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Limits of Contaminants Vapor Extraction from Soil by Hot Air Injection Based on Propanol Clean-up Analyses

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Extended Abstract

Soil vapor extraction (SVE) is a recognized method for removal of toxic substances from contaminated soils. The method has been proved to be environmentally and economically effective. There are several methods of performing SVE operations, among which are thermally enhanced soil vapour extraction methods (TESVE). Both, electrical soil heating and steam injection are examples of established TESVE methods. The current research work is aimed to define the conditions that justify conducting TESVE operations solely by injection of hot air. That method has not yet received adequate attention. To conduct the study, an analytical model was developed and extended to reveal the physical parameters that governs the contaminants clean-up rate around air injection wells. In the current research, it was previously discovered that incorporation of in-situ heat regeneration could save substantial heating energy. This is implemented by using the soil stored heat, gained during the first phase of the clean-up operation, to heat the ambient air injected subsequently. This practice is aimed to leave minimal residual heat in the soil at the operation end. The model was tested against numerical calculation and is currently used to evaluate the effectiveness of this SVE method subject to the contaminant physical properties. For realist considerations, the method limitations were examined through the study of a propanol clean-up operation. In principle, the analytical model contains groups of mathematical expressions that govern the clean-up duration time. Each of this expression depends on a combination of dimensionless physical properties and operational parameters, which encompass: the ratio of the vapor to air density, the ratio of the injected air heat capacity to that of the soil, the ratio of the vapor latent heat to the injected air sensible heat, and dimensionless expressions of the temperatures. Each of the expression has a physical significance as well as a quantitative value. To study the impact of each material property and operational condition on the attractiveness of the clean-up operation, each property and operational condition was separately changed by 10%. The results unveiled the relative importance of the dimensionless parameter and the conditions that warrants the incorporation of the hot air injection method. For a propanol spill, heating the injected air by 30°C reduces the clean-up duration time by roughly 20%. The analyses indicates that the hot air method is slightly more advantageous for spills of materials which have larger latent heat properties. For example, if the propanol latent heat was 10% larger, the reduced clean-up duration time would be 22% rather than 20%. As expected, the vapor-density impact on the clean-up duration time is far reaching. However, the benefit of the hot air method for propanol was found to steeply diminish for spill of materials that have higher ratios of vapor to air densities both, in terms of absolute values and higher sensitivity to temperature changes. In reference to the clean-up duration time, it is therefore concluded that the hot air SVE method is particularly attractive for clean-up of low-volatility material spills. As for volatile materials, initial analyses indicate that the saved clean-up duration time tracks quiet proportionately the vapor to air density-ratio-rise with temperature.