Thermal In Situ Sustainable Remediation (TISR®): Accelerating the Path to Site Restoration

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Introduction and Background

TISR® is a low-temperature thermal remediation technology that transfers energy from solar radiation and/or waste heat to the subsurface to maximize conductive heat transfer and target low temperature thermal remediation temperature ranges. These sustainable energy sources are used to heat the subsurface by means of a closed-loop heating system circulating through borehole heat exchangers (BHEs). Thus, TISR® serves as a sustainable alternative to traditional mass recovery methods like excavation or energy-consuming treatment systems and can also be used to complement other remedial technologies such as air sparging, biosparging, chemical oxidation, biologic, and other degradation processes.

Figure 1 provides a layout of the various components of the TISR® system. Additionally, TISR® components include a conveyance manifold and branches, monitoring wells, and temperature sensing points.

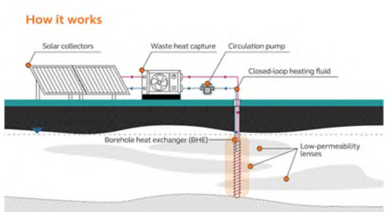

Figure 1: Process Flow Diagram for TISR™ (solar or waste heating)

Solar and Waste Heating Applications

TISR® uses solar collectors to heat the circulating closed-loop fluid system. Circulation may automatically stop at night when solar energy is unavailable.

In addition to solar applications, waste heat has been utilized from remediation equipment and steam sources to supplement solar energy or as a standalone energy source. This technology can be integrated into existing production or processing facility with no impact to operations.

Technology Overview

- Applicable to a broad range of hydrogeologic settings, can overcome low and complex hydraulic conductivities (K), and well suited for focused source zone applications.
- Targets an ideal temperature range for mesophilic microorganisms (30-60°C).
- Moderate heat enhances abiotic mechanisms, including volatilization, desorption, and solubility.
- Primary remedial mechanisms are enhanced microbial degradation, hydrolysis, and mass transfer.
- Compliments existing enhanced in situ bioremediation (EISB) and other technologies and can be a "Bolt on" accelerant for air sparging/soil vapor extraction systems.
- Reusable components and flexible energy sources make it a versatile and customizable solution.
- Reduces carbon footprint of environmental cleanup by using sustainable energy sources, reducing vehicle travel/operation and maintenance, and leveraging and reusing infrastructure.

Providing an innovative solution that aligns to a "Triple Bottom Line" sustainability framework

Case Study: TISR® Operations and Sustainability Assessment in California

This technology was applied to enhance the treatment of chlorinated ethenes at a site on the central coast of California. The project aimed to demonstrate subsurface heating efficiency and treatment enhancement at a chlorinated solvent source zone undergoing active EISB. The site was chosen due to several technical and practical factors; however, a key criterion was the complex and heterogenous geology which limited the effectiveness of EISB and resulted in persistent high concentrations despite over a decade of active treatment. For these same reasons, well MW-41 was selected as the center of TISR® treatment. During TISR® treatment, MW-41 exhibited temperatures about 4-5ºC above observed background groundwater temperatures. Water adjacent to the BHEs was 30-35 ºC. Temperatures elevated above background supports accelerated enhanced reductive dechlorination (ERD) through EISB and increased microbial population and activity, while freeing up hard to reach mass through desorption.

Figure 2: TISR® infrastructure for solar heating (Solar Collectors) and waste heating (blower heat exchanger) applications.

Figure 3 (below): Remote monitoring and controls allows for efficient operations and fewer trips, lowering the GHG footprint.

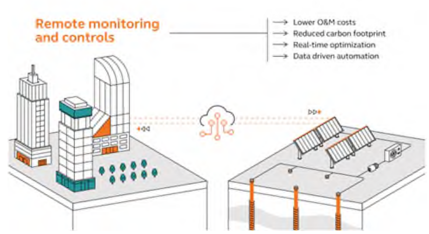

Figure 4 shows concentration trends for chlorinated ethenes at MW-41 before and after TISR® operations began. Concentration trends prior to TISR® implementation included a temporary drop off immediately after EISB carbon injections followed by rebound to concentrations similar to those observed prior to EISB. After TISR® implementation, concentrations slightly increased during the heat up phase followed by a sustained decrease in concentration of chlorinated ethenes.

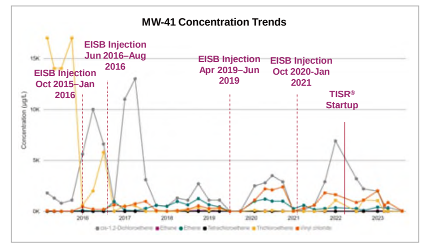

Figure 4: Chlorinated solvent concentration trends at MW-41 including carbon amendment addition and TISR® start up

A sustainability evaluation was completed comparing the site's remedial strategy with and without TISR® implementation. The sustainability analysis was completed using the GSR SiteWise™ tool developed by the Battelle Memorial Institute and the U.S. Department of Defense and maintained by the Sustainable Remediation Forum (SURF).

The first scenario considered the historical EISB strategy to present and used concentration trends to extrapolate the anticipated remedial lifecycle at the site, including an additional 20 carbon injection events for 10 years. In contrast, the TISR® scenario considered the historical EISB approach prior to TISR®, TISR® system install, and TISR® operation for 2.5 years.

As shown in Figure 5, the greenhouse gas (GHG) footprint for TISR® is driven by the heavy equipment operations, consumables, and personnel transport associated with system install. Due to the use of sustainable energy sources and remote monitoring and control of the system, the operations and maintenance have negligible carbon footprints. Overall, installing a TISR® system at the site resulted in approximately 32% lower GHG emissions, as well as lower energy and water use (Figure 6).

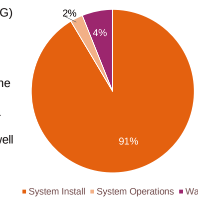

Figure 5: Breakdown of TISR's GHG footprint

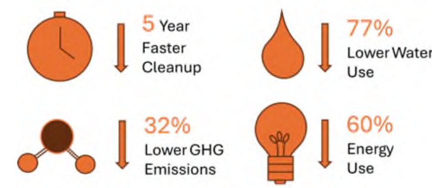

Figure 6: Sustainable impacts of adding a TISR® system at EISB site.

Additionally, TISR® implementation has community benefits that lower the social impact of site remediation. These benefits include faster cleanup and restoration as well as less traffic and noise that could be disruptive to community members. Finally, by reducing remedial timeframe, TISR® may be a more climate resilient solution for some sites by reducing long-term risks of impact migration from such events.

Conclusion

TISR® implementation has proved to be an effective, versatile, and sustainable remedial strategy by successfully:

- Supplying heat to the subsurface through sustainable heat sources such as solar collectors.
- Increasing subsurface and groundwater temperatures in MW-41 at the center of treatment area by 4-5 ºC, closer to the ideal biotic range.
- Shortening the remedial timeframe by 8.5 years, allowing the site to be restored sooner and reducing long-term risk of migration and disruption to community members.
- Lowering the GHG, water, and energy footprints compared to the "business as usual" approach.