Applied NAPL Science Review

Demystifying NAPL Science for the Remediation Manager

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Applied NAPL Science Review (ANSR) is a scientific ejournal that provides insight into the science behind the characterization and remediation of Non-Aqueous Phase Liquids (NAPLs) using plain English. We welcome feedback, suggestions for future topics, questions, and recommended links to NAPL resources. All submittals should be sent to the editor.

Redevelopment of LNAPL Sites with Deed Restrictions

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Petroleum facilities with light non-aqueous phase liquid (LNAPL) in soil and groundwater have historically been required to implement active LNAPL mass removal. However, we now understand that considerable volumes of residual LNAPL may remain in the subsurface despite active remediation. Deed restrictions, as permanent property title records, are a powerful tool to mitigate future risk from this residual LNAPL as part of a site redevelopment plan to return these properties to beneficial use.

LNAPL Risk-Based Remedy Process

The first step is to craft a robust LNAPL conceptual site model (LCSM) that comprehensively delineates LNAPL (source mass, dissolved-, vapor-, and sorbed-phases) both laterally and vertically (ASTM 2006). The LCSM supports a sound corrective action decision framework, and is also a powerful tool for effective communication and coordination among stakeholders about LNAPL remaining at these facilities.

If active LNAPL mass removal is implemented via conventional technologies (e.g., hydraulic pumping), a meaningful performance metric such as LNAPL transmissivity can be used to quantitatively define and measure progress towards the mass removal endpoint. Any additional remedy (beyond conventional LNAPL mass removal) to address the residual LNAPL can be evaluated for its risk reduction versus energy/resource consumption to determine the net environmental benefit.

Stakeholders have recognized that risk can be mitigated without removal of all LNAPL in the subsurface (ITRC 2009, TCEQ 2013). However, the LCSM and corrective action decision framework must be sufficiently robust to ensure that any potential human health risk is correctly delineated and resolved.

LNAPL plumes typically stabilize fairly quickly and do not exhibit significant migration risk under the historically observed range of hydrogeologic conditions for a site. However, uncertainty with regard to residual LNAPL stability under unknown future conditions may be a concern for regulatory agencies and may preclude a closure determination upfront. In those cases, a long-term passive LNAPL remedy (e.g., natural source zone depletion) may be a solution so long as risk is resolved and plume stability is demonstrated.

After any potential human health risk is resolved, one way to efficiently address sites with residual LNAPL is to segregate remedy planning:

1. Shallow soil, LNAPL, and groundwater with relatively higher potential human health risks
2. Deeper soil, LNAPL, and groundwater with relatively lower potential human health risks

Shallow soil remediation may be relatively simple by excavation or onsite treatment compared to the deeper soil, LNAPL, and groundwater. If potential human health risks are resolved during a shallow soil cleanup, a shallow soil closure could theoretically be granted by environmental regulatory agencies.

If LNAPL and daughter phase plumes are stable and any potential human health risks are resolved, a long-term passive remedy for deeper soil, LNAPL, and groundwater could be selected with the concurrence of environmental regulatory agencies and implementation of a corresponding risk management plan that may include institutional controls.

Deed Restrictions

Institutional controls can be either physical or legal. One common form of legal institutional control is a deed restriction. Deed restrictions control the use of property to protect present and future human health and safety and/or the environment as a result of the presence of LNAPL or other contaminants, but can also incorporate maintenance requirements with respect to physical controls implemented to achieve site closure.

For example, an LNAPL contaminated site might be restricted to use for commercial/industrial purposes and at the same time require the maintenance of a cap, such as asphalt, on the site to control potential vapor exposure. Similarly, deed restrictions can contain reporting requirements in the event that excavation occurs within areas that are controlled with physical capping.

