Superheated In-situ Thermal Treatment of SVOCs/VOCs Sites with Simultaneous Vapor Treatment Applying GTR-O Technology

GTR | Gas Thermal Remediation

Dr. Xiaosong Chen, PE

GEO | Environmental Remediation Company

Outline of Today's presentation

(1) One Successful Case Study

- **Why Thermal Remediation**

(2) Several Failed Case Studies

- **What Challenge we encountered**

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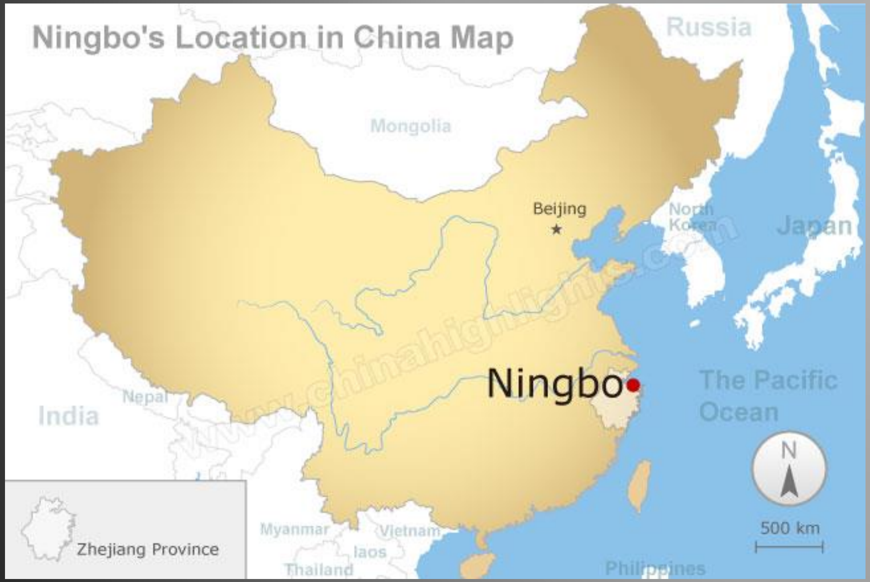
(1) One Case Study (Ningbo, China)

- **Area: 600 m^2 * 14 m bgs**
- **Former chemical industrial area**



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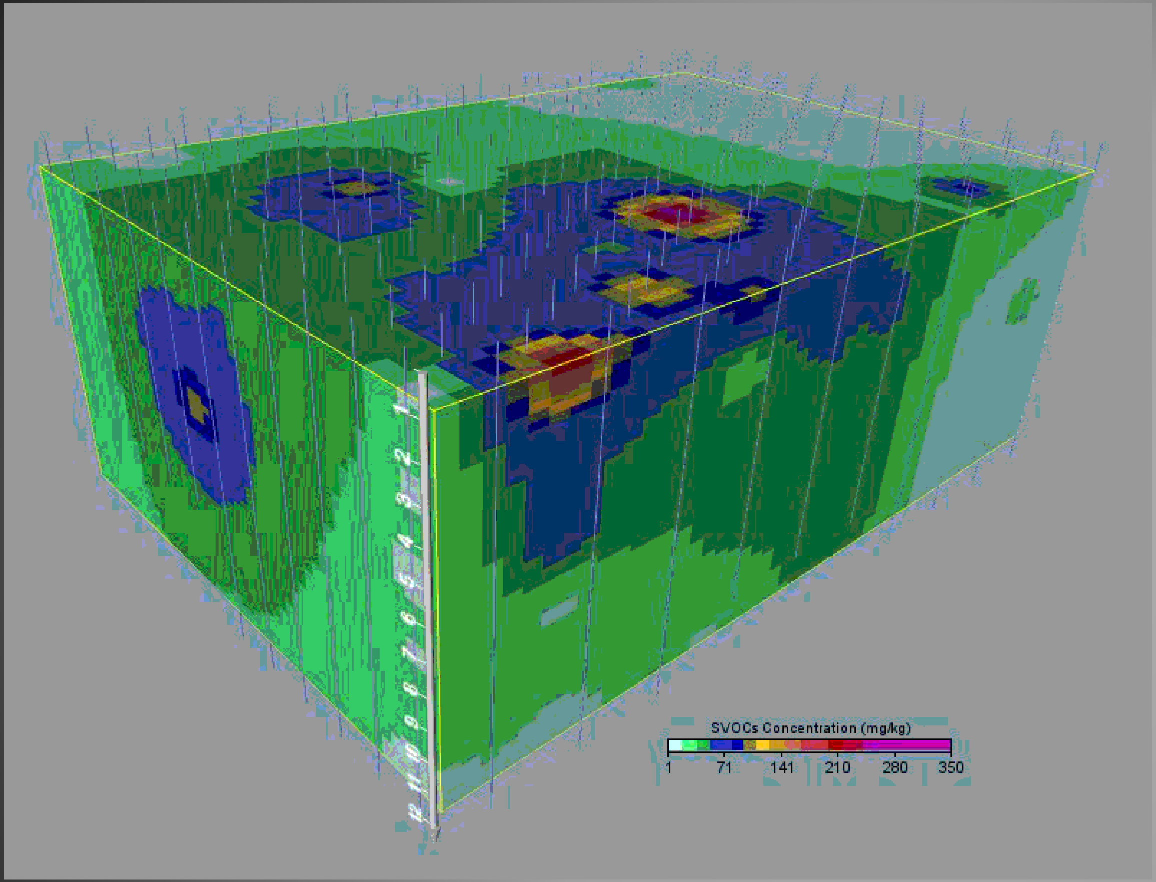
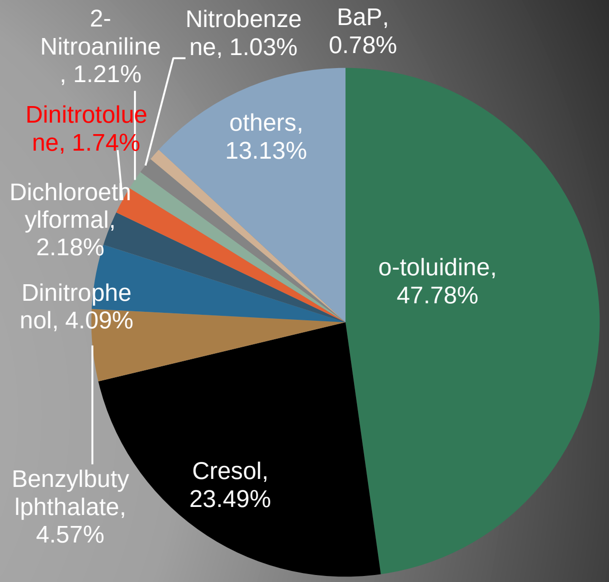
Site Challenge 1

- Lithology: silt and clay
- **Low Soil Permeability**
- **Highly Heterogeneous Hydrogeology**
- Groundwater level: <1m bgs
- hydraulic conductivity < 1×10^{-6} cm/s

Site Challenge 2





COC	Max Conc. (mg/L)	Remedial Goal (mg/L)
o-toluidine	770	0.43
Vinyl Chloride	26.1	0.023
DCE	0.816	0.19
2,6-Dinitro-toluene	1.05	0.051
2,4-Dinitro-toluene	3.22	0.058
5-nitro-o-toluidine	54	3.35
TPH	44.9	2.42

COC	Max Conc. (mg/kg)	Remedial goal (mg/kg)	Boiling point (° C)
Dinitro-toluene	65	11.43	300
o-Toluidine	271	20.77	200
DCE	147	10.65	84

Challenge 3

- Tight schedule

  less than 5 months from mobilization to de-mob

- Tight Budget

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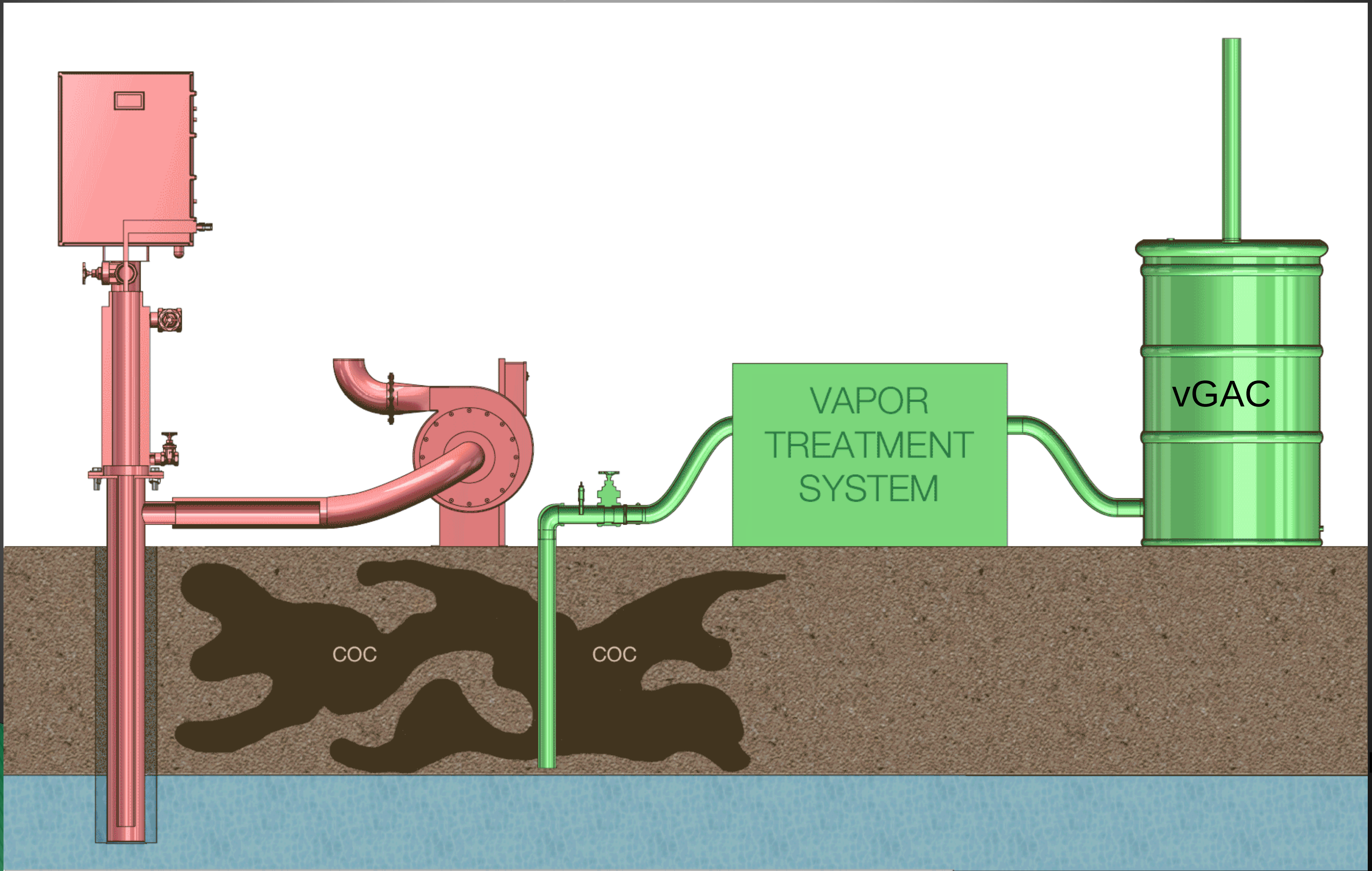
What is GTR

GTR= Gas Thermal Remediation

- Propane/Natural gas/Diesel as fuel to heat the thermal conduction heater wells.
- Soil and groundwater are heated indirectly through conduction. Treatment temperatures from **~100°C** to **>400°C.**
- Vaporized contaminants collected from extraction wells are routed to the appropriate vapor treatment module.
- Closed-loop in-situ thermal conduction heating system. No pollution emission into atmosphere.



