Thermal Treatment: How Much Energy Does It Take?

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Background/Objectives. Thermal conductive heating (TCH), electrical resistance heating (ERH) and steam enhanced extraction (SEE) are widely used thermal technologies capable of effectively remediating a variety of chemicals from different geological settings, ranging from tight clays to permeable sands. During thermal applications, the energy needed to reach project goals, is one of the major resources that contributes to the environmental footprint and cost associated with implementing these thermal technologies. It is crucial that sufficient energy is delivered to the subsurface to overcome site heat demands, balance heat losses, and to facilitate enough boiling and steam stripping to meet remedial objectives. This study focused on a detailed analysis of these energy needs and certain vendor claims of superior energy efficiency.

Approach/Activities. A thorough review of actual energy usages on several thermal projects utilizing both TCH, ERH and SEE was conducted. Data assembled from over 100 sites that were completed by a number of major in-situ thermal vendors were reviewed and the energy usage was correlated with not only the technology, but also the specific site conditions, contaminant type and mass removal, operational timeframe and final remedial goals achieved to generate a representative dataset. The following relationships, among others, were evaluated:
• The role of key soil properties like porosity and saturation for the subsurface heat capacity and therefore for the energy needed to increase the temperature and boil off portions of the pore water.
• Specific site conditions like the size and shape of the site and local groundwater flow.
• The influence of the volatilization and mobility of the target contaminants with temperature and associated changes in vapor pressure, Henry's constant, viscosity and soil-water partitioning coefficient with temperature.
• The thermal design and heating technology applied. Pumping and extraction strategies dictate the amount of energy removed from the subsurface, injected liquids adds heat capacity while a thermal-vapor cap mitigates heat losses at the surface.
• The numeric remedy goals and exit strategy.
These factors play into the overall site energy balance and therefore the total energy usage to reach the remedy goals.

Results/Lessons Learned. Datasets indicated a big differential on energy usages - even within the same technology for the same contaminants. While a theoretical calculation shows that 90-150 kWh/m^3 (70-115 kWh/cy) typically will be required to meet treatment goals for VOCs, actual site data indicate that 290-330 kWh/m^3 (220-250 kWh/cy) are typically required. Heat losses play a major role in energy consumption and needs to be properly evaluated. Once the site specific conductive and convective energy losses and additional specific heat requirements associated with groundwater flow at the sites is properly considered and accounted for, the energy demands for the three different heating technologies are very similar.