While deed restrictions are crafted to obtain site closure, they can also serve another different and useful purpose. Once properly recorded, deed restrictions become part of the chain of title for the property, effectively providing notice to all future purchasers of the property. Owners and developers interested in reducing potential future liability to distant purchasers, or who want to ensure distant purchasers understand maintenance obligations for physical remedial controls, should consider deed restrictions as a mechanism to notify those distant purchasers about the condition of the property and any environmental obligations that go with it before they purchase. Additional protection may also be afforded by registering the deed restrictions with dig notification organizations such as “one call” or “811”.

Because consent is recognized as a defense to a variety of claims that might otherwise be asserted, a recorded deed restriction has the potential to avoid later claims resulting from LNAPL left in place. Since passive remedies typically take significant time, institutional controls such as deed restrictions may play a major role in redevelopment to satisfy various stakeholders.

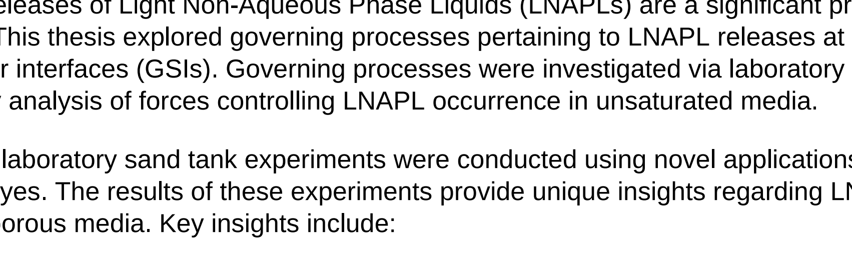
References:

ASTM
2006 Standard Guide for Development of Conceptual Site Models and Remediation Strategies for Light Nonaqueous-Phase Liquids Released to the Subsurface, ASTM E2531-06E1.

Interstate Technology and Regulatory Council (ITRC)
2009 Evaluating LNAPL Remedial Technologies for Achieving Project Goals, December 2009.

Texas Commission on Environmental Quality (TCEQ)
2013 Risk-Based NAPL Management, RG-366/TRRP-32, July 2013.

Research Corner



Thank you to Dr. Tom Sale of the Colorado State University, Center for Contaminant Hydrology, for providing access to selected graduate level NAPL research.

Processes controlling the behavior of LNAPLs at groundwater surface water interfaces
Click to download thesis

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Abstract: Releases of Light Non-Aqueous Phase Liquids (LNAPLs) are a significant problem at many sites. This thesis explored governing processes pertaining to LNAPL releases at groundwater surface water interfaces (GSIs). Governing processes were investigated via laboratory studies and a preliminary analysis of forces controlling LNAPL occurrence in unsaturated media.

A total of six laboratory sand tank experiments were conducted using novel applications of fluorescing dyes. The results of these experiments provide unique insights regarding LNAPL behavior in porous media. Key insights include:

- LNAPLs occur in three distinct zones, herein referred to as Zone 1, 2, and 3. Zone 1 refers to the area below the water capillary fringe where LNAPL is a discontinuous nonwetting phase. Zone 2 refers to the area below the LNAPL capillary fringe where LNAPL is a continuous nonwetting phase. Zone 3 refers to the area above the LNAPL capillary fringe where LNAPL is a continuous intermediate wetting phase. Each zone has unique attributes controlling LNAPL mobility
- Solutions for LNAPL releases at GSIs need to address transport of LNAPL in all three zones
- Modeling fluid saturations versus height in a porous media using a force balance is more complex than two forces and requires further research

A common theme with current solutions for LNAPLs at GSIs is their failure with time. Failure is defined as the observation of LNAPL down-gradient of the solution. A better understanding of these failures is advanced through a volume balance on a representative elementary volume (REV) of porous media at a GSI. Key factors controlling releases to surface water include inflows, natural losses, enhanced losses, and recovery of LNAPL in the REV. Furthermore, the timing of failure is dependent on the capacity of the REV to store LNAPL prior to releases to surface water.

