C14 Chemistry Ignored — A Case Study

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After attending this presentation, attendees will understand how the evaluation of chemical tracers in ground water can play an important role in a site investigation.

This presentation will impact the forensic science community by illustrating a valid and useful means of evaluating ground water data to interpret the source and migration of contaminant plumes that is readily available but not routinely used.

In an all too familiar scenario, drinking water wells in a residential neighborhood were found to be contaminated with low concentrations of chlorinated solvents; 1,1-dichloroethene (11DCE) was the initial red flag. A chemical release from a neighboring manufacturing facility (Facility A) was alleged, and, in the subsequent toxic tort litigation, the facility was named as a source of the contamination. After multiple site investigations were performed by at least five different consultants, the analytical data were compiled into a single data base. Evaluation of these data yielded an unexpected result: two plumes were identified, and only one was linked to Facility A.

While it was clear that both a “Northern Plume” and a “Southern Plume” were present, it was not clear where, or if, they overlapped. Since both plumes contained chlorinated solvents and ultimately migrated toward the affected neighborhood (Neighborhood A), this was an important determination. Initially the request was to review isotopic analysis data to determine if the plumes could be differentiated on this basis, but since isotopic data were only available for Facility A, there was nothing to compare. Instead, the entire set of ground water data was reviewed with a focus on chlorinated solvent chemistry, and used the biodegradation and hydrolysis daughter products of the source contaminants as chemical tracers to map the plumes.

Results for three source contaminants (1,1,1-trichloroethane [TCA], trichloroethene [TCE], and tetrachloroethene [PCE]) and four degradation products (11DCE, 1,1-dichloroethane [11DCA], 1,2-dichloroethane [12DCA], and cis-1,2-dichloroethene [c12DCE]) were plotted separately. For simplicity, the plotted result for each sample location was estimated as an average over time and depth. From this first set of maps, several things were clear: (1) there was a significant source (Facility B) of PCE south and west of Facility A; (2) no PCE was detected above 10 ppb at Facility A; and, (3) both Facility A and Facility B were significant sources of 111TCA and 11DCA in the ground water. 111TCA was looked at more clearly.

111TCA hydrolyzes to form 11DCE. Because biodegradation is not involved, this chemical reaction in ground water affords an opportunity to estimate the age of the 111TCA (i.e., how long it has been dissolved in the ground water at that location) based on the relative concentrations of these two analytes, the temperature of the ground water, and the kinetics of the hydrolysis process. At the likely source of the Southern Plume, estimated 111TCA ages ranged from 14-20 years; immediately down gradient of this source (Neighborhood B), ages were estimated at 26-41 years. At Facility A, there were not enough data to calculate any 111TCA ages, but estimates ranging from 22-39 years, were calculated for Neighborhood A. A plot of the estimated ages shows a plume that travels east, then curves to the northeast, skirting Facility A entirely. This trend did not; however, convince the clients. So, it was tried again.

111TCA biodegrades in ground water to form 11DCA. The ratio of the 11DCA concentration to the total calculated 111TCA concentration (measured 111TCA + measured 11DCA + [4.545 x measured 11DCE]) allows us to evaluate the relative amount of 111TCA biodegradation that has occurred at each sample location. This plot showed a clear distinction between the two plumes: at Facility A, the ratios ranged from 0.27 to 0.62, while at Facility B they ranged from 0 to 0.08. Clearly, the 111TCA at Facility A is more biodegraded than the 111TCA at Facility B. At Neighborhood A, the ratios were a striking match to the 111TCA from Facility B, and it was concluded that Facility A (the Northern Plume) did not contribute to the contamination in Neighborhood A.

Unfortunately, the clients were not comfortable with the approach and conclusion, partly because results less than 10 parts per billion were excluded, where analytical error is highest, and partly because this was not a standard approach to using ground water tracers. Remaining confident; however, that the chemistry of chlorinated solvents in ground water is a reliable and readily available means of mapping plumes and identifying sources of contamination.

Chlorinated Solvents, Groundwater, Chemical Tracer

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