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Analyses of Soil Volatile Contaminants Extraction by Hot Air Injection

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Abstract : Remediation of soil containing volatile contaminants is often conducted by vapor extraction (SVE) technique. The operation is based on injection of air at ambient temperatures with or without thermal soil warming. Thermal enhancements of soil vapor extraction (TESVE) processes are usually conducted by soil heating, sometimes assisted by added steam injections. The current study addresses a technique which has not received adequate attention and is based on using exclusively hot air as an alternative to the common TESVE practices. To demonstrate the merit of the hot air TESVE technique, a sandy soil containing contaminated water is studied. Numerical and analytical tools were used to evaluate the rate of decontamination processes for various geometries and operating conditions. The governing equations are based on the Darcy law and are applied to an expanding compressible flow within a sandy soil. The equations were solved to determine the minimal time required for complete soil remediation. An approximate closed form solution was developed based on the assumption of local thermodynamic equilibrium and on a linearized representation of temperature dependence of the vapor to air density ratio. The solution is general in nature and offers insight into the governing processes of the soil remediation operation, where self-similar temperature profiles under certain conditions may exist, and the noticeable role of the contaminants evaporation and recondensation processes in affecting the remediation time. Based on analyses of the hot air TESVE technique, it is shown that it is sufficient to heat the air during a certain period of the decontamination process without compromising its full advantage, and thereby, entailing a minimization of the air-heating-energy requirements. This in effect is achieved by regeneration, leaving the energy stored in the soil during the early period of the remediation process to heat the subsequently injected ambient air, which infiltrates through it for the decontamination of the remaining untreated soil zone. The characteristic time required to complete SVE operations are calculated as a function of, both, the injected air temperature and humidity. For a specific set of conditions, it is demonstrated that elevating the injected air temperature by 20oC, the hot air injection technique reduces the soil remediation time by 50%, while requiring 30% of additional energy consumption. Those evaluations clearly unveil the advantage of the hot air SVE process, which for insignificant cost of added air heating energy, the substantial cost expenditures for manpower and equipment utilization are reduced.

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