A novel solution demonstrated in this thesis was the use of capillary barriers to limit LNAPL lateral migration. Herein, capillary barriers are defined as vertical walls of fine-grained media that preclude lateral movement of LNAPL via a capillary pressure less than the displacement pressure in Zone 2 and an elevated water capillary fringe in Zone 3. A capillary barrier alone can delay releases; however, the barrier will fail when LNAPL storage capacities are exceeded. In contrast, the use of a recovery well to deplete accumulating LNAPL, in combination with a capillary barrier, provides a sustainable solution. During a laboratory experiment, 92% of the delivered LNAPL held behind the capillary barrier was recovered by aggressively pumping at low water stages.

A second strategy explored to control LNAPL releases at GSIs was organoclay barriers. Herein, organoclay barriers are defined as vertical walls of organoclay-sand mixtures. Organoclay is hydrophobic and retains LNAPL via sorption. Using a "simple" organoclay barrier, breakthrough to surface water was observed when only 11% of the organoclay was saturated with LNAPL. Early failure was attributed to preferential pathways and slow water drainage. Adding vertical baffles and vertical coarse-grained drains improved the efficacy of organoclay barriers. Fractions of the clay contacted at breakthrough were 43% and 34%, respectively, for baffles and drains.

A concern that arose from the sand tank studies was the necessary water capillary rise in the capillary barrier to preclude LNAPL migration in Zone 3. This led to an attempt to develop a force-based model describing LNAPL (intermediate wetting phase) saturations in Zone 3. The model would be beneficial to determine the vertical rise of LNAPL at sites with non-tidal conditions. Key factors included in the model include spreading coefficients and gravity. The model developed (Model 1) was compared to three-phase data. It was found that Model 1 had poor correlation to the data and lacked some key factor affecting saturations. The model was altered by raising Model 1 to the power of lambda and adding the residual saturation, resulting in Model 2. Model 2 was compared to two-phase data and the Brooks-Corey equation and showed promising similarities.

The work described in this thesis provides a basis for future work on remediation solutions and mathematical models for LNAPLs at GSIs. Work could include development of strategies to enhance natural losses of LNAPLs at GSIs and further refinements to Model 1 and Model 2 to better capture factors controlling fluid saturations in Zone 3.

The primary objective of ANSR is the dissemination of technical information on the science behind the characterization and remediation of Light and Dense Non-Aqueous Phase Liquids (NAPLs). Expanding on this goal, the Research Corner has been established to provide research information on advances in NAPL science from academia and similar research institutions. Each issue will provide a brief synopsis of a research topic and link to the thesis/dissertation/report, wherever available.

Practical Stats

Top Twelve Tip #3: Objectives drive what statistics to use

Dr. Dennis Helsel
www.practicalstats.com

What is the correct numerical summary to use, mean or median? Which type of hypothesis test should be used, parametric or nonparametric? The answer should depend solely on your objectives.

For multiple measurements at a sampling location, the mean is the appropriate statistic to use to summarize the location. The mean is a standardized total for that location. When you sum a series of values to produce a total, as when the interest is in the mass, volume, or cumulative exposure, the mean is the appropriate summary statistic to use. Summing a series of medians will underestimate the total amount.

If your goal is to express the typical concentrations seen at ten wells in the region, the median is a better choice than the mean. A median is resistant to the effect of unusual values. When nine of the ten wells have low concentrations but one is much higher, the median is relatively unaffected by the one high value and looks much like the concentrations in the other nine. The mean would be pulled up toward the high value, perhaps being higher than all of the other nine observations. When the interest is in a representative value, the median is the appropriate summary statistic.

If your interest is in testing differences between groups, consider what you are planning to test. The question “does one group generally have higher values than the second?” is a frequency question -- do higher values occur more frequently in one group? Nonparametric methods directly test differences in frequencies -- they are computed using ranks (percentiles). Do not decide which type of test to use based on whether data follow a normal distribution – this pre-test is decades out of date. Nonparametric tests work well on data that follow a normal distribution. The newer permutation tests will test differences in means without requiring that data follow a normal distribution. Decide which type of test to use based solely on the objectives of your study. If you are interested in totals, mass, etc., test differences in group means. If you are interested in whether one group exhibits higher values than another, test differences in percentiles.

