Radio Frequency Heating for *In Situ* Thermal Treatment

*Ethylene Dichloride and 1,1,2-Trichloroethane in Groundwater*

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Abstract 176

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04 Lessons Learned
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RADIO FREQUENCY HEATING FOR IN SITU THERMAL TREATMENT OF ETHYLENE DICHLORIDE AND 1,1,2-TRICHLOROETHANE IN GROUNDWATER
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Progression of Business Approach

RADIO FREQUENCY HEATING FOR IN SITU THERMAL TREATMENT OF ETHYLENE DICHLORIDE AND 1,1,2-TRICHLOROETHANE IN GROUNDWATER

• Contamination within fractures
• Water-filled porosity <5%
• >95% basalt

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01 – Introduction (Abiotic Hydrolysis)

RADIO FREQUENCY HEATING FOR IN SITU THERMAL TREATMENT OF ETHYLENE DICHLORIDE AND 1,1,2-TRICHLOROETHANE IN GROUNDWATER
02 – Approach (Electromagnetic Energy)

Industrial, Scientific, Medical (ISM) Frequencies

- 5.8 GHz
- 2.45 GHz
- 915 MHz
- 433.92 MHz
- 40.68 MHz
- 27.12 MHz
- 13.56 MHz
- 6.78 MHz

Alternating Current (AC) generates electrical (red) and magnetic (blue) fields.

22.11 metres
02 – Approach (Radio Frequency Heating)

- Radio frequency (RF) electromagnetic energy transmitted *through* basalt to preferentially heat polar molecules (e.g. water).

- Similar to a microwave oven heating a cup of tea (but not the mug).
  \[ \text{Heat}_{\text{TEA}} \gg \text{Heat}_{\text{MUG}} \]

- Increased temperature *increases solubility*, making the DNAPL more *susceptible to biodegradation*, and *abiotic hydrolysis*

- Direct *source removal*

- Low O&M

- No waste production

RF at 13,560,000 Hz (13.56 MHz)

Standard 50 Hz AC
02 – Approach (Equipment)

**Input Power**
220V / 3 phase / 50 Hz

**Radio Frequency Generator**
24 kW Output / 13.56 MHz

**Matchbox**
24 kW Output / 13.56 MHz

**Coaxial Cable**
1000 V / 46 mm

**Dipole Antenna**
5 m x 89 mm

**Chiller**
Coolant Water / 43 Lpm
02 – Approach (Equipment)

- Master Power
- Temperature Controller
- RF Generator
- Matchbox
- Coaxial Cable
- Fibreoptic Temperature Sensor
- Antenna Wellhead

RADIO FREQUENCY HEATING FOR IN SITU THERMAL TREATMENT OF ETHYLENE DICHLORIDE AND 1,1,2-TRICHLOROETHANE IN GROUNDWATER
03 – Results (Antenna)

Max Antenna Temperature
114°C

Temperature inferred (sensor failure)

Max power transmitted
17 kW

Power cycling (on/off) during:
- Maintenance
- Temperature monitoring
- Groundwater sampling
03 – Results (Groundwater Temperature)

Jan 2019

Initial Groundwater Temperature
~20°C (~68°F)

Apr 2019

Maximum Groundwater Temperature
~78°C (~172°F)

Depth (metres)

A 19.9 20.9 20.9
B 19.9 20.5 20.3
C 19.8 20.0 19.9
D 18.9 19.3 19.6

Initial Groundwater Temperature
~20°C (~68°F)

Maximum Groundwater Temperature
~78°C (~172°F)
03 – Results (Groundwater Temperature)
03 – Results (Groundwater Chemistry)

Decreasing EDC
Increasing VC

Progression of Business Approach

RADIO FREQUENCY HEATING FOR IN SITU THERMAL TREATMENT OF ETHYLENE DICHLORIDE AND 1,1,2-TRICHLOROETHANE IN GROUNDWATER

RFM_4A
RFM_3A
RFM_2A
RFM_1A

Percent Contribution

Total CVOC Concentration (µg/L)

EDC
CVOCs
Aromatics
04 - Lessons Learned

ROI >4 metres for an individual well

Model simulations predict compounded thermal influence at full-scale

Next steps to include:
• Multiple-well configurations
• Options for renewable energy source to power RFH System (e.g. solar)
05 - Conclusions

- **Focused**. RFH effectively targets polar molecules (groundwater)
- **Effective**. Simply increasing the temperature accelerates abiotic hydrolysis
- **Efficient**. Energy not wasted through directly heating the basalt
- **Heat Storage**. Basalt absorbs and retains heat from the groundwater = opportunity for optimisation
- **Sustainable**
  - **Energy Consumption**. Low energy consumption (25 kW) per antenna
  - **Low Cost**. Electricity cost ~ $60/day
  - **No Waste**
Thank you!

The business of sustainability