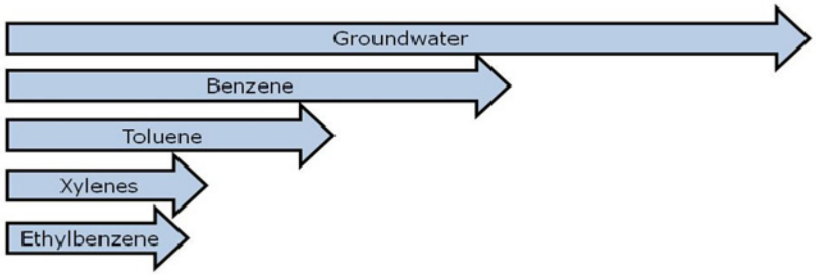
Light nonaqueous phase liquids: (LNAPLs) are lighter than water. If enough LNAPL is released, it will "float" on the water table. Gasoline and heating oil are examples of frequently encountered LNAPLs.

Dense nonaqueous phase liquids: (DNAPLs) are heavier than water. If enough DNAPL is released, it will sink through the groundwater. Trichlorethene (TCE), a metal degreaser, and perchlorethene (PCE), used in dry cleaning, are commonly encountered DNAPLs.

Both LNAPLS and DNAPLS can take the form of "pools" of chemicals but can also occur as a "residual," resulting in isolated "globules" of LNAPL/DNAPL in soil pores.

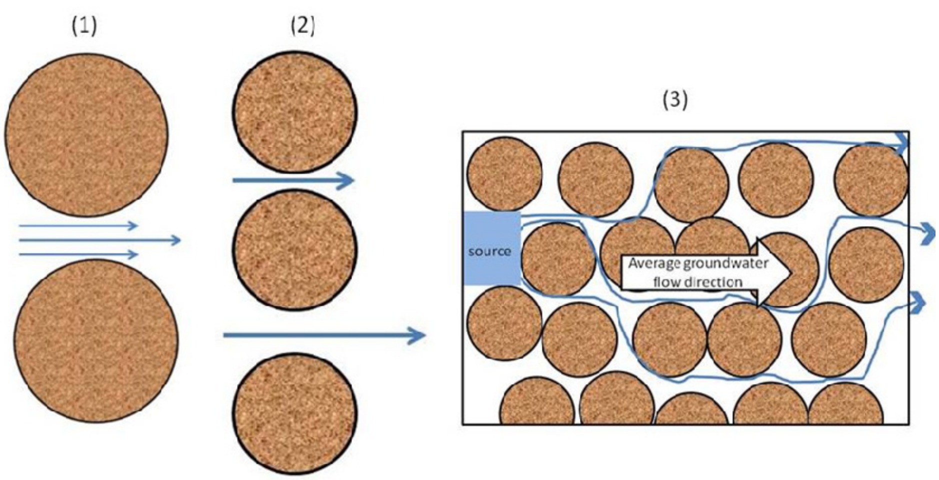
LNAPLs and DNAPLs have some solubility in groundwater. We frequently hear the ***misconception*** that if TCE is dissolved in groundwater, the groundwater will sink downward. Understanding this is important, as it can affect your site assessment and remediation efforts.

Many chemicals, particularly organic chemicals, move much slower than the groundwater because they have greater affinity for the soil than the water. The movement of these chemicals is described as "retarded" relative to the groundwater velocity. The degree of retardation depends largely on the chemical and the organic carbon content of the soil, which is why you need to collect data to understand organic content of the soil.



Let's consider an example of a release of gasoline that can result in several different chemical plumes moving in the groundwater. The most common chemicals we deal with from a gasoline release are called the BTEX chemicals (benzene, toluene, ethylbenzene, and xylenes). Each of these chemicals has a different transport rate roughly represented by the arrows above. Accordingly, if there is a release of gasoline resulting in dissolved BTEX in groundwater, generally benzene would be expected to travel a bit slower than the groundwater, but faster than the toluene, xylenes, and ethylbenzene. But what else can happen to the BTEX chemicals that can confound the plume lengths?

How does a point release become a contaminant plume?