Related Links

API LNAPL Resources

ASTM LCSM Guide

Env Canada Oil Properties DB

EPA NAPL Guidance

ITRC LNAPL Resources

ITRC LNAPL Training

ITRC DNAPL Documents

RTDF NAPL Training

RTDF NAPL Publications

USGS LNAPL Facts

ANSR Archives

ANSR Archives

Coming Up

Look for more articles on LNAPL transmissivity as well as additional explanations of laser induced fluorescence, natural source zone depletion and LNAPL Distribution and Recovery Modeling in coming newsletters.

Announcements

The Eighth International Conference on Remediation and Management of Contaminated Sediments:
January 12-15, 2015
New Orleans, LA

Details at http://battelle.org/media/conferences/sedimentscon

The conference is organized and presented by Battelle and Sponsors including public- and private-sector organizations active in environmental assessment, remediation and management. The conference is expected to include scientists, engineers, regulators, remediation site owners, constructors, and other environmental professionals representing universities, government agencies, consultants, and R&D and service firms from approximately 30 countries.

The Third International Symposium on Bioremediation and Sustainable Environmental Technologies:
May 18-21, 2015
Miami, FL

Details at http://battelle.org/media/conferences/biosymp

The 2015 Symposium will present information on advances in bioremediation and the incorporation of green and sustainable practices in remediation. The program is designed for scientists, engineers, regulators, remediation site owners, and other environmental professionals, representing universities, government agencies, and consulting, research and development, and service firms from around the world.

ITRC 2-DAY CLASSROOM TRAINING:

Light Nonaqueous-Phase Liquids (LNAPL): Science, Management, and Technology
April 7-8, 2015
Denver, CO
Register now at https://www.regonline.com/ITRC-LNAPL-CO

Light Nonaqueous-Phase Liquids (LNAPL): Science, Management, and Technology
September 15-16, 2015
Seattle (area), WA

Light Nonaqueous-Phase Liquids (LNAPL): Science, Management, and Technology
November 18-19, 2015
Austin, TX

The Interstate Technology and Regulatory Council (ITRC) is offering 2-day training classes from the ITRC LNAPL team. ITRC offers this 2-day classroom training course, based on ITRC’s Technical and Regulatory Guidance document, Evaluating LNAPL Remedial Technologies for Achieving Project Goals (LNAPL-2). This 2-day ITRC LNAPL classroom training led by internationally recognized experts should enable you to:

• Develop and apply an LNAPL Conceptual Site Model (LCSM)
• Understand and assess LNAPL subsurface behavior
• Develop and justify LNAPL remedial objectives including maximum extent practicable considerations
• Select appropriate LNAPL remedial technologies and measure progress
• Use ITRC’s science-based LNAPL guidance to efficiently move sites to closure

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An updated version of the ASTM Guide for Calculating LNAPL Transmissivity is Now Available for Purchase at www.astm.org.

ASTM Standard E2856 - Standard guide for Estimation of LNAPL Transmissivity is now available

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The ASTM LNAPL Conceptual Site Model (LCSM) workgroup is actively updating the ASTM LCSM guidance document. If you are interested in participating on this team or would like to send comments for consideration - please contact Andrew Kirkman of BP Americas (team leader).

ANSR now has a companion group on LinkedIn that is open to all and is intended to provide a forum for the exchange of questions and information about NAPL science. You are all invited to join by clicking here OR search for "ANSR - Applied NAPL Science Review" on LinkedIn.

If you have a question or want to share information on applied NAPL science, then the ANSR LinkedIn group is an excellent forum to reach out to others internationally.

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