Heaters Safety

Industrial requirement: 0.8MPa；
Business requirement: 0.4MPa；
Residential requirement: 0.1~0.2MPa

Household stove
1.5~3 Kpa

3.4 Kpa

0.5~2 Kpa
0.074 KW

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Fuel source

Propane Tanks

Natural Gas Pipe

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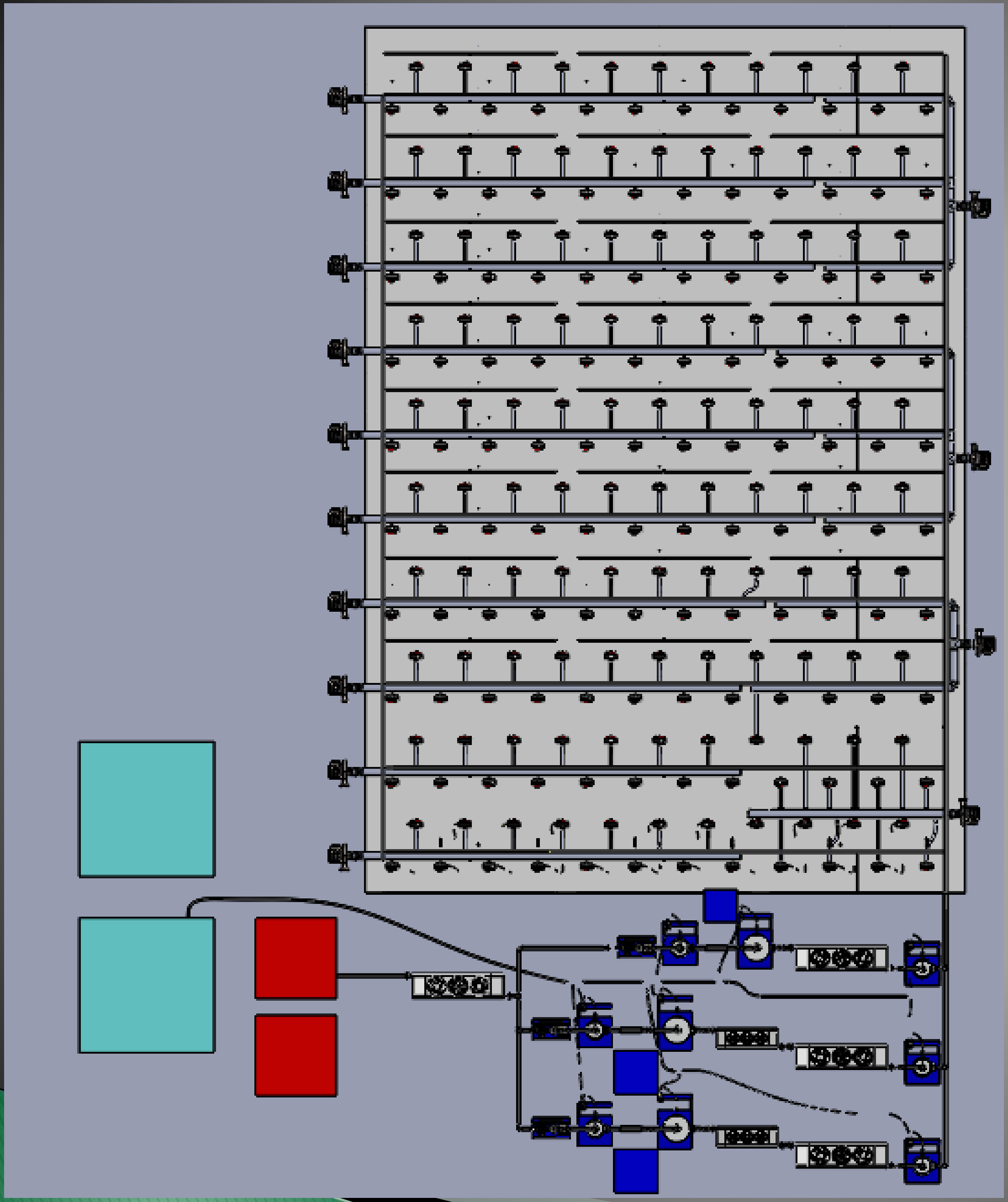
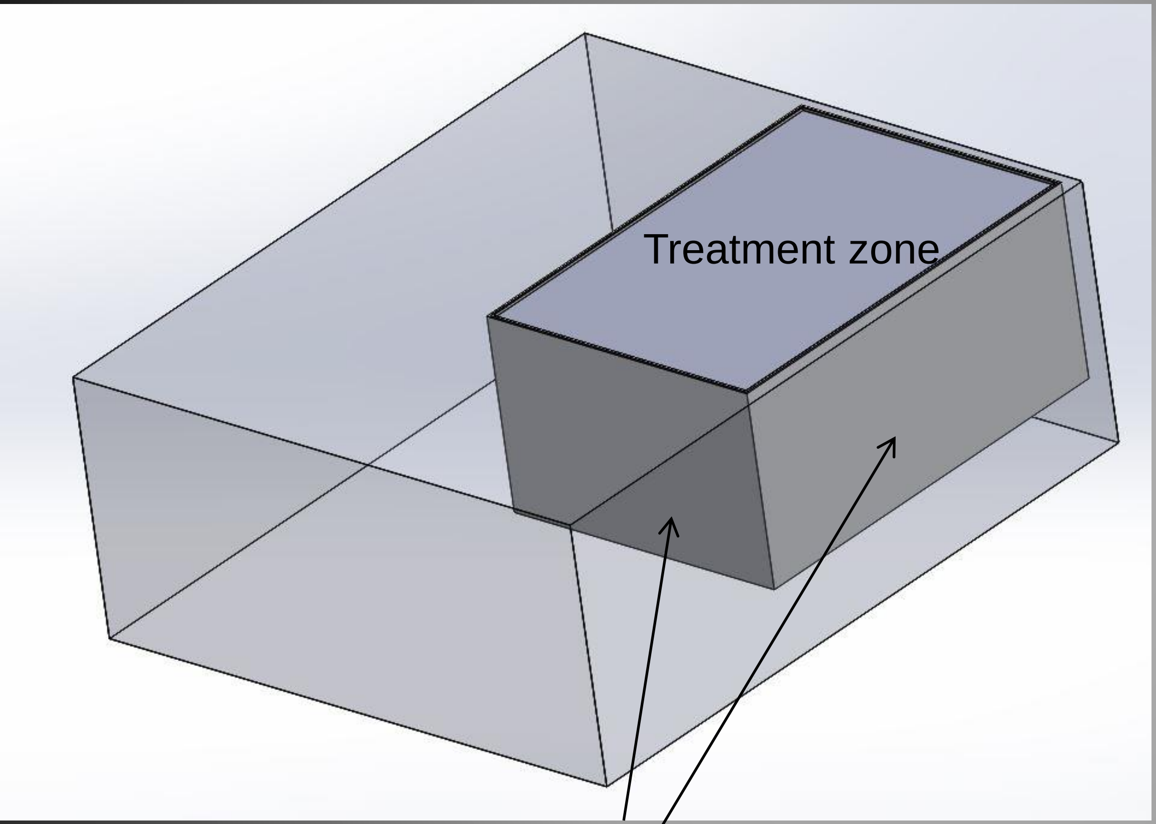


In Situ GTR =

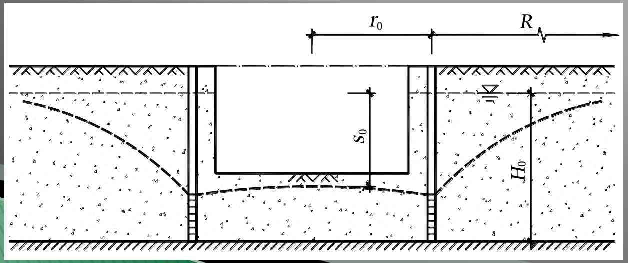
In Situ Heating

+Vapor Extraction and Treatment

ISTR installation
Site Preparation and sheet pilling



Sheet pilling



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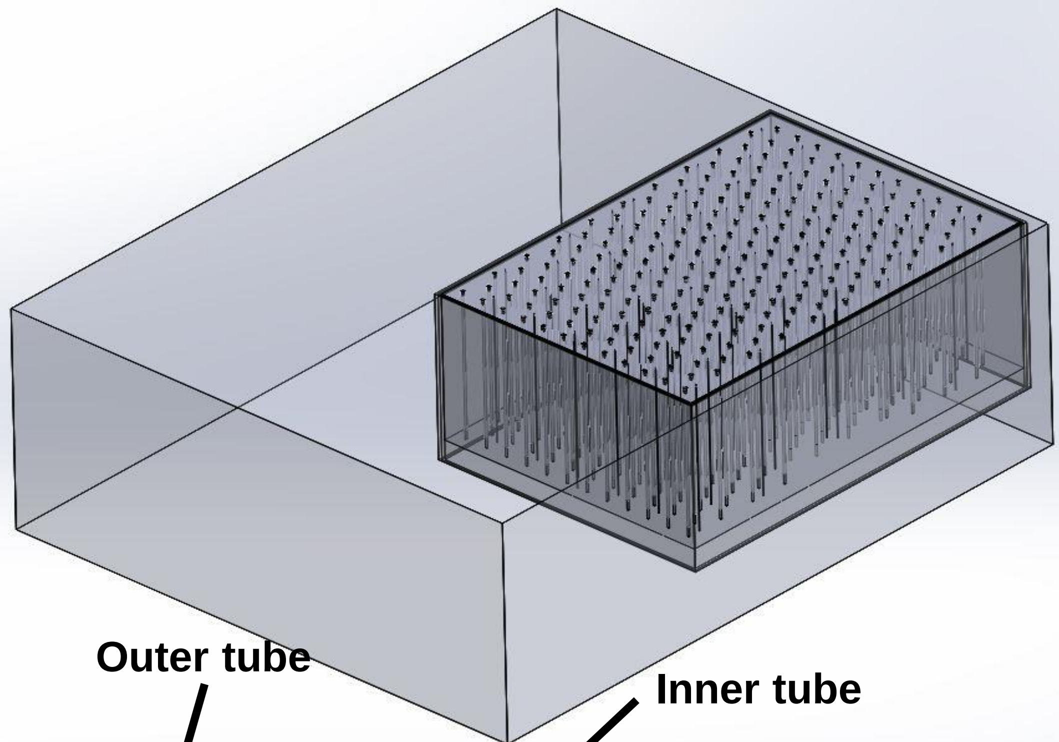
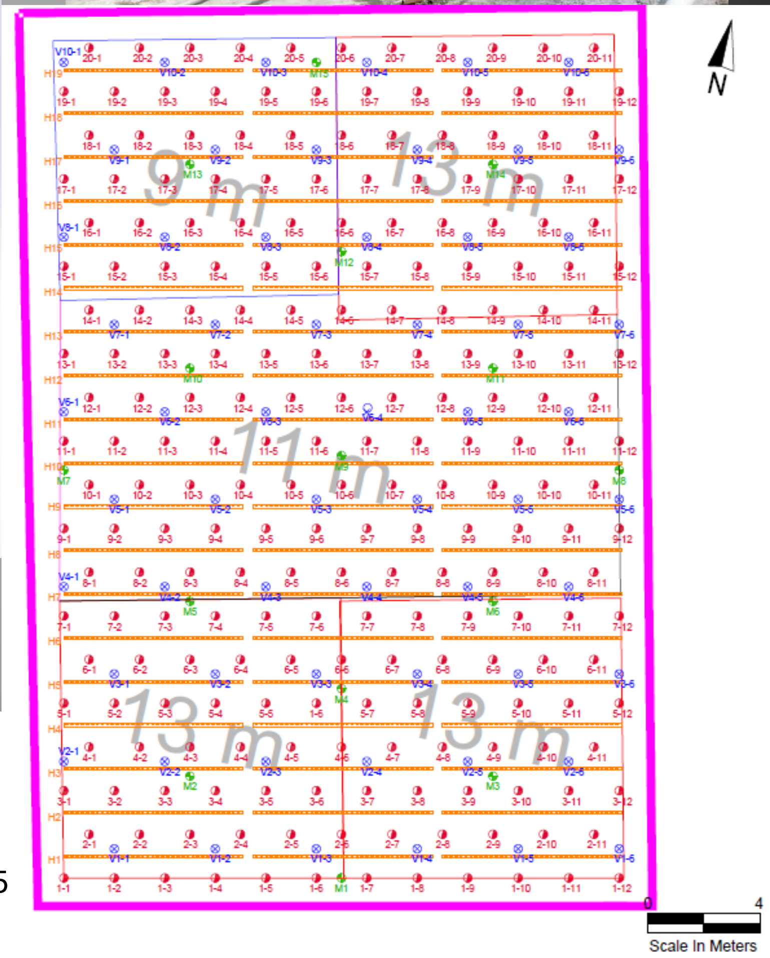
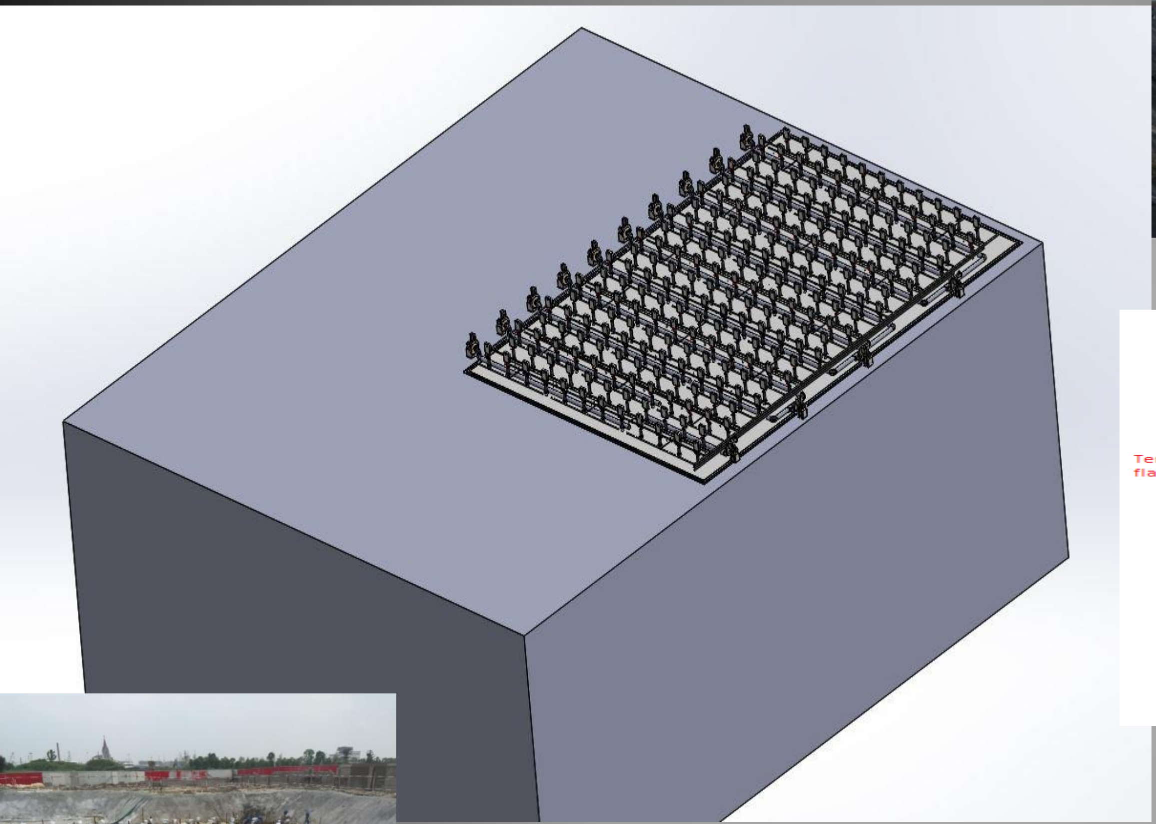
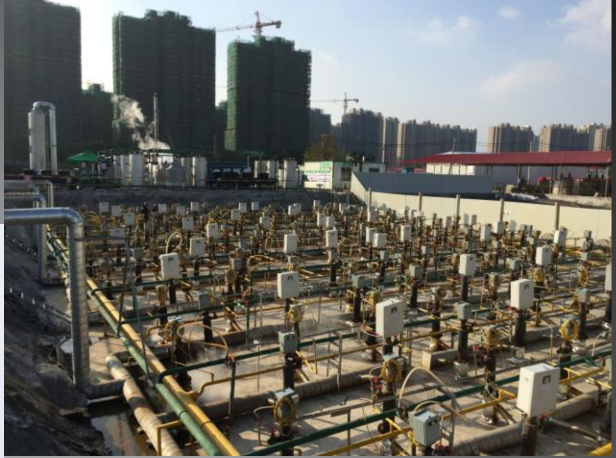
ISTR installation
Drilling and Well Displacement

