Thermal Conductive Heating (TCH): comparison of power consumption to heat the soil between electrical resistance and gas fired burners

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Thermal desorption is an environmental remediation technology that uses heat to increase the volatility of contaminants (organic and/or inorganic) as such that they can be removed from solid matrix (typically soil). A thermal remediation installation for soil treatment consists in two phases. Firstly, the properly called thermal desorption, which separates contaminants from the soil by temperature elevation. Secondly, the recycling or destroying of the separated pollution (Saadaoui et Haemers 2015)

This document will focus on two existing in situ thermal desorption techniques used to heat the soil to a desired temperature. Injection of heat with the use of electrical resistance and with thermal conduction from combustion of natural gas. In situ thermal desorption uses thermal conductive heating elements to directly transfer heat to soil.

Heating efficiency

Even if the two cited techniques differ by which source the heat is injected, the physical principles stay the same. The designs and calculations are made considering the injection of power per linear meter of heating element. The first method typically injects 2 kW per meter of heating element with thermal conduction with hot air from combustion of natural gas. From these 2 kW/m, only 1 kW/m will be injected into the soil. On the other hand, the second method typically injects around 1 kW directly into the soil using electrical power (Heron et al. 2015) (J. Bukowski et al. 2018).

The amount of energy injected into the soil regardless of the technique is the same because it can be estimated that most soils cannot accept more than approximately 1 kW per linear meter of heating element (United States. Army. 2009).

To summarize, the method of heat injection with electrical power directly injects 1 kW/m, when the method of heat injection by thermal conduction has a 50-55% efficiency, therefore needs to produce 1.8-2 kW/m to inject 1 kW/m. The question now is how is this electricity produced ? Is it really more effective to use electricity than thermal conduction with hot air from combustion to heat the soil ? Table 1 shows typical values of power yields of different electricity production sources.

Source of electricity production	Yield	Power needed to create 1 kW of electricity (kW)
Thermal conventional	35 – 40 %	2.5 – 2.85
Thermal with combined cycles	Up to 50 % (60% for gas)	2 (1.6)

Table 1: Yield of different sources for electricity production (Trüby 2014)

We can see that the yield of conventional thermal plants can vary between 35 and 40%, which means that the amount of energy to be brought (in the form of combustion of natural gas for example) to produce 1 kW of electricity is between 2.5 and 2.85 kW. As for the new thermal plants, that significantly improved their yield in the last years, it can go up to 60% of efficiency for electricity production from the combustion of natural gas. It means that the energy amount to be brought to produce 1 kW of electricity can be brought down to 1.6 kW.

Power consumption

It is also interesting to compare the typical global power consumptions of the two techniques to heat the soil. The electrical technique typically uses 200 – 400 kWh/m³ of soil (Heron et al. 2015), when the combustion technique typically uses 45-65 kg of natural gas per cubic meter of soil, which means 619 – 894 kWh / m³ of soil (considering the combustion heat of natural gas as 49.500 kJ/kg). These results have a wide range because the final consumption will depend on several factors such as the soil initial humidity, porosity and remediation targets.

Again, these two power consumptions must be brought to the same level of comparison, as the needed power in terms of natural gas to produce 1 kW of electricity can vary from 1.6 kW to 2.85 kW depending on the type of thermal plant (Table 1). If we take these two extremes of yields, we get to an electrical power consumption in terms of combustion of natural gas between 320 – 640 kWh/m³ for the best case and 570 – 1140 kWh/m³ for the worst case (when the direct natural gas consumption to heat the soil with thermal conduction can vary from 619 to 894 kWh/m³).

Conclusion

The difference between the two techniques in terms of power efficiency and consumption will depend on the type of thermal electricity production. Whether the electricity production is advanced or not, the advantage given to one technique can easily become the advantage of the other depending on the electricity production rates of the countries in which thermal remediation projects will take place. As of now, very few thermal plants can reach a yield of 60% with natural gas. We can globally admit that with the current sources of electricity production, the two techniques are very close to each other in terms of consumption and efficiency.

Of course, an important factor to consider is the location of the remediation sites, as depending on their sizes, a thermal desorption installation using electrical resistance may need a lot of electrical power supply, up to several megawatts, which cannot always be supplied. As a matter of fact, because of this issue, this method requires more time and power (due to power loss over time) because the number of electrical elements must be reduced (distance between each element increases), which explains the time needed to heat the soil. A problem that does not encounter thermal desorption installations using thermal conductivity from combustion, as natural gas (or other) can be supplied more easily.

Another advantage for thermal desorption with thermal conductivity from combustion is that these installations can apply what is called “reburn”. It consists in burning the vaporized contaminants (hydrocarbons only) directly inside the combustion chamber used for the heating. It needs a much smaller installation and can reduce the natural gas consumption and increase the thermal efficiency.

References

Heron, G., K. Parker, S. Fournier, P. Wood, G. Angyal, J. Levesque, et R. Villecca. 2015. « World’s Largest In Situ Thermal Desorption Project: Challenges and Solutions ». *Groundwater Monitoring & Remediation* 35 (3): 89100. https://doi.org/10.1111/gwmr.12115.

J. Bukowski, Robert, James P. Galligan, Ken Parker, Courtney M. Duteau, Myron Kuhlman, et Edward H. White. 2018. « IN-SITU THERMAL DESTRUCTION (ISTD) OF MGP WASTE IN A FORMER GASHOLDER: DESIGN AND INSTALLATION », septembre.

Saadaoui, Hatem, et Jan Haemers. 2015. « La désorption thermique pour les sols pollués ».

Trüby, Johannes. 2014. « Thermal Power Plant Economics and Variable Renewable Energies ». *International Energy Agency* Insight Series: 38.

United States. Army. 2009. *Engineering and design : design, in situ thermal remediation /*. Washington, D.C. : U.S. Army Corps of Engineers,.