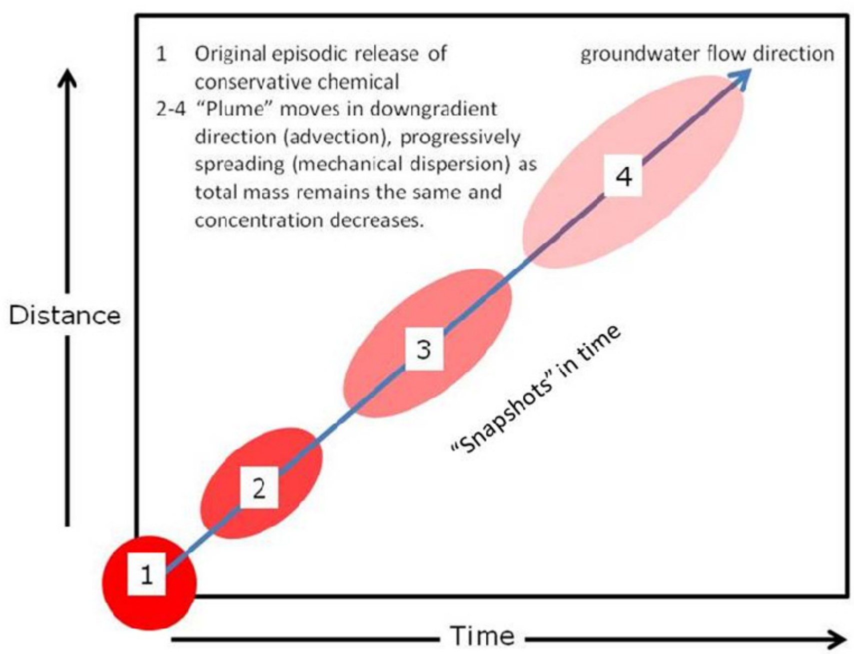


What makes a chemical release to groundwater so challenging is that the groundwater is moving (for a discussion on how groundwater moves, see Environmental Minute #5 "Introducing Groundwater"). Groundwater might be moving off site, under a building, toward utilities, venting into a water body, etc… The point is that because groundwater is moving, the chemical release, too, is moving... and spreading.

Chemicals move predominantly by advection and mechanical dispersion if the groundwater velocity is significant, or by molecular diffusion if the groundwater velocity is negligible.

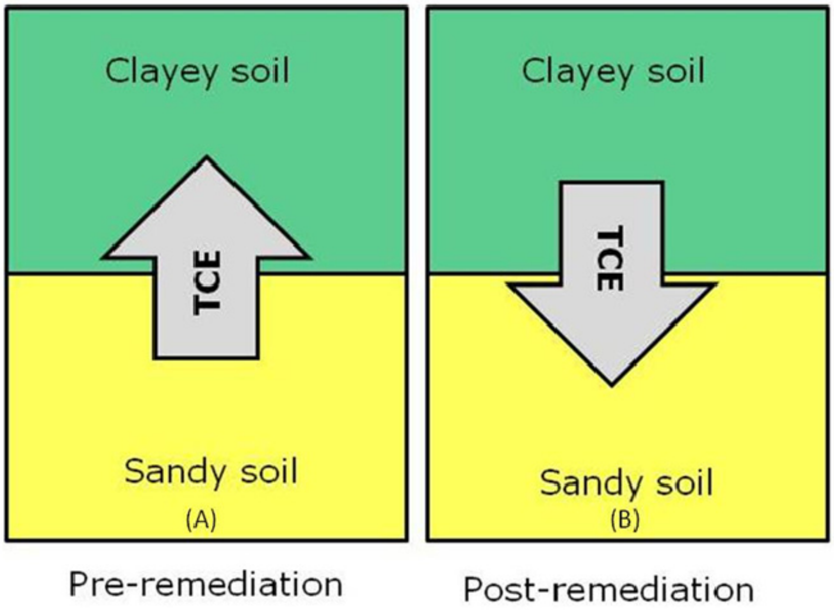
Advection and Mechanical Dispersion:
Advection is transport with the bulk movement of the groundwater. Mechanical dispersion is a spreading of the chemical mass due to movement in the porous geologic materials through which it passes. Spreading by mechanical dispersion results from (1) velocity variations within pores, (2) velocity variations between pores of different sizes, and (3) tortuosity – the tortuous path chemicals follow through the porous medium.

The diagram to the right, based on Barker et al. (1987), shows how a simple episodic release of a conservative chemical (one that travels with the groundwater; its concentration only changes by mixing with groundwater with a different chemistry) forms a classic "cigar-shaped" plume in groundwater.



Molecular Diffusion: Molecular diffusion or "diffusion" is the movement of chemicals due to a concentration gradient. A good example of diffusion can be observed when making tea. There is no movement of water in the cup (no advection, therefore, no mechanical dispersion), but the tea color gradually moves outward from the tea bag (high concentration) into the water (low concentration).

Molecular diffusion can be a particularly insidious problem for remediation where fine-grained soil or porous rock is adjacent to a moving plume. For example, over a period of many years, TCE can diffuse from contaminated groundwater into the adjacent clayey soil (Sketch A below). Later, TCE-impacted groundwater in the sandy soil may be remediated quickly using chemical injections.



Believing the remediation to be complete and the TCE is gone (as well as the entire budget), you may encounter an unpleasant surprise. The TCE begins to diffuse from the clayey soils into the groundwater because the concentration gradient has reversed (Sketch B).

Avoiding, or at least limiting, surprises such as TCE rebounding at a site requires that you have a thorough understanding of the entire site characterization process.

This was just a *very* brief look at what can be a complicated topic involving a number of disciplines.

Any conclusions you might reach after examining potential contaminant transport factors at your site still rest on getting the fundamentals right. Short of getting the basics right, remediation will likely take far too long and/or cost far too much.

Concluding Thoughts

We hope you have enjoyed reading our series of eight Environmental Minutes focused on how to achieve successful remediation. Our first Environmental Minute described the concept of ***contact*** as the heart of successful remediation. That is, if you don't understand the complexities of the subsurface, your chance of successfully designing a remediation program (whatever that may be) that will "get to the contamination" is jeopardized, and significant time and money can be wasted. In the seven subsequent Environmental Minutes, we discussed the importance of doing the upfront work properly to understand site conditions and building a representative and robust Conceptual Site Model (CSM) to improve your ***contact***.

Our experience has demonstrated the importance of developing a robust CSM, whether it is used to design appropriate remediation, to negotiate with regulators, or for preparing and defending a litigation case. If you have found these Environmental Minutes useful, please feel free to contact us, and we can talk about our how we might help you better understand and overcome your environmental challenges.

Dragun Corporation
Environmental Advisors