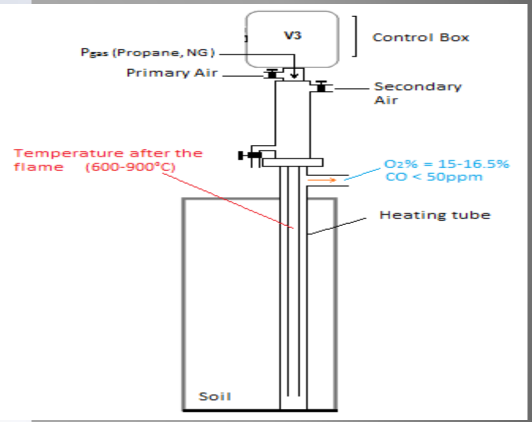


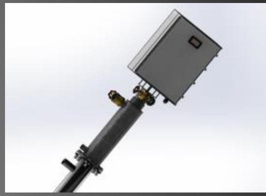


ISTR installation
Plumbing and Well Connecting









Insulation layer

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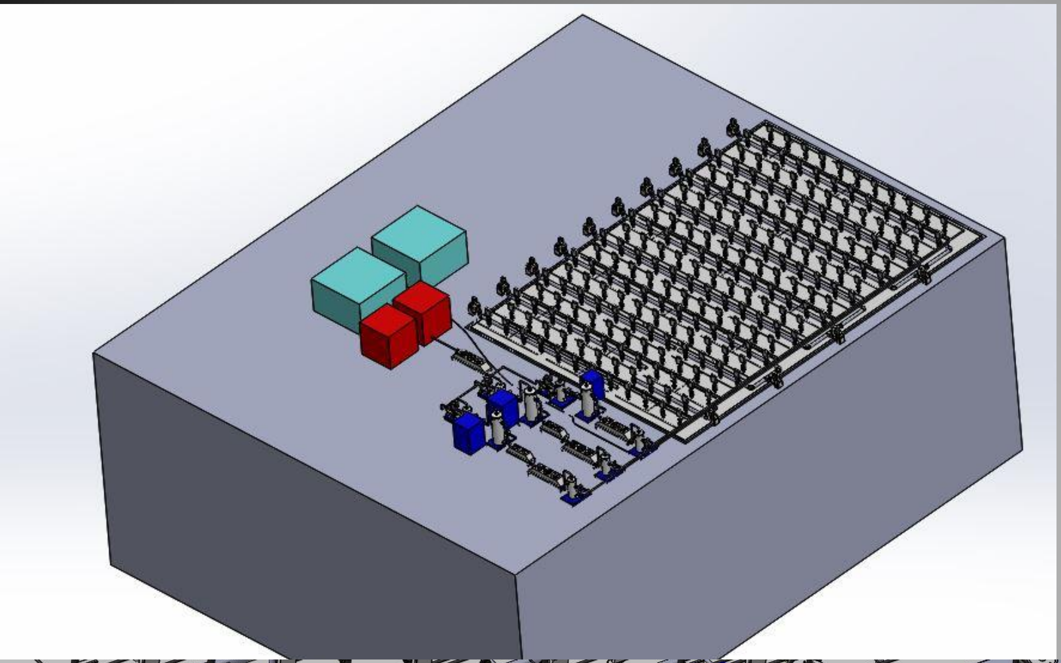
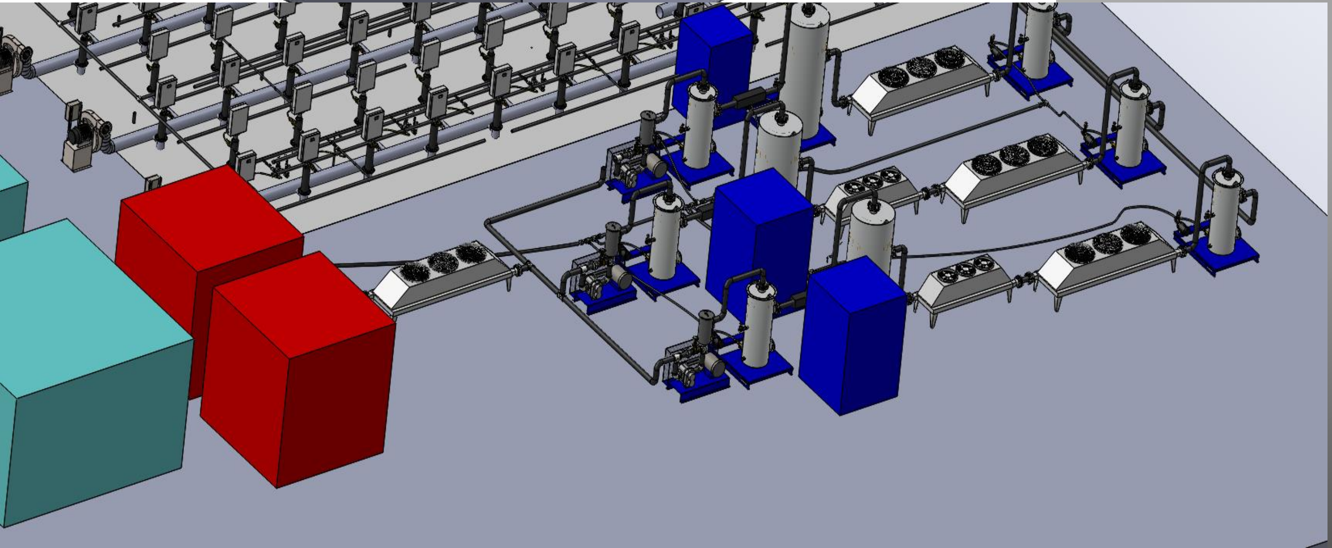
ISTR installation
Vapor Treatment System Connecting





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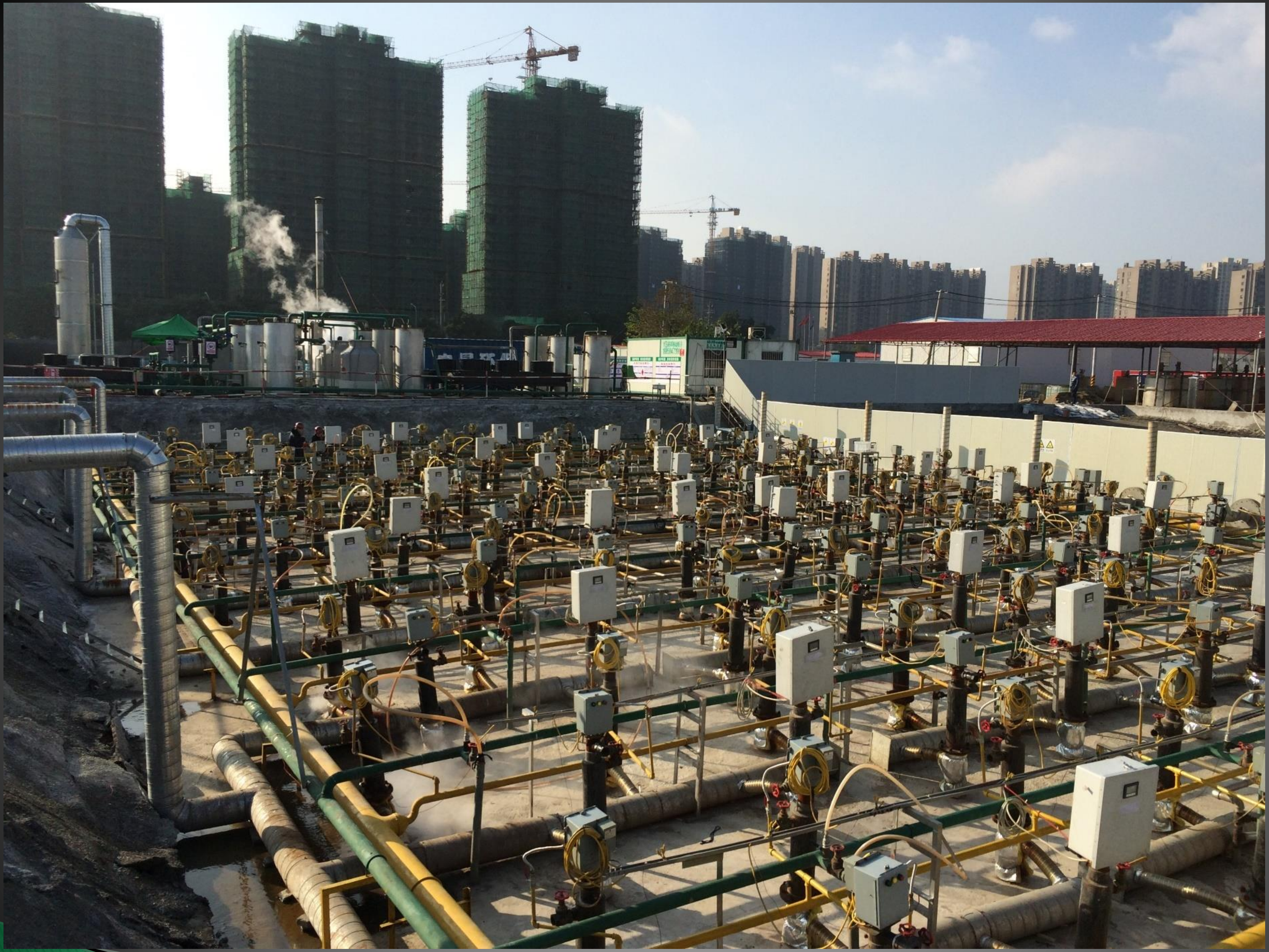

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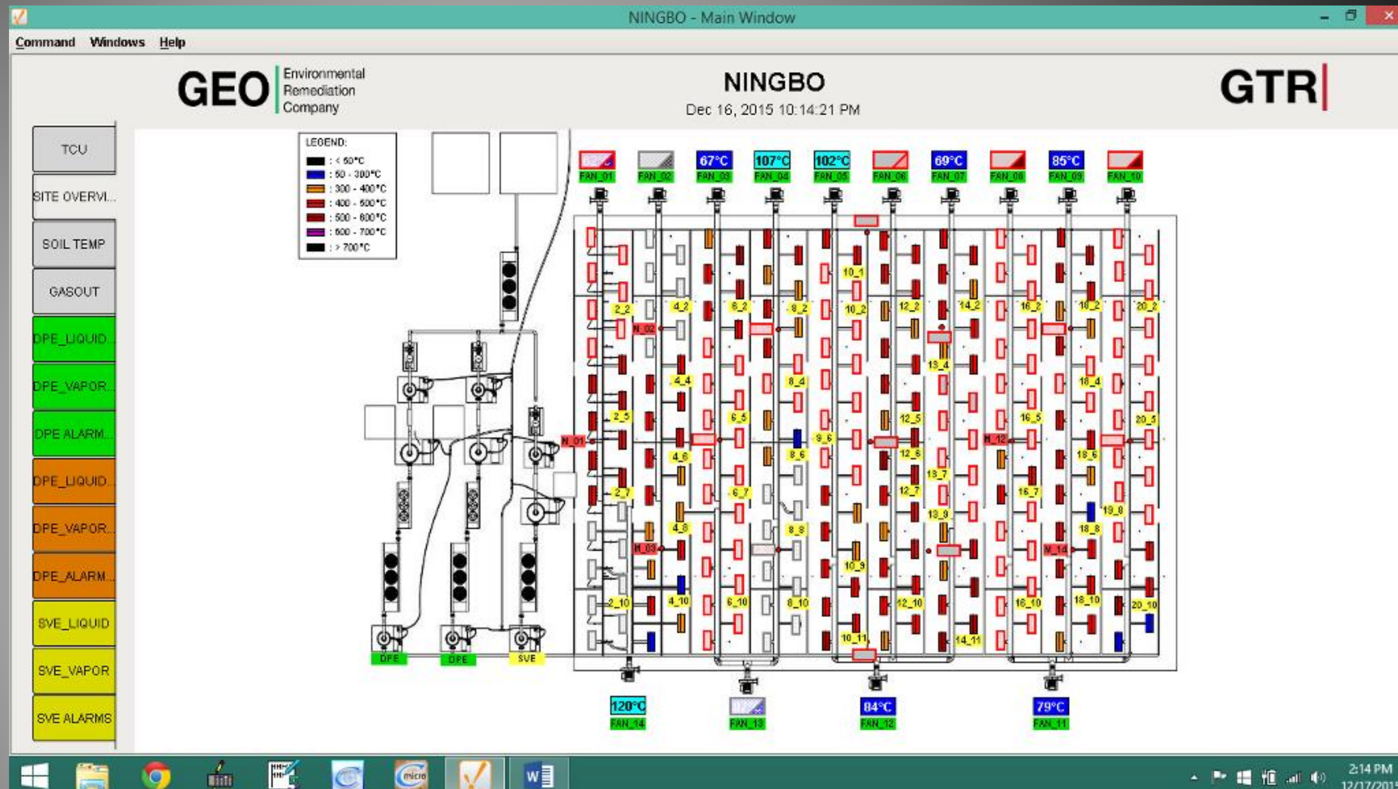
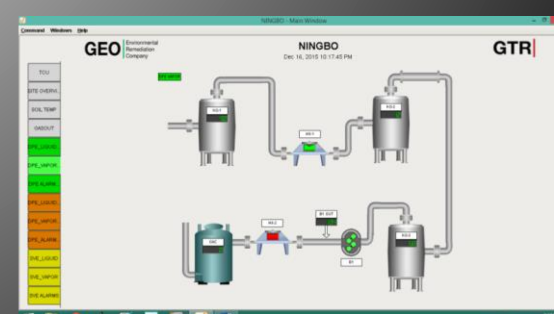
Remote Monitoring System



