C60 Resolving Uncertainty in Groundwater Plume Investigations

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The goal of this presentation is to raise awareness of the critically important role which the scale of inquiry plays in the development of an adequate understanding of groundwater plumes, their sources and the processes affecting them.

This presentation will impact the forensic science community by showing how geology and classical water-supply type hydrogeology have focused on the macro-scale, subsurface contamination is controlled on the micro-scale and the ability to adequately understand groundwater contami- nant plumes and their sources depends on very different approaches than have commonly been applied.

New investigation techniques such as the Triad Approach focus on understanding and managing uncertainty in decision-making relative to investigation of a site. Decision uncertainty stems from both sampling uncertainty and analytical (or measurement) uncertainty. Sampling uncer- tainty, by far the largest source of uncertainty, arises from the heterogeneity inherent in natural porous media. Examples include the spatial structure of: (1) hydraulic conductivity controlling groundwater flow, (2) capillary pres- sure controlling non aqueous phase liquid movement, and (3) soil water partitioning coefficients, controlling retardation of VOCs. In addition, hydrodynamic dispersion is a very weak process in directions normal to the primary groundwater flow direction, resulting in very steep concentration gradients.

Conventional techniques used to investigate groundwater contamina- tion in porous media, such as monitoring wells, result in depth-integrated, flow weighted average concentrations and large spacing between samples that result in a high level of uncertainty in the conceptual site model and hence in decision making. The Triad approach utilizes real-time measure- ment techniques that provide many more data points at a more appropriate scale than conventional methods. The real-time data are used to update the conceptual model and modify the investigative approach while the investigation is under way.

Direct push investigation tools and techniques have advanced greatly in both capability and acceptance over the 12 years since the Waterloo Profiler first entered commercial use. Investigators of plumes in porous media are now equipped with a toolbox that they can rely upon for managing uncertainty.

The Waterloo Profiler is a direct push groundwater sampling tool that has been modified to allow for the collection multiple data sets that are used collaboratively to test and revise the conceptual site model. The modified Waterloo Profiler provides discrete groundwater samples at virtually any vertical spacing while developing a continuous log of the Index of Hydraulic Conductivity as well as hydraulic head distributions and specific conductance, pH, oxidation/reduction potential and dissolved oxygen of groundwater. With these modifications the Waterloo Profiler has become a very powerful data collection system for sites with solvents in porous media. The number and range of sites at which the profiler is an effective technol- ogy has been increased by the modifications to the profiler tip; the drive rod; the addition of the gas drive pump and the use of a variety of drive platforms.

The Membrane Interface Probe is a relatively new semi-quantitative screening tool that can rapidly provide a large body of data on the distribu- tion of VOCs in the subsurface. The MIP provides a continuous log of the responses to various detectors to VOCs in the subsurface along with a continuous log of the electrical conductivity of the porous medium. The MIP can complete on the order of 200 linear feet of exploration in a day. However, correlation between MIP data and results of laboratory analysis of soil and groundwater samples is not straightforward.

The MIP and the Waterloo Profiler/Onsite Lab data were used collab- oratively to test and revise a conceptual site model on an industrial site in Connecticut. This site had been under investigation for 17 years and had remedial systems in place. The remedial efforts were ineffective because the essential site contaminant distribution and transport issues had not been resolved. A Triad investigation team incorporated source zone data collection in the vadose zone using a passive soil gas survey, membrane interface probe explorations and conventional soil coring and onsite analyses along with the integrated data sets provided by the Waterloo Profiler below the water table to revise a conceptual site model through a dynamic investigation. The uncertainty that had been hindering use of the site for over a decade was reduced as a result of the investigation and the stakeholders were able to move forward.

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