

Thermally Enhanced Mass Transfer from Entrapped DNAPL Sources

Jose Gago and Tissa Illangasekare

Center for Experimental Study of Subsurface Environmental Processes, Colorado School of Mines, Golden

Abstract. Many technologies that rely on thermal process to either enhance the dissolution or remove or destroy entrapped organic waste products that are in the form of dense non aqueous phase liquids (DNAPLs) are used in subsurface remediation. These technologies include steam injection, hot water flooding and resistive heating, among others. Even though the effectiveness of specific technologies has been studied, little knowledge exists on how to model the dissolution behavior of these chemicals under expected ranges of temperature at various scales of interest. In dissolution modeling, the dimensionless form of mass transfer rate coefficient in the form of modified Sherwood number is related to other dimensionless groups such as Reynolds and Schmidt number through empirical models that are referred to as Gilland-Sherwood correlations. To extend these models to estimate thermally dependent mass transfer rate coefficients, it is assumed that only the temperature dependent physical properties need to be adjusted. Experimental data to validate this assumption and/or to develop alternate models that are applicable at various scales from the laboratory to field are scarce. This paper presents the preliminary results from a study that is designed to fill this knowledge gap in the application of thermal technologies at field sites with complex DNAPL entrapment architecture.

Concentration data obtained from a series of column experiments using a test DNAPL (PCE), entrapped at residual saturation was used to estimate temperature dependent mass transfer rate coefficients. The data was analyzed based on a factorial design with temperature, grain size and water interstitial velocity as factors. Rate coefficients estimated from the experimental data were used to develop Gilland-Sherwood expressions. Analysis of the expressions shows a physically unrealistic inverse relationship between Sherwood number and DNAPL content may be a result of how the residual zone was created in the experiment. Examination of the exponents of the dimensionless groups in the G-S correlations shows that they are dependant on the temperature and grain size. This observation suggests that G-S correlations can introduce significant errors, when used to predict mass transfer rates at temperatures and grain sizes that are different from the conditions of the experiments that were used to develop these empirical correlations. Further study is needed to resolve this issue to develop practical methods to up-scale laboratory information to field applications.