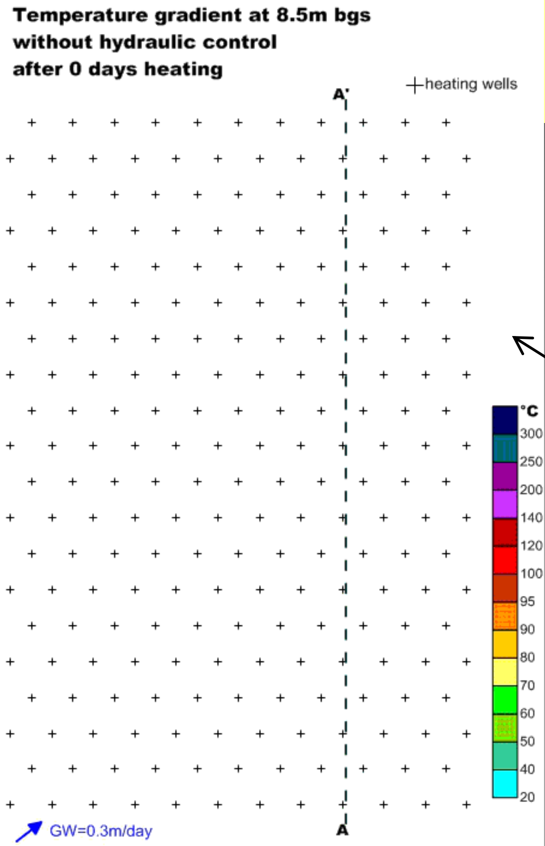


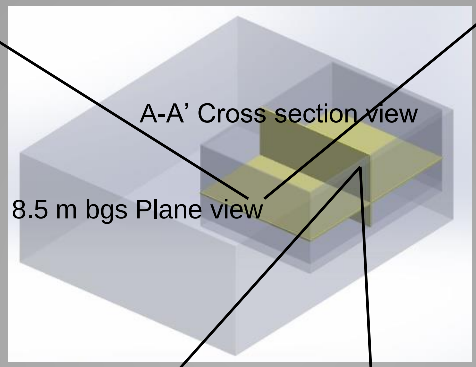
under GW affect

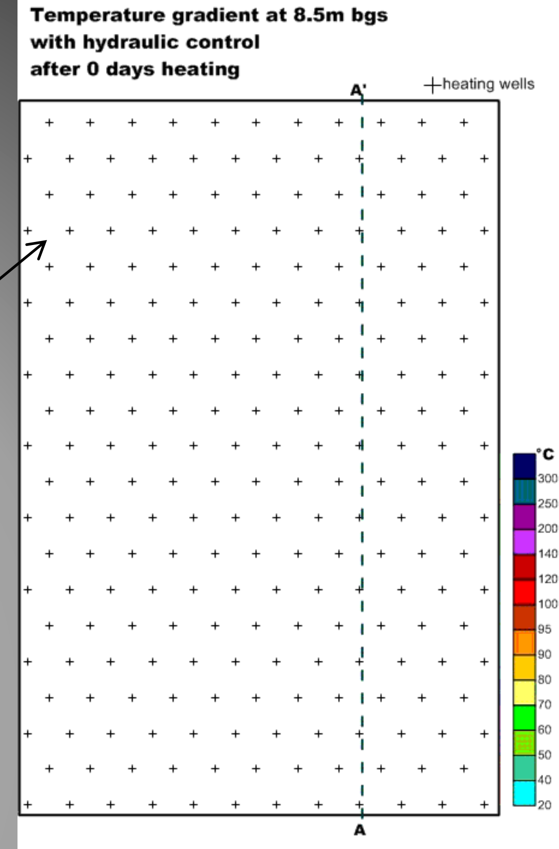
With hydraulic control

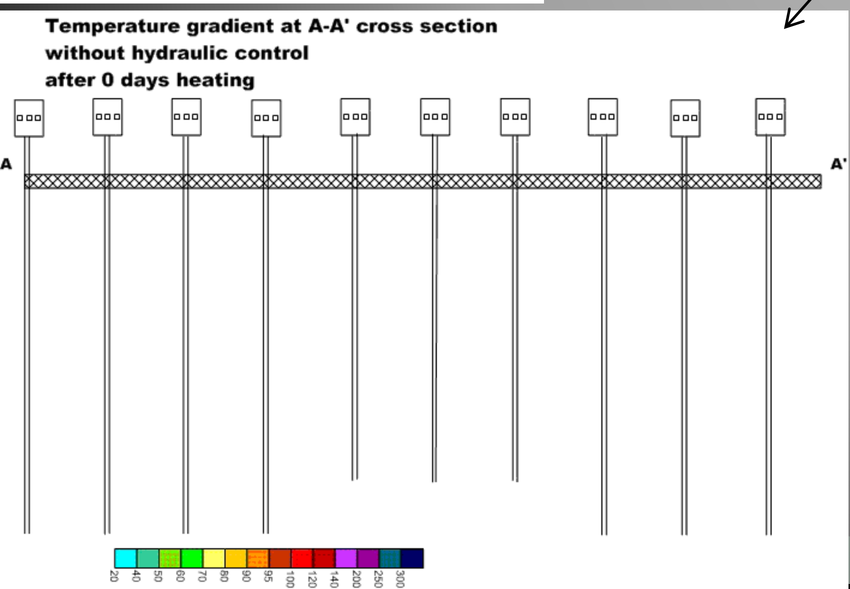
TTT= 210°C at vadose zone

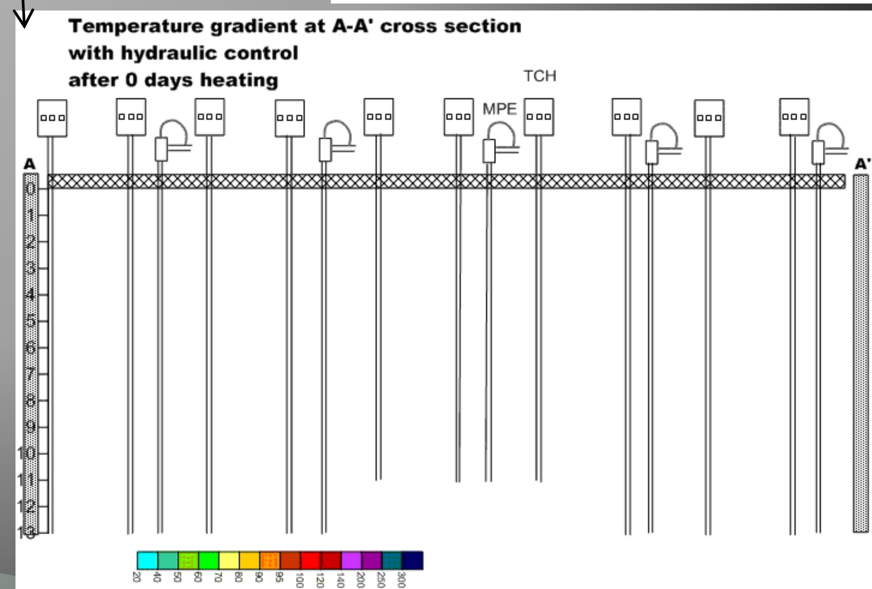
and 100°C at saturated zone



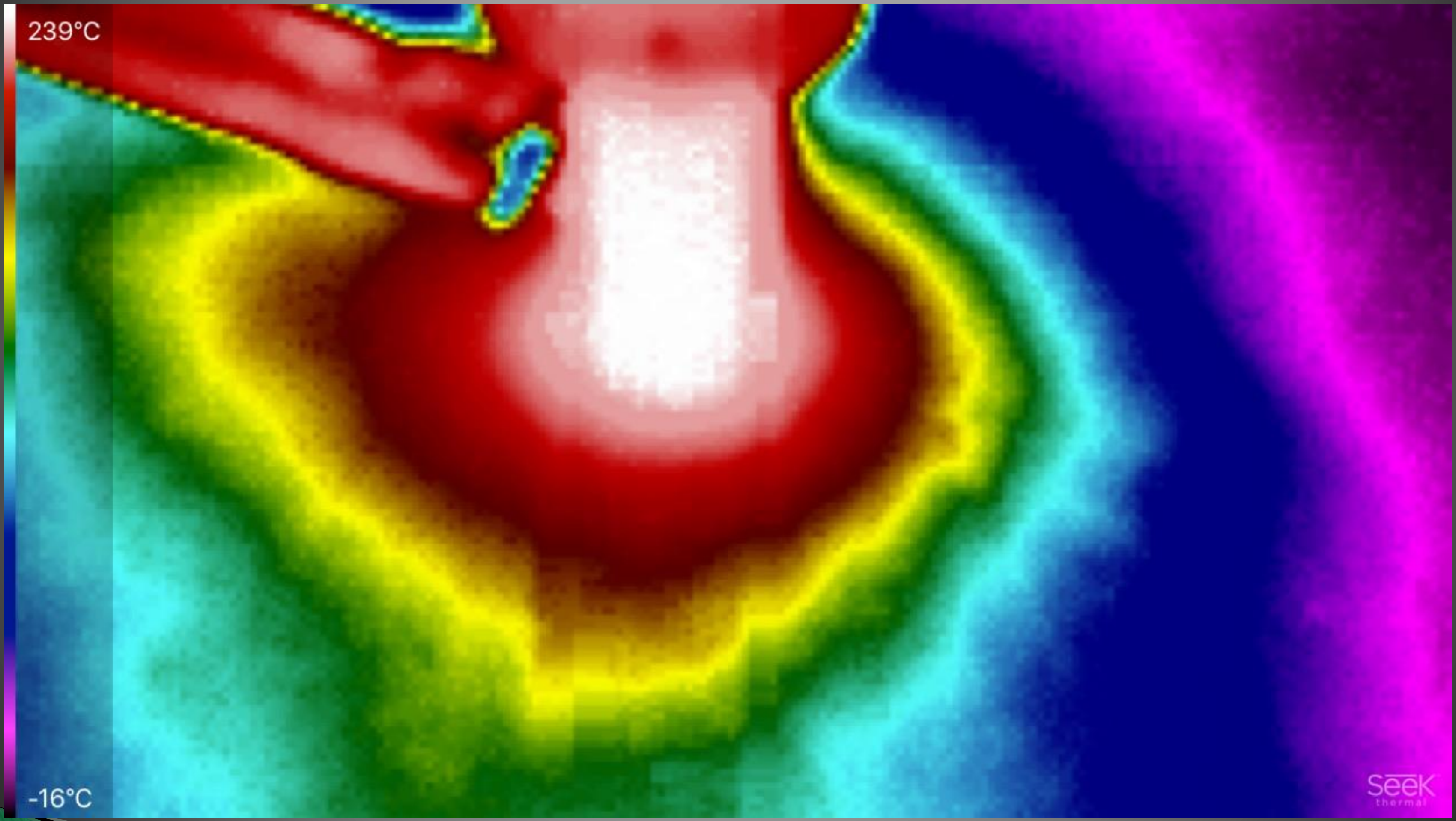








Heating wells thermal picture



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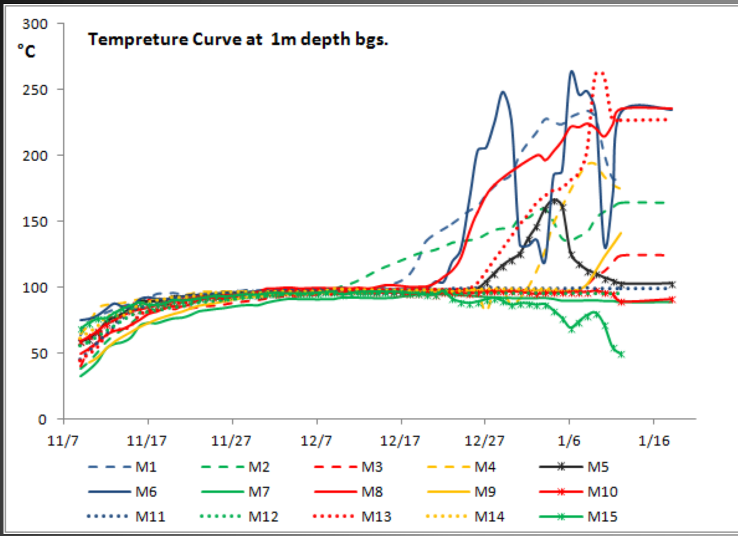
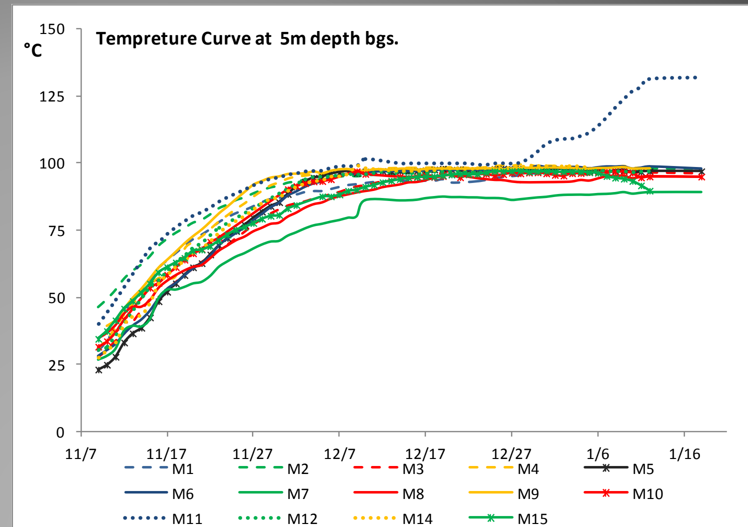
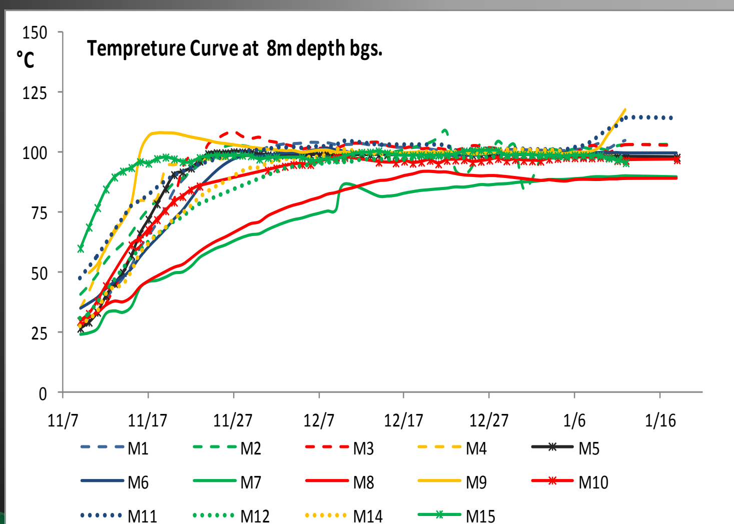
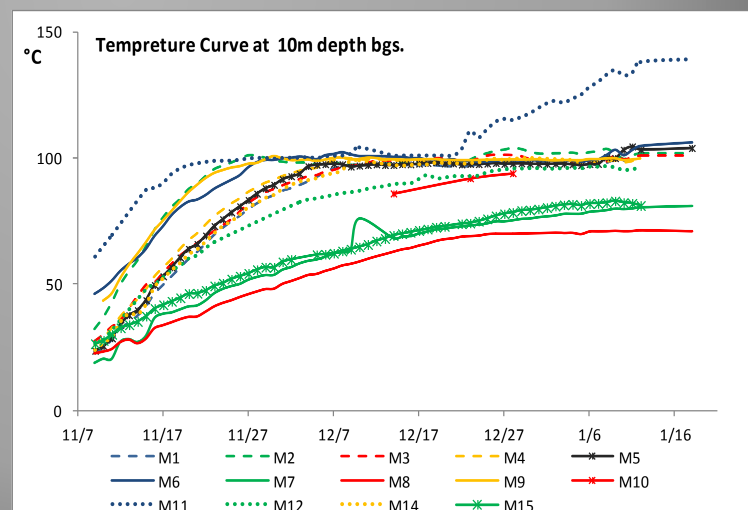
Recorded Temperature Evolution









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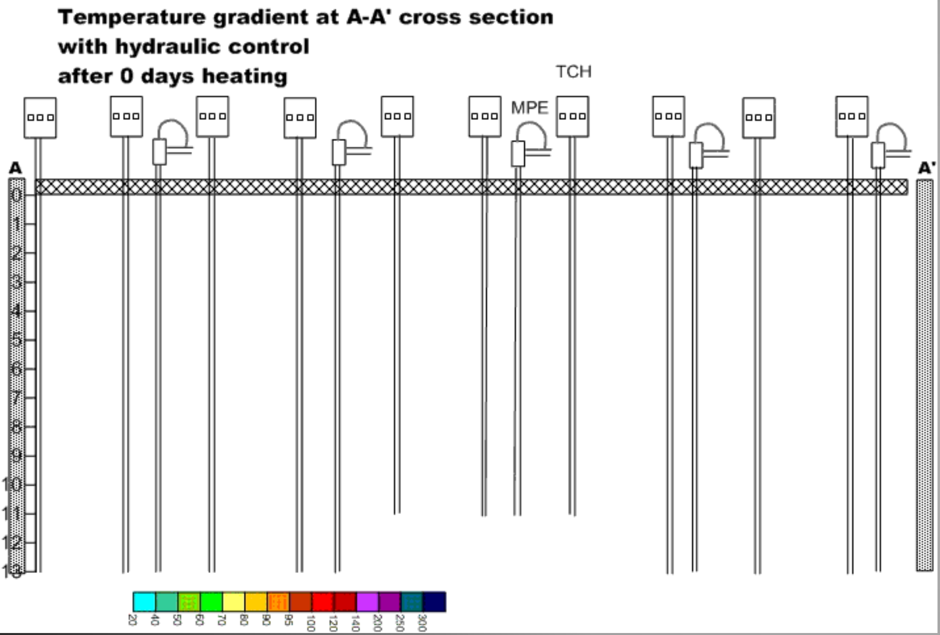
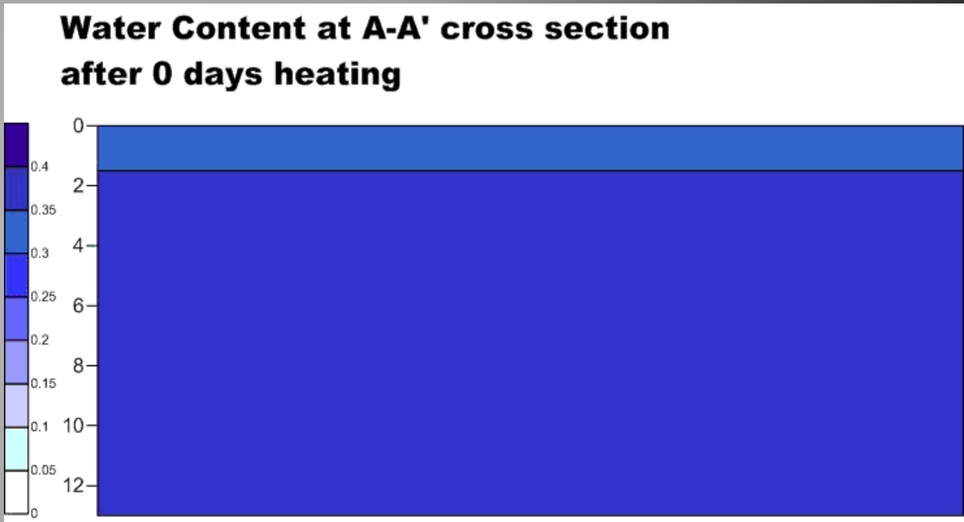
Computer Simulated Water Removal with Temperature Evolution





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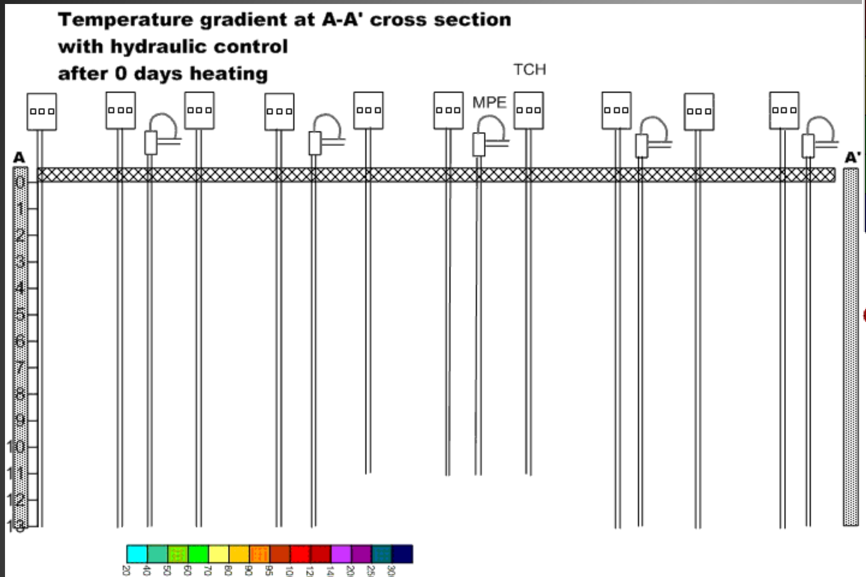
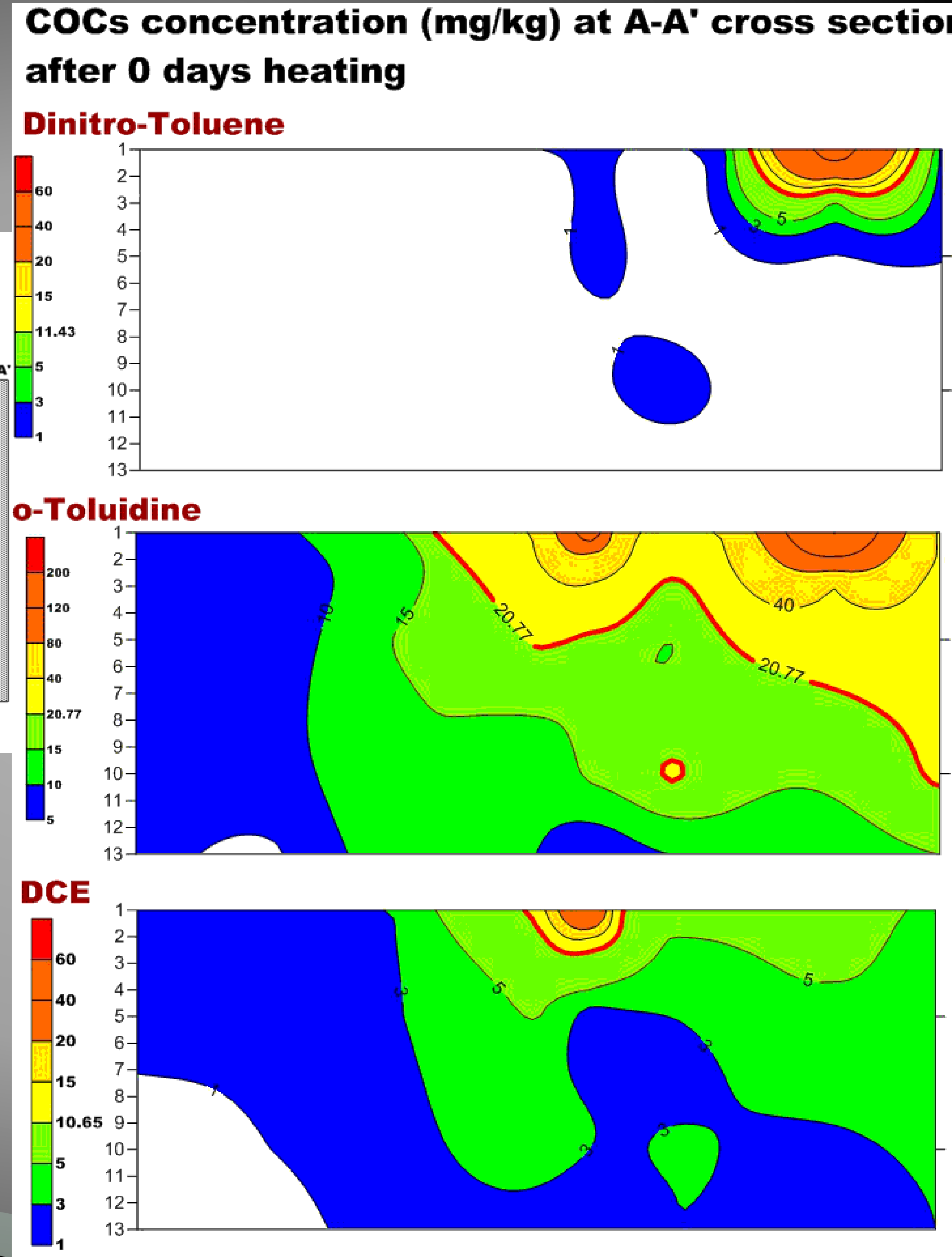
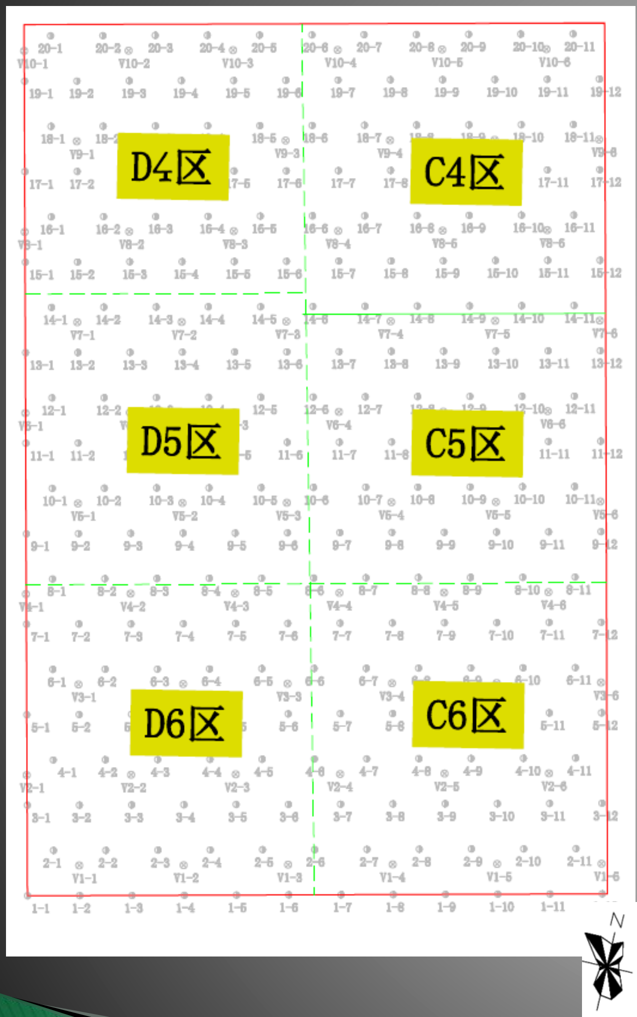
Computer Simulated COCs Reduction with Temperature Evolution

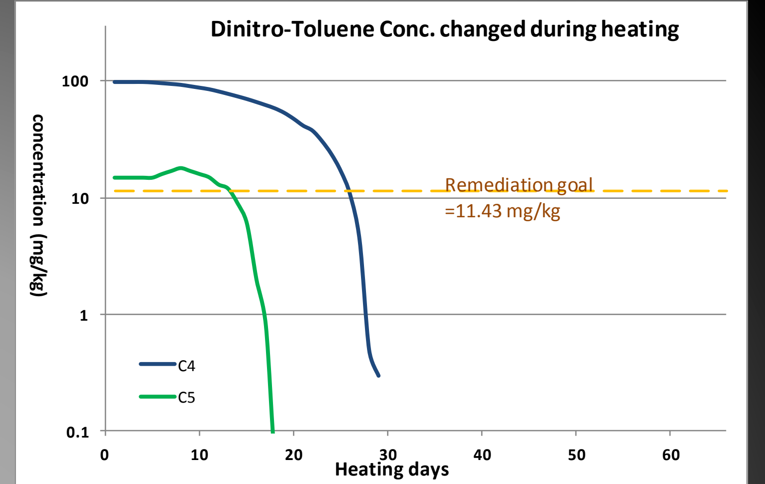


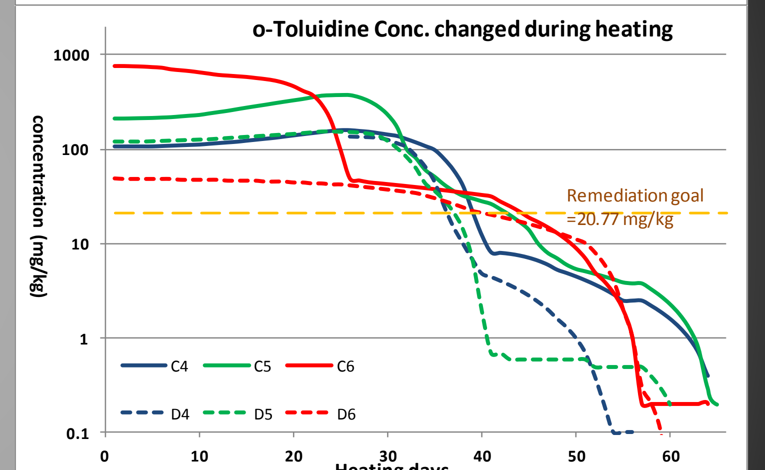
COC	Max Conc. (mg/kg)	Remedial goal (mg/kg)	Boiling point (° C)
Dinitro-toluene	65	11.43	300
o-Toluidine	271	20.77	200
DCE	147	10.65	84

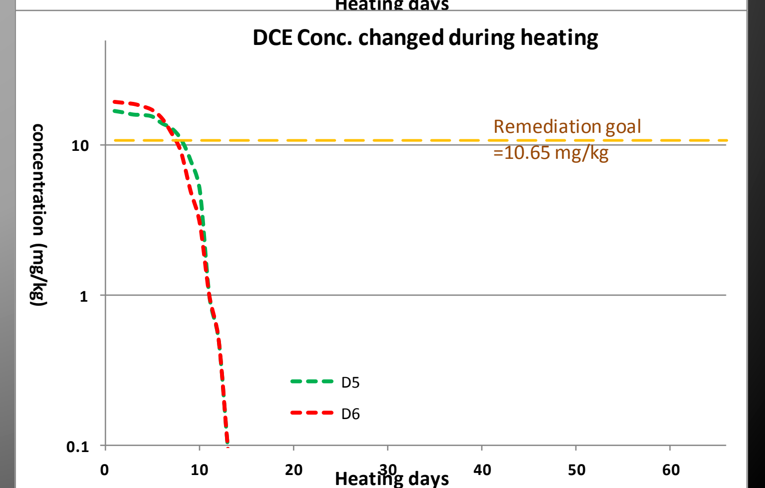


Soil Concentration Sampling during Treatment









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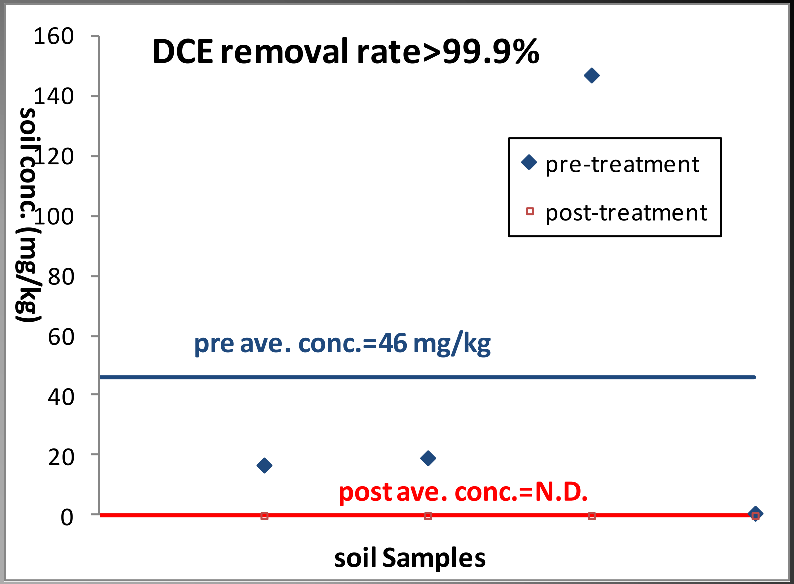
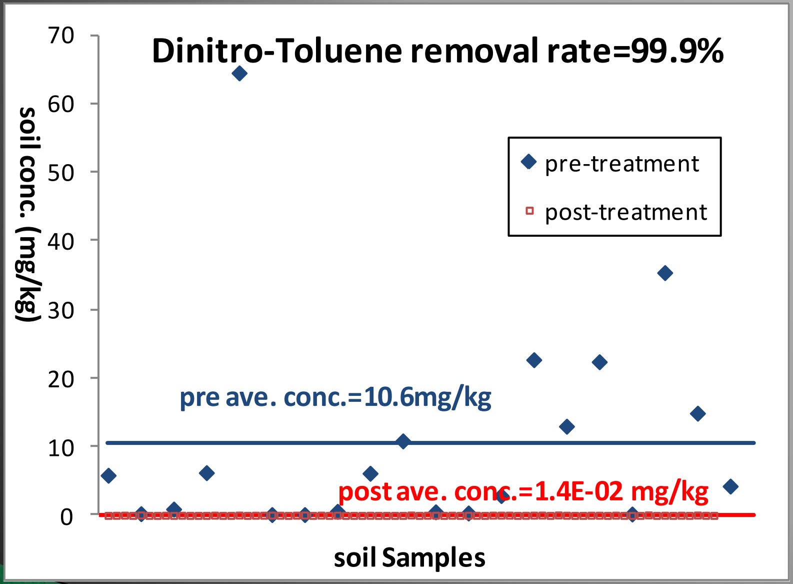
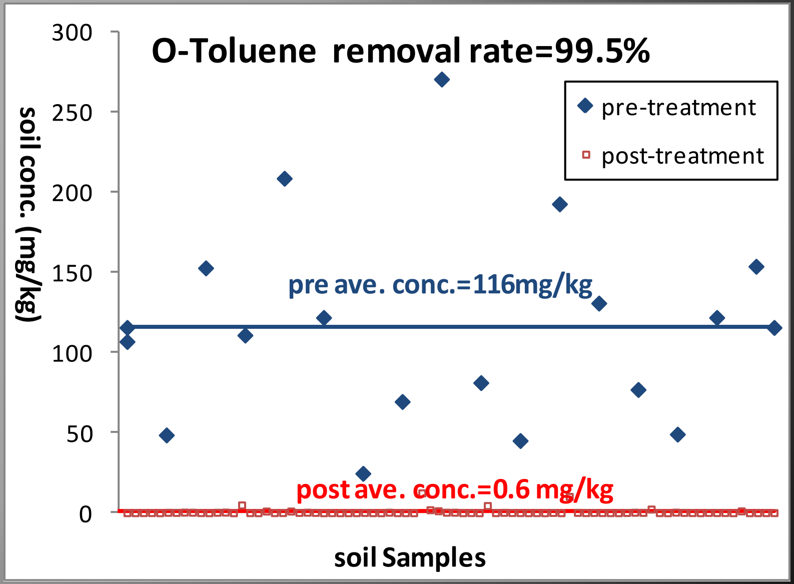
Results

All soil sampling results suggested remediation goals were achieved in proposed duration







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Results

All groundwater sampling results suggested remediation goals were achieved in proposed duration

Groundwater sampling	Pre-treatment (μg/L)	Post-treatment (01/19/2016)	Remediation goal (μg/L)
2,6-dinitro-toluene	33.3	ND	51
2,4-dinitro-toluene	20.6	ND	58
o-toluidine	28,400	ND	430
DCE	29,800	ND	190
Vinyl Chloride	207	ND	23
5-nitro-o-toluidine	313	ND	3,350
TPH	24,622	60	2420

DBBS DADI BENESOURCE

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Soil before Treatment

Soil after Treatment

GW before Treatment

GW after Treatment

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Results

Soil bearing test suggested the soil property was not changed during thermal treatment

	Soil type	CPT		Bearing capacity (kPa)
		q_c (MPa)	f_s (kPa)	
Pre-treatment	Silty clay	0.546	10.2	73
Post treatment	Silty clay	0.608	13	80

Why GTR: more soil types

$$q''_x = -k(dT/dx)$$

Where:

q''_x = heat energy flux in the x direction ($W \cdot m^{-2}$)
k = thermal conductivity ($W \cdot m^{-1} \cdot K^{-1}$)
dT/dx = temperature gradient in the x direction ($K \cdot m^{-1}$).

Thermal Conductivity

$$\frac{Clay}{Sand} = \frac{1.3}{0.52} = 2.5$$

Hydraulic Conductivity

$$\frac{Sand}{Caly} = \frac{10^4}{10^{-4}} = 100{,}000{,}000$$

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Why GTR: less time

Duration for Different remediation technology

In Situ Remediation	Thermal	Chemical injection	flushing	Bio-remediation	pump and treat
VOCs (Benzene, DCE, ect)	1~2	3~9	4~12	6~18	12~24
VOCs (BTEX, TCE,PCE,gasoline,partial diesel, ect)	1~3	4~12	6~18	12~24	12~36
SVOCs (motol oil, MPG, PAHs, PCBs, dioxins,etc)	2~6	6~18	9~24	12~36	18~54

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Why GTR: better guarantee

No Rebound → Less long term cost

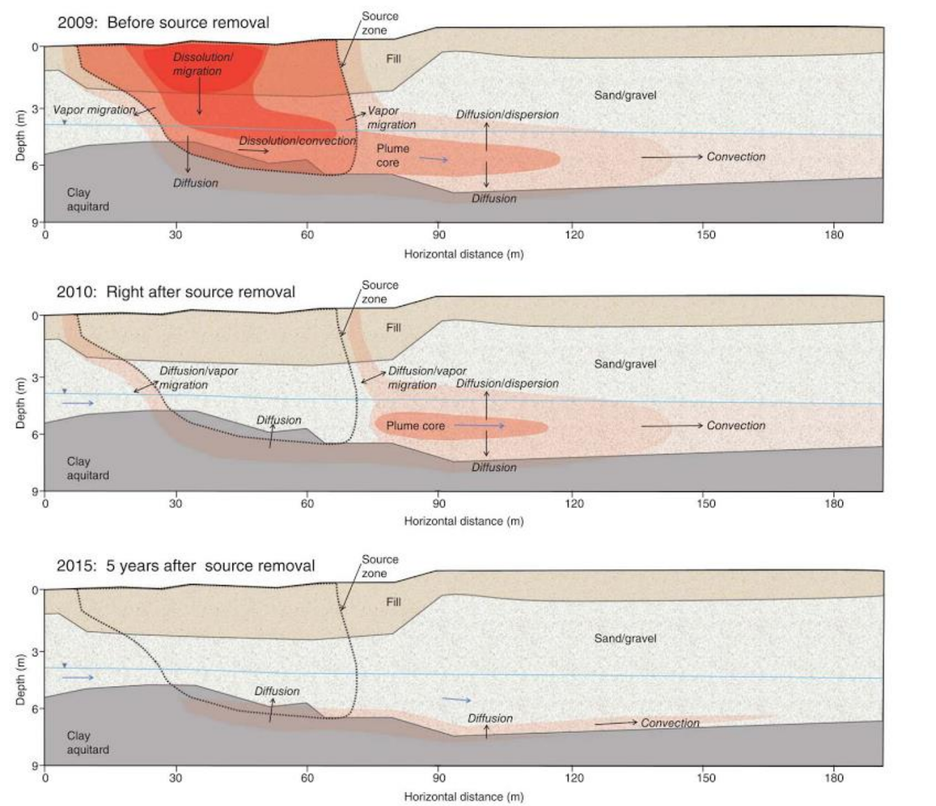
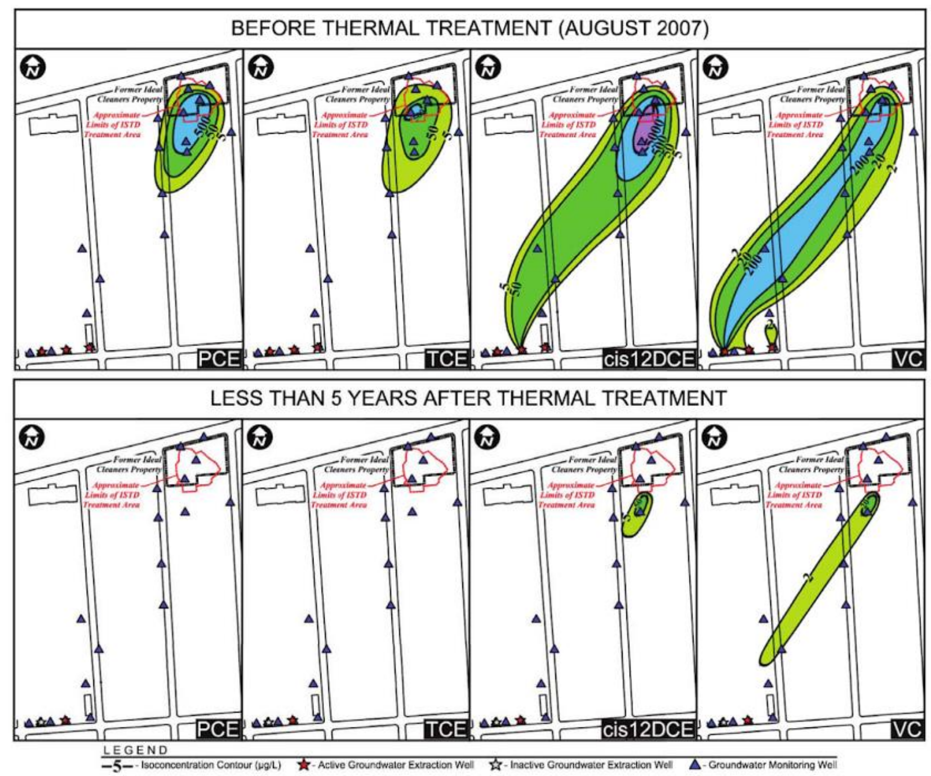


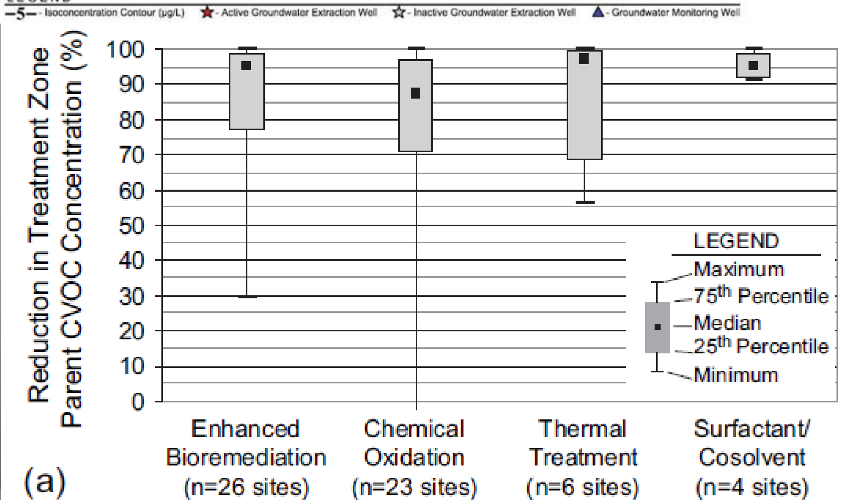
Figure 8. Conceptual model of natural attenuation processes leading to rapid plume shrinkage after source zone mass reduction. The conceptual situations are depicted for before and right after thermal treatment and 5 years after treatment.



Ground Water Monitoring & Remediation

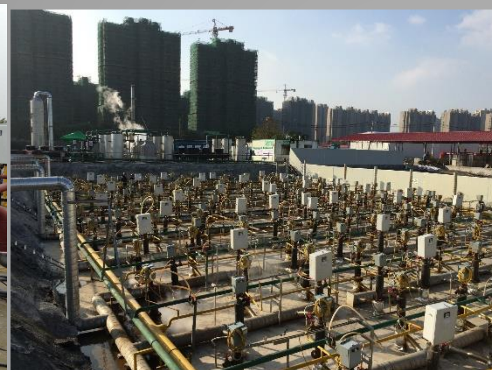
Performance of DNAPL Source Depletion Technologies at 59 Chlorinated Solvent-Impacted Sites

by Travis M. McGuire, James M. McDade, and Charles J. Newell



(2) One Challenge Encountered - Vapor Treatment

5 Case Studies in China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Case #1

Short Duration

(2 months from mob to demob)

- 10/08/2013 Mobilization and Installation
- 11/03/2013 Commissioning
- 11/05/2013 Start Heating
- 12/08/2013 Stop Treatment
- 12/12/2013 Confirming Sampling

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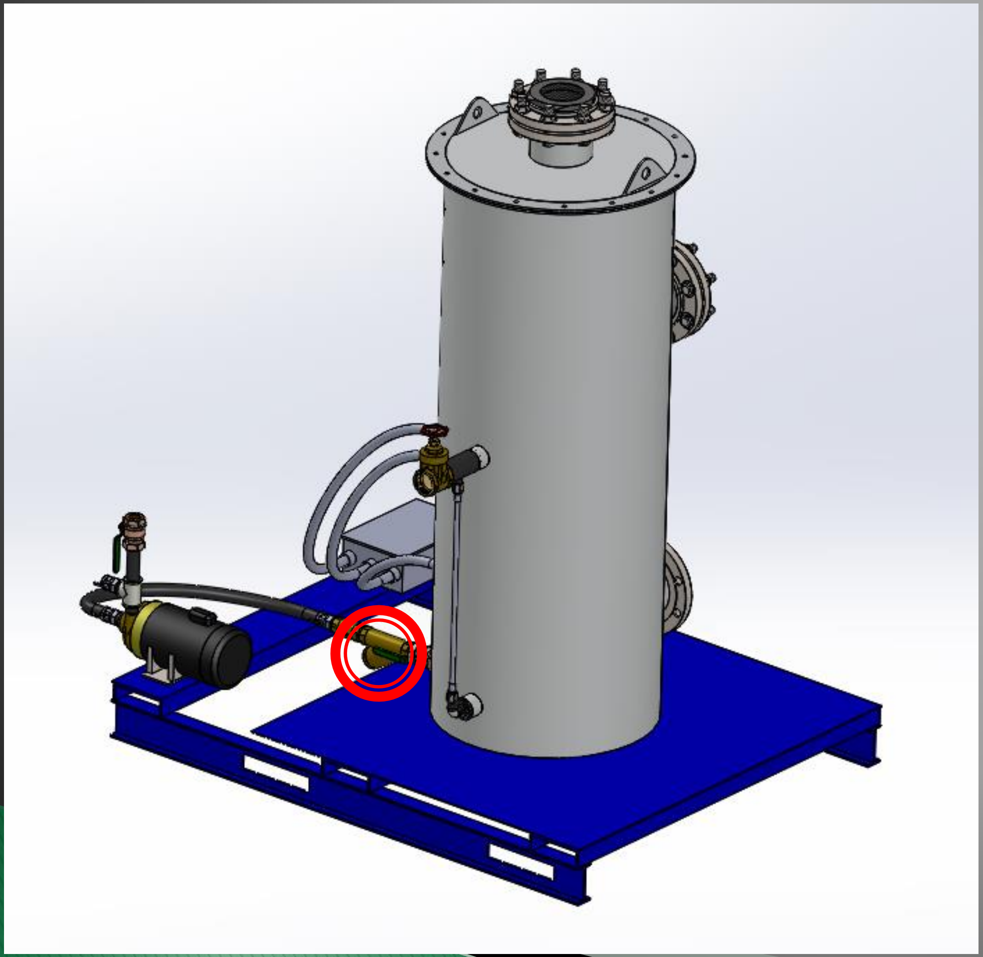
Case #1

- Reach 100°C in less than 1 month
- Removed >99% of COCs from soil and groundwater

Vapor treatment unsuccessful reason:

(1) No Time
(2) No Site Investigation

Case #2



Vapor treatment need improvement:

(1) Same problem: Unexpected significant higher VOCs concentration than provided site investigation report
(2) Failure of some small parts of local equipment

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Case #3

Vapor treatment need improvement:

One unreported chemical: Sulfide

Some adjustment done for this site immediately

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Vapor Treatment Development

(1) Cooling
(2) VGAC polishing

(1) Cooling
(2) Therm oxidation
(3) VGAC polishing

(1) Cooling
(2) C3
(3) VGAC polishing

(1) Cooling
(2) GTR-O
(3) VGAC polishing

(1) Cooling
(2) Catalytic oxidation
(3) VGAC polishing

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Vapor Treatment first step: cooling

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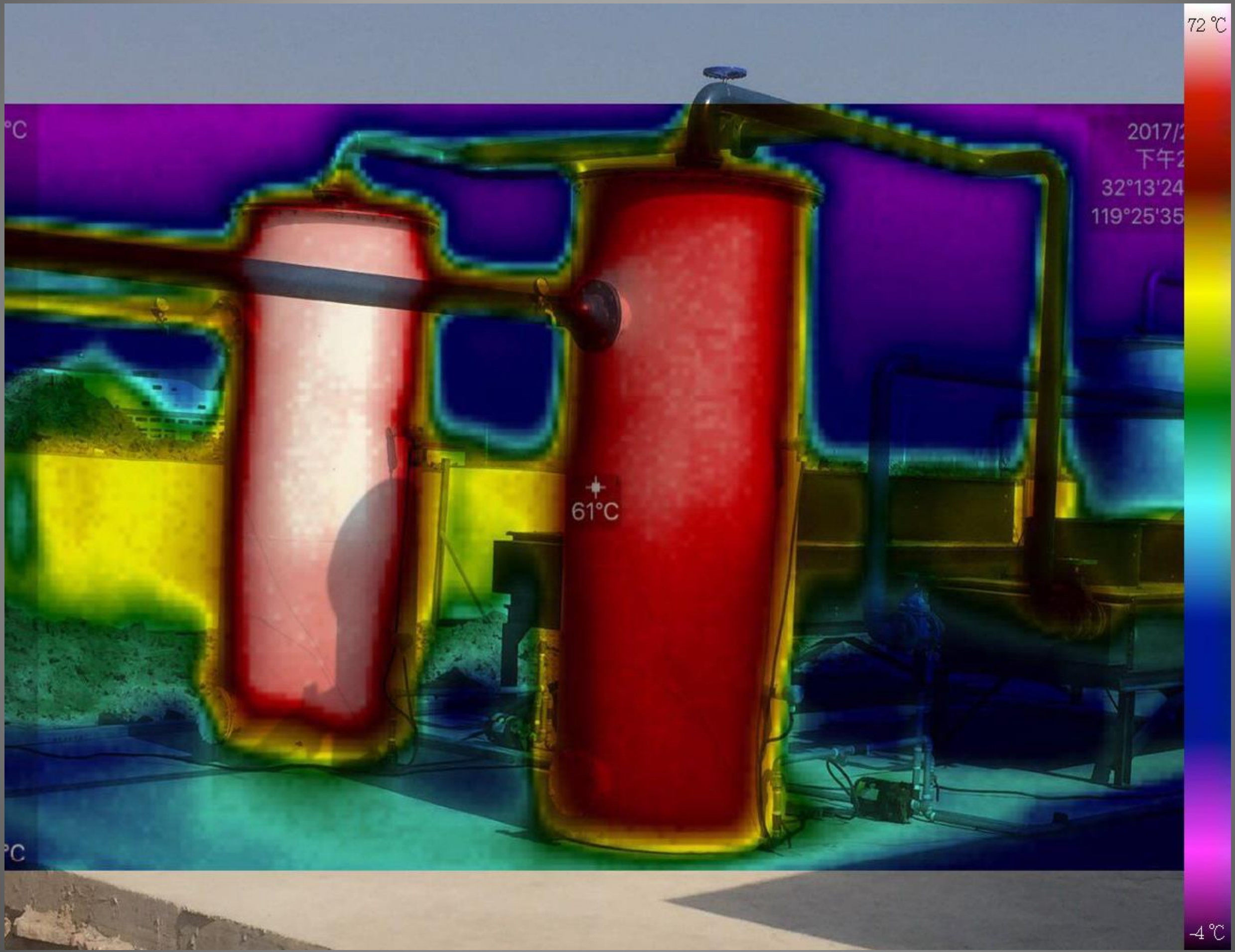
Vapor Treatment first step: cooling



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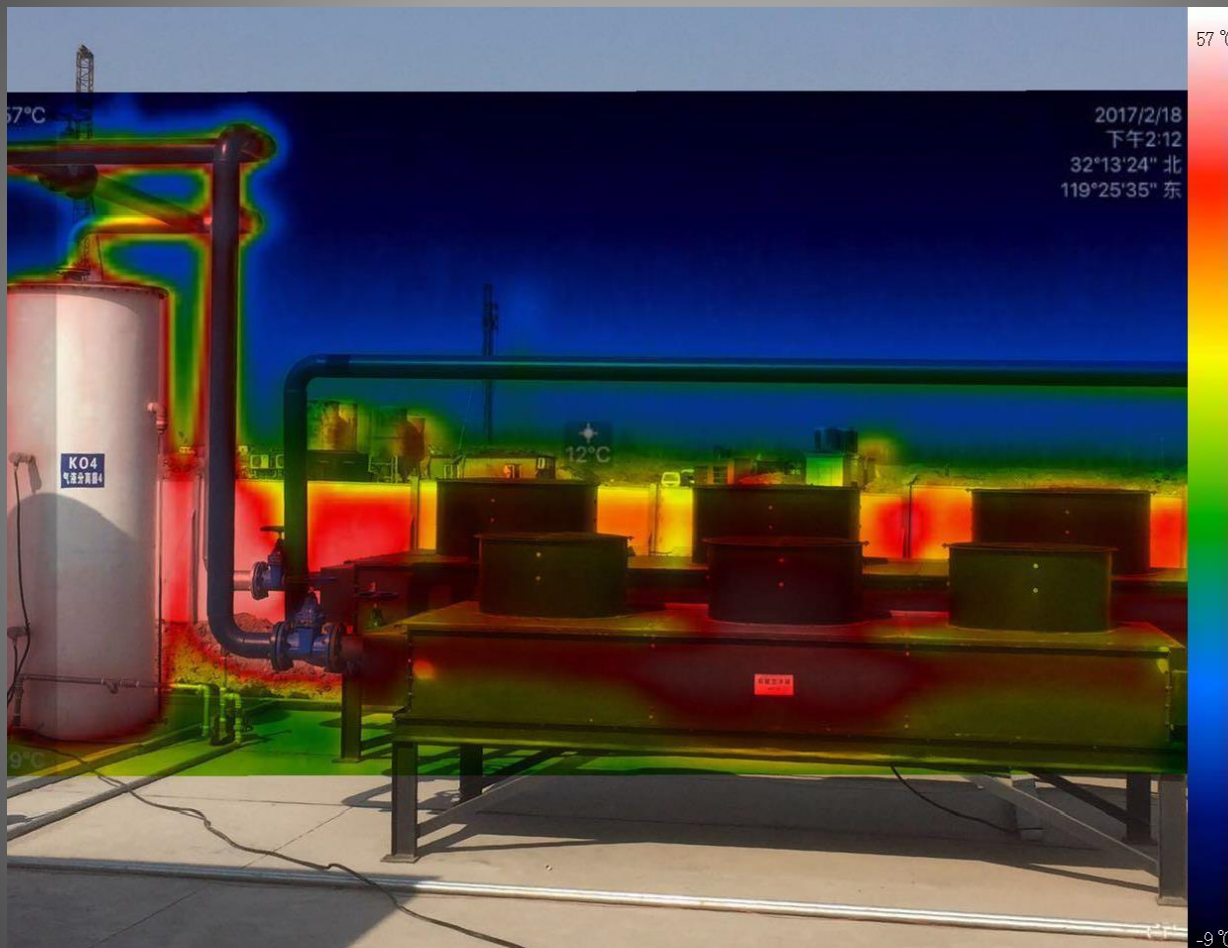
Vapor Treatment first step: cooling



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Vapor Treatment first step: cooling

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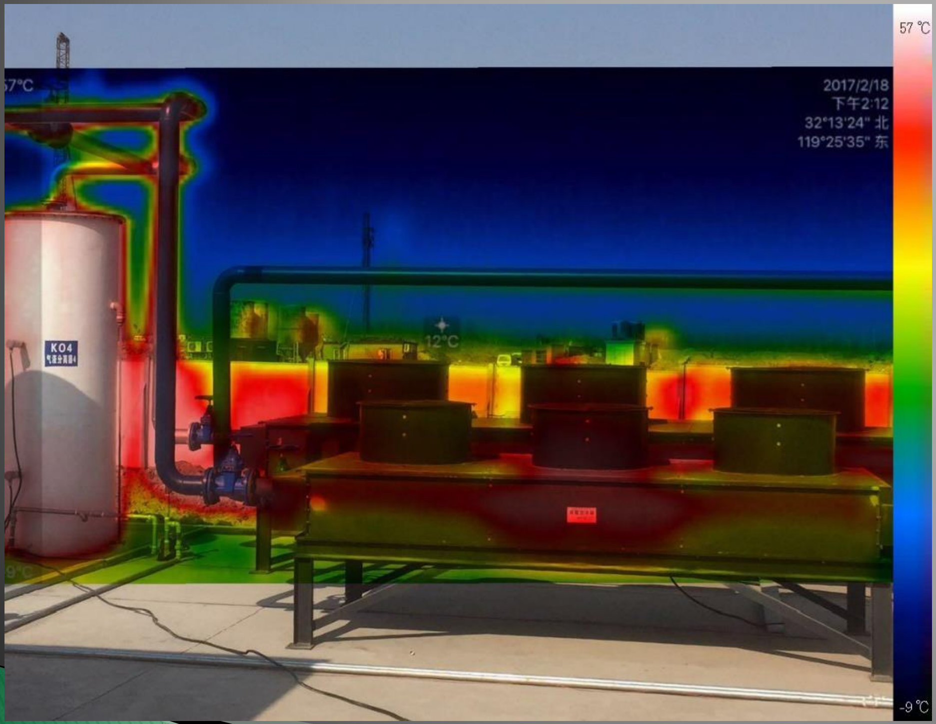
Method 1: Cooling+VGAC

Good for SVOCs sites or low VOCs concentration sites



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Vapor Treatment Development

(1) Cooling
(2) VGAC Polishing

(1) Cooling
(2) Therm Oxidation
(3) VGAC Polishing

or

(1) Cooling
(2) Catalytic Oxidation
(3) VGAC Polishing

(1) Cooling
(2) C3
(3) VGAC polishing

(1) Cooling
(2) GTR-O
(3) VGAC polishing

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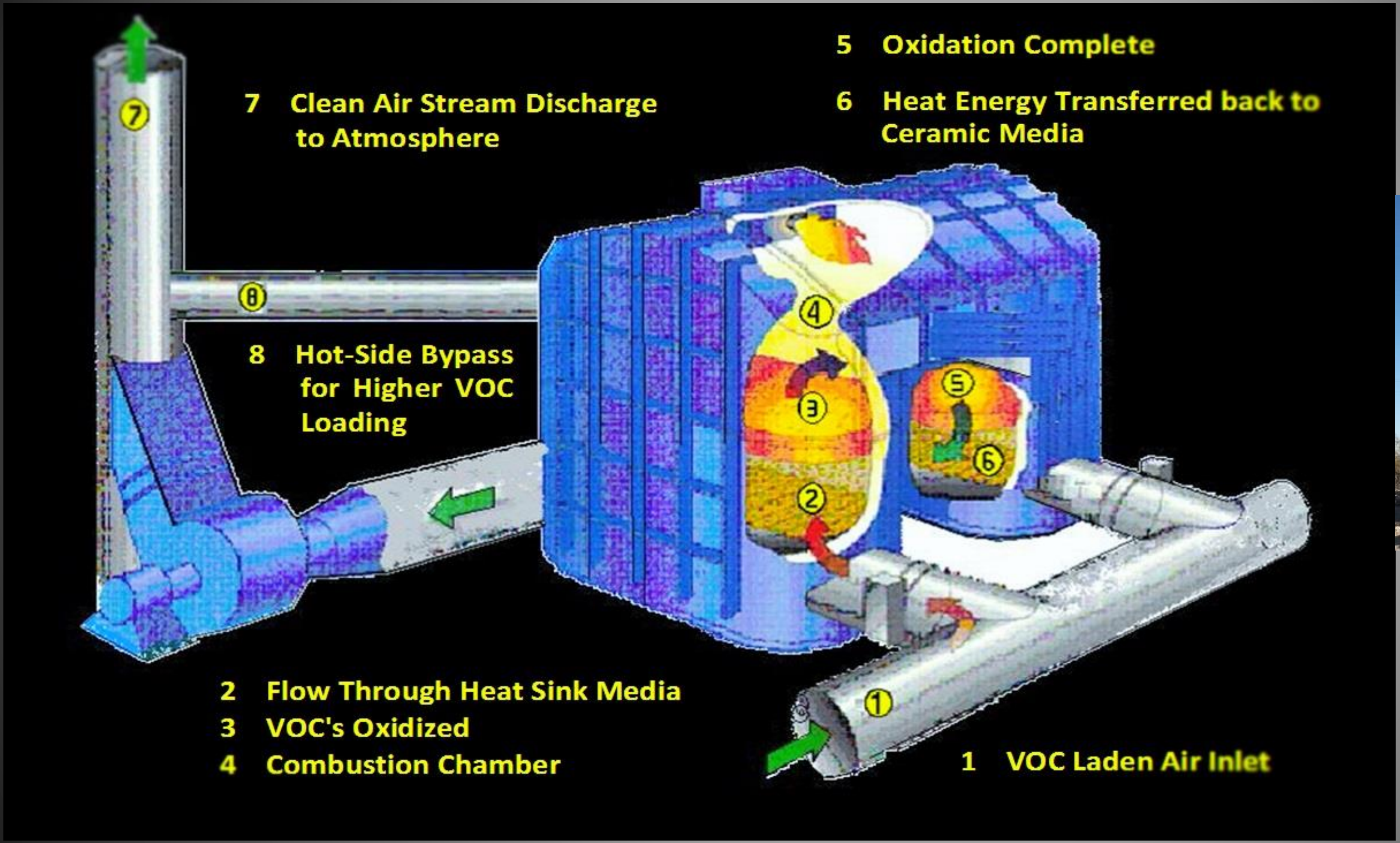
Method 2: Thermal Oxidizer



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Method 2: Thermal Oxidizer

- chlorinated solvents < 5,000 ppmv
- petroleum hydrocarbons <10,000 ppmv
- Potential formation of dioxins and furans and untreated VOCs
- CO, CO_2, and nitrogen / sulfur oxides
- Uptime is low = high O&M costs
- Supplemental fuel costs are rising
- Scrubber maintenance costs are high
- Moderate carbon footprint can be high

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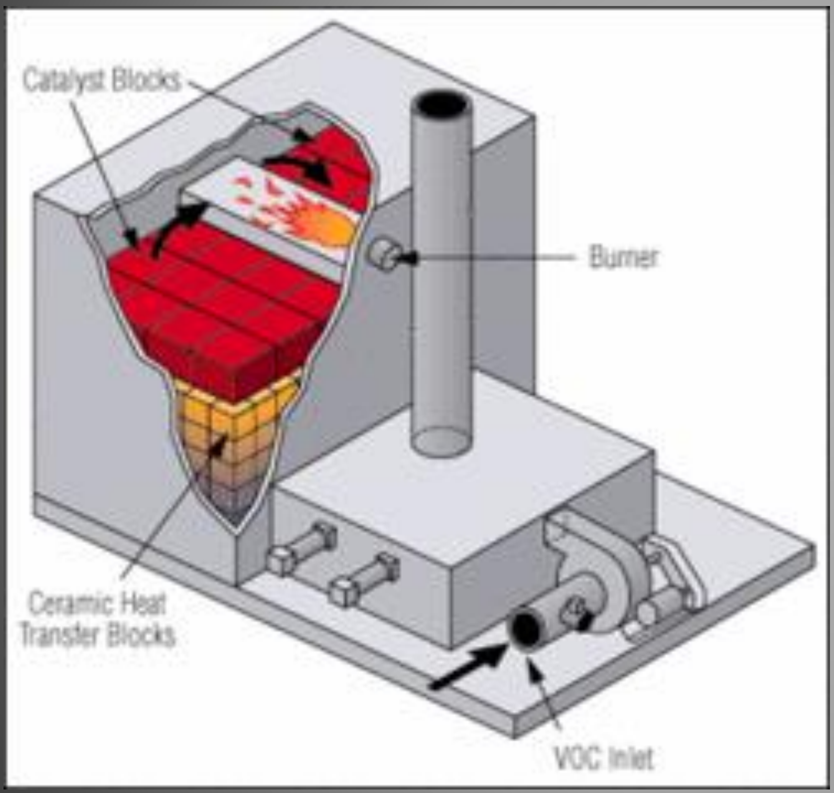
Method 3: Catalytic Oxidizer



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Method 3: Catalytic Oxidizer

- chlorinated solvents < 2,000 ppmv
- petroleum hydrocarbons <4,500 ppmv
- Potential formation of dioxins and furans and untreated VOCs
- CO, CO2, and nitrogen / sulfur oxides
- Uptime is low = high O&M costs
- Supplemental fuel costs are rising
- Scrubber maintenance costs are high
- Moderate carbon footprint can be high

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Vapor Treatment Development

(1) Cooling
(2) VGAC Polishing

(1) Cooling
(2) Therm Oxidation
(3) VGAC Polishing

or

(1) Cooling
(2) Catalytic Oxidation
(3) VGAC Polishing

(1) Cooling
(2) C3
(3) VGAC polishing

(1) Cooling
(2) GTR-O
(3) VGAC polishing

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