Finite Element Modeling of Heterogeneous Soils with Non-linear Properties for the Design of an Electrothermal In Situ Thermal Remediation Project

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Background/Objectives. Modeling the electromagnetic field coupled with the heat and mass transfer equations, which are the fundamental physics of an electro-thermal remediation process, is a required step in the design of a system for a site-specific application. There are inherent limitations with the numerical modeling process. However, it is a significant achievement if the model can incorporate non-linear physical properties and the heterogeneities of site-specific geology. With this information, the model can then be used in engineering design to confirm the electrode spacing, power system and cable specifications, vertical and lateral placement of the electrodes in the heated volume, and so on. Fortunately, the state of the art in numerical modeling provides tools to solve such problems. It is possible to assemble the multi-physics equations with non-linear properties using open source finite element software and obtain useful results. The focus of this study is to detail the assembly of the multi-physics equations, describe the non-linear properties, and demonstrate how they are coupled in the model. A site-specific scenario was modeled that helped in the engineering design of an electro-thermal in-situ thermal remediation process.

Approach/Activities. The case for the relevant multi-physics equations for an electro-thermal heating process is made. The non-linear physical properties of import are specified using data from the public domain and a specific site. The geologic conceptual model with all its heterogeneity is defined based on known lithology obtained from core wells. The model input data set along with the equations defining the physics are assembled and several runs are completed to provide a design basis for an electro-thermal in-situ thermal remediation process.

Results/Lessons Learned. The results demonstrate the utility of using finite element modeling in providing a basis for engineering an electro-thermal process for in-situ thermal remediation. The non-linear property that most affected electrical operating parameters was the dependency of the soil's electrical resistivity with temperature. A threefold decrease in resistivity over the temperature transformation results in making sure the Power Delivery System is designed to deliver the maximum operating current throughout the duration of the project. The modeling also demonstrates how important it is that the vertical placement of electrodes considers the geology. Improper placement of the electrodes can result in current taking the path of least resistance and preferentially heating one region over another. The impact of other non-linear properties on design is also discussed.