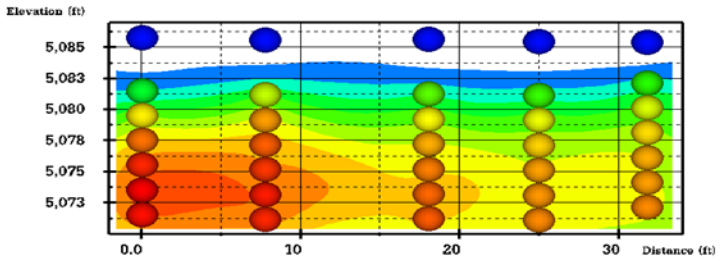
# Thermally-Enhanced Natural Assimilation




**University Consortium 2015 Fall Focus Meeting**
**Brown Palace Hotel, Denver, Colorado – Central City Room**
**November 3 and 4, 2015**

## Topic

University Consortium (UC) research, and the work by others, is driving recognition that natural assimilation processes often play a large role in managing risks at older subsurface releases of organic compounds. While natural assimilation processes are often consequential, they are also often slow with respect to desired time frames for cleanup. An emerging focus is the use of low level heating ($\Delta T$ = 5-20 °C) to passively enhance natural assimilation rates. Potential benefits of thermally enhanced natural assimilation include reduced longevity of releases, greater sustainability, and reduced life cycle costs for sites.

## Overview

Heat is fundamental to rates of biotic, rates of abiotic reactions, transport processes, and partitioning of contaminants between phases. At a physical level, heat affects 1) vaporization, sorption, and (for some compounds) aqueous solubilities of organic compounds, 2) flow of fluids due to reduced viscosities, 3) diffusive fluxes through increased diffusion coefficient, and 4) frequencies of high-energy collisions between contaminants and reactants. Additional effects for biotic reactions are shifts in the microbial community, leading to increased rates of reactions by enabling advantageous metabolic pathways. Use of heat to enhance reaction rates is common in both waste-water treatment and refining processes. Respectively, examples include elevating temperature in tertiary waste-water treatment systems and use of heat to accelerate reactions in

chemical refining processes. Conversely, lowering temperature (e.g., refrigeration) is a common strategy for constraining degradation of organic compounds.

Appealing aspects of heat include 1) its storage and movement are largely well understood, 2) the parameters governing heat fall into narrow ranges as compared to parameters associated with transport of chemicals in porous media, 3) continuous measurement of temperature is simple, and 4) secondary known water-quality effects are limited. Numerous options exist for increasing subsurface temperatures. Examples include electrical resistance heating, conductive heating, convective heating (e.g., warm water floods), and modifying surface energy fluxes (e.g., solarization). Sources of energy for low-level heating can include electric power from conventional and or renewable sources, direct solar inputs, and/or waste heat from industrial processes. In addition, heat can be supplied through accelerating degradation of contaminants that degrade through exothermic reactions. For example, in-situ degradation of petroleum produces heat in the same way that landfills and compost piles generate heat.

## Purpose

The purpose of the meeting is to examine the state-of-the-art science relating to thermally-enhanced natural assimilation. Furthermore, the meeting will identify research opportunities supporting advancement of a promising solution for older subsurface releases of organic contaminants.

## Scope

Per prior focus meetings, the first day will center on presentations from leading experts and related discussions. Specific topics that will be addressed include:

- The effects of heat on reaction rates for biotic and abiotic processes
- A review of processes controlling temperature in subsurface media
- Methods for increasing subsurface temperatures
- Methods for monitoring the performance of thermally-enhance natural attenuation
- Results from laboratory and field demonstrations of thermally-enhance natural attenuation

On the second day (morning), key knowledge from the first day will be summarized, and future research needs will be resolved. Per prior focus meetings, it is anticipated that the second day will be a lively conversation leading to novel insights and a constructive path forward. Presentation material that the speakers are free to share will be distributed along with meeting notes after the meeting.

# DRAFT PROGRAM

**10/26/15**

All speakers should plan on splitting the allocated time between presentations and discussion/questions.

| **Tuesday, November 3rd, 2015** | | |
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| **7:30 – 8:00 Continental Breakfast** (coffee, juice, baked goods, fruit) | | |
| **Overview**<br>**Moderator: Tom Sale (Colorado State University)** | | |
| 8:00-8:05 | John Cherry/ Univ. of Guelph | Welcome & focus meeting format |
| 8:05-8:25 | Tom Sale | Meeting logistics & comments on thermally-enhanced natural assimilation |
| 8:25-8:50 | Paul Tratnyek/ Oregon Health & Science University | Effect of heat on physical processes and abiotic reactions |
| 8:50-9:15 | Shaily Mahendra/ UCLA | Effects of heat on biotic reactions |
| 9:15-9:40 | Jay Ham/Colorado State University | Natural processes controlling subsurface temperatures |
| **9:40 – 10:00 Break** | | |
| **Effects of heating on contaminant assimilation**<br>**Moderator: Beth Parker (University of Guelph)** | | |
| 10:00-10:20 | Beth Parker/ University of Guelph | Monitoring temperature in boreholes |
| 10:20-10:45 | Susan de Long/ Colorado State University | Thermal microcosm studies for petroleum hydrocarbons |
| 10:45-11:10 | Emily Crownover/ TRS Group | Thermally-enhanced production of volatile fatty acids |
| 11:10-11:35 | Bruce McGee/ McMillan-McGee | Lessons from resistive heating projects |
| 11:35-12:00 | Gorm Heron/ TerraTherm | Steam, hot water, and conductive heating – effects of heating on degradation rates |
| **12:00 – 1:00 Lunch** | | |
| **Case Studies**<br>**Moderator: Doug Mackay (University of California Davis)** | | |
| 1:00-1:25 | Maria Irianni-Renno/Colorado | Sustainable thermally-enhanced natural attenuation (STELA) – Casper field demonstration |

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|---|---|---|
| | State University | |
| 1:25-1:50 | Chuck Newell/GSI Environmental Inc. | Enhancing subsurface temperature via solarization |
| 1:50-2:15 | Tom Sale/ Colorado State University | Heat from natural source zone depletion reactions at petroleum sites |
| 2:15-2:40 | Fred Payne/ ARCADIS | Acceleration of 1,1,1-TCA hydrolysis |
| 2:40-3:00 | Open Discussion | |
| **3:00 – 3:15 Break** | | |
| 3:15-3:40 | Mark Kluger/ Dajak | Low temperature resistive heating at Tacoma well 12A Superfund site |
| 3:40-4:05 | Wilson Clayton/ Trihydro | Experience with heated water floods |
| 4:05-4:30 | Greg Smith/ERM | Temperature-driven gas driven stripping of contaminants |
| 4:30-5:00 | Open Discussion | |
| **7:00 – Hockey Game**<br>Colorado Avalanche versus Calgary Flames | | |
| **Wednesday, November 4, 2015** | | |
| **7:30 – 8:00 Continental Breakfast** (coffee, juice, baked goods, fruit) | | |
| **Meeting Observations and Conclusions**<br>**Moderator: John Cherry (University of Guelph)** | | |
| 8:00-8:45 | Summary of key points from day 1 | |
| 8:45-10:00 | Opportunities to apply thermally-enhanced natural assimilation | |
| **10:00 – 10:30 Break** | | |
| 10:30-11:15 | Vision for future research | |
| 11:15-11:30 | Closing remarks | |
| **Meeting ends at 12:00**<br>**Lunch is not arranged** | | |

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Draft Questions for Friday

- Is there value in low level increases in temperature?
- What would monitoring look like for thermally enhanced natural attenuation?
- What are the most promising niches for thermally enhanced natural attenuation?
- What issues are most likely to inhibit use?
- What are likely costs?
- Are there regulatory hurtles?
- What would a demonstration for chlorinated solvents look like?
- What would a demonstration for petroleum hydrocarbon look like?
- Are there laboratory studies that would help resolve cost and performance?
- Is half of a long time any better than a long time?