# Using Multiple Techniques to Monitor Effectiveness of In Situ Injections

***Thomas A. Harp*** (tharp@LTEnv.com) (LT Environmental, Inc., Arvada, CO, USA)

**Background/Objectives.** Challenges of injecting abiotic/biotic, reagents/amendments into the subsurface to remediate soil and/or groundwater can include unexpected treatment results and deleterious/catastrophic affects to solute transport. “Everything’s good” right up until the moment when it’s not. Practitioners find themselves asking questions like: “Did matrix variation deflect distribution of injectate? Are injections propagating out to the design radius, or falling short? Did temporary hydraulic mounding expand the plume or push fugitive emissions into unintended locales? Fortunately, answers can often be found using commonsensical convention; however, some answers are more elusive and require innovative cleverness. Success is riding on it; so, multiple techniques have been developed and implemented to achieve project objectives. Then there are occasions when “all remains good” throughout a project and the task at hand is merely to document just how effective an injection program truly was.

**Approach/Activities.** Sampling to observe solute-concentration reductions and monitoring hydraulic-head changes in pertinent wells during injection activities are simple and recommended techniques to evaluate injection effectiveness. If object wells are not responding as hoped, however, more “detective work” is necessary such as collecting groundwater samples from intervening locations using discrete sampling methods, e.g., hydro-punch or “implants”, or conducting forensic drilling to observe whether injectate is present in the matrix adjacent to a subject well. If injection radii cannot be determined by these rather conventional techniques, then more innovative efforts can be employed such as measuring surface uplift caused when injectate displaces the native matrix. This differential movement, ranging from abrupt to subtle, provides a map of “where injectate is and where it isn’t”. The key to success is gathering such intel when outcomes deviate from the plan, such that adjustments in the injection process can be made, accordingly.

If “hydraulic push” is a concern, then a relatively-straightforward technique is to compare the total-fluid injection volume with the estimated native matrix pore-water volume. If displacement potential needs to be more-accurately quantified, then a hydrology assessment can be conducted whereby temporary piezometers equipped with transducers are installed at different radial distances from a pilot-test injection point such that hydraulic-head changes can be calculated to evaluate temporary mounding and/or pressure pulsing. Again, if risk potentials are exacerbated due to injections, mitigating adjustments can be made to avert unintended consequences.

On the other hand, if all appears to go well on an injection project, confirmatory sampling can be conducted to estimate mass reductions in soil and non-aqueous phase liquid and dissolved-phase plumes. This technique is used to compare “after” results with initial (pre-treatment) concentrations to evaluate injection effectiveness.

**Results/Lessons Learned.** Conducting successful, in situ injections is as much an art as it is a science. It’s not easy predicting or accounting for subtle nuances inherent to a target matrix. Even if considered homogeneous, matrix architecture can result in failed injection efforts. Gathering “effectiveness” data during or immediately following an injection program allows the practitioner to identify critical problems or expected outcomes. Being “nimble” in the field can make the difference between failed and successful remediation treatment.