Soil, Sediment, Bedrock and Sludge

Thermal Treatment

Introduction

Steam/hot air injection or electrical resistance/electromagnetic/fibre optic/radio frequency heating is used to enhance the volatilisation rate of semi-volatiles and facilitates in the removal or extraction process.

Description:

Thermally enhanced SVE is a full-scale technology that uses electrical resistance/electromagnetic/fibre optic/radio frequency heating or hot-air/steam injection to increase the volatilisation rate of semi-volatiles and facilitate extraction. The process is otherwise similar to standard SVE, but requires heat resistant extraction wells.

Thermally enhanced SVE is normally a short- to medium-term technology. In this case it may be adopted as an emergency approach as the cost issue may prohibit it as a long-term approach.

Electrical Resistance Heating:

Electrical resistance heating uses electrical currents to heat less permeable soils so water and contaminants trapped in these moderately conductive regions are vaporised and available for vacuum extraction. Electrodes are positioned into the less permeable soil matrix and activated so that electrical current passes through the soil, creating a resistance, which heats the soil causing it to fracture. The fractures cause the soil to be more permeable therefore permitting the use of SVE to remove the contaminants. The heat furthermore forces trapped liquids to vaporise and shift to the steam zone for removal. Six-phase soil heating (SPSH) is an electrical resistance heating which employs low-frequency electricity delivered to six electrodes in a circular array to heat soils. The temperature of the soil and contaminant is increased, thus increasing the contaminant's vapour pressure and its removal rate. SPSH also generates an *in situ* source of steam to strip contaminants from soil.

Radio Frequency/Electromagnetic Heating:

Radio frequency heating is an *in situ* process that uses electromagnetic energy to heat soil and improve soil vapour extraction. The technique heats an isolated volume of soil using rows of vertical electrodes embedded in soil. The volumes are surrounded by two rows of ground electrodes with energy applied to a third row midway between the ground rows. The three rows operate as a buried triplicate capacitor. When energy is directed to the electrode array, heating commences at the top centre and continues vertically downward and laterally outward through the soil. The technique can heat soils to over 290 °C.

The process boosts SVE in four ways: (1) contaminant vapour pressure and diffusivity are increased by heating, (2) soil permeability is increased through drying, (3) an increase in the volatility of the contaminant from *in situ* steam stripping by the water vapour; and, (4) a decrease in the viscosity which aids mobility. The technology is self-limiting due to the fact the soil heats and dries, the current will stop flowing. Extracted vapour can be treated by means of a number of existing technologies, for instance granular activated carbon or incineration.

Hot Air/Steam Injection:

Hot air or steam is injected below the contaminated zone to heat the contaminated soil. The heating enhances the release of contaminants form soil matrix. A number of VOCs and SVOCs are removed from the contaminated zone and transported to the surface by way of soil vapour extraction.

Applicability:

High moisture content is a limitation of SVE that thermal enhancement might overcome. Heating, particularly radio frequency heating and electrical resistance heating can enhance airflow in high moisture soils via evaporating water. The system can treat SVOCs but is also able to treat VOCs. Thermally enhanced technologies are valuable in treating some pesticides and fuels, this being governed by the temperatures accomplished by the system. After application of this process, subsurface conditions are good for biodegradation of remaining contaminants.

Limitations:

- Debris or other large objects buried in the media can cause operating difficulties and the penetration is compromised.
- Performance in extracting certain contaminants varies depending upon the maximum temperature achieved in the process selected.
- Soil with a reduced permeability to air constrains the operation of thermally enhanced SVE and requires more energy input to increase vacuum and temperature.
- Soil with highly variable permeabilities may result in uneven delivery of gas flow to the contaminated regions.
- Soil that has a high organic content has a high sorption capacity of VOCs, which results in reduced removal rates. In such cases a clean-up target based on total concentration of chemical of concern could be difficult to realise.
- Air emissions may need to be regulated to eliminate possible harm to the public and the environment. Air treatment and permitting will increase project costs.
- Residual liquids and spent activated carbon may require further treatment.
- Thermally enhanced SVE is not effective in the saturated zone; however, lowering the aquifer can expose more media to SVE (this may address concerns regarding LNAPLs).
- Hot air injection has limitations due to low heat capacity of air.

Data Needs:

The depth and extent of contamination, concentration of contaminants, depth to water table, and soil properties such as texture, permeability, and moisture content are all desirable.

Performance Data:

Thermally enhanced SVE processes are especially different and must be examined independently for detailed information. As it is an *in situ* technology and all contaminants are under a vacuum throughout operation, the likelihood of contaminant release is significantly reduced.

As with SVE, remediation projects utilising thermally enhanced SVE systems are dependent upon the soil and chemical properties. The average site consisting of 18,000 tonnes of contaminated media would necessitate roughly 9 months.

Cost:

The key cost driver is soil type, which also drives the soils permeability. For thermal treatment, soils with lower permeability are less costly to treat, as they need less gas flow.

Depth to the contaminated area is a secondary cost driver. A deeper and thicker region of contaminated soils will incur higher remediation costs.