Fiber Optic Sensors for Distributed Monitoring of Soil and Groundwater during In Situ Thermal Remediation

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This paper is focused on the development and field deployment of multi-parameter and distributed fiber optic sensors for monitoring of soil and groundwater during in-situ thermal remediation of contaminated brownfields. In situ thermal remediation (ISTR) is a process in which the soil and groundwater are heated using localized heat sources to evaporate and extract hazardous substances and pollutants from brownfields. In this research, the unique advantages of fiber optic sensors are leveraged through the development of transducers for distributed sensing of soil temperature and level of groundwater which are critical performance parameters for assessing the efficiency of any ISTR process.

ISTR is an efficient contamination removal process using localized heat sources inserted deep into the soil to heat up the soil to a target temperature. Elevated temperature causes the vaporization of hazardous substances and pollutants which are then extracted by the soil vapor extraction (SVE) system. The success of the ISTR process is highly dependent on the accurate measurement of soil temperature distribution and water table at multiple locations. Environmental remediation is a process which occurs deep in the soil saturated with highly corrosive chemicals such as chlorinated solvents and volatile organic compounds (i.e., tetrachloroethylene, polychlorinated biphenyls, and methylene chloride) known as VOC. However, due to the severe conditions (high temperature, harsh chemicals, and the electromagnetic interference generated by electric heaters), the state-of-the-art electronic based sensors fail or lose performance in such environments.

In this study, a distributed fiber optic pressure and temperature sensor, based on fiber Bragg gratings (FBG), has been developed for the accurate and high-fidelity measurement of soil temperature and the level of groundwater through hydrostatic pressure sensing. The prototypes have been successfully field-tested in brownfields and federal Superfund remediation sites and the results have been compared with electronic transducers. In this research, several key challenges related to material compatibility of transducers, high-resolution and low-pressure sensing, and temperature compensation for pressure monitoring have been addressed by using metal embedded fiber optic sensors.

The sensors have been deployed in Superfund sites and other brownfield in-situ remediation projects. The performance of the temperature sensors has been benchmarked against standard thermocouple sensors by co-locating arrays of both types of sensors in a thermal well in a remediation project using electric conductive heating (ECH). The fiber optic temperature sensors outperform existing temperature sensors especially in remediation projects in which electric heating generates electromagnetic interference. One of the distinguishing features of fiber optic sensors is their premium performance unaffected by the deployment depth, i.e., sensors located near the ground surface and the ones placed at the bottom of the wells have the same accuracy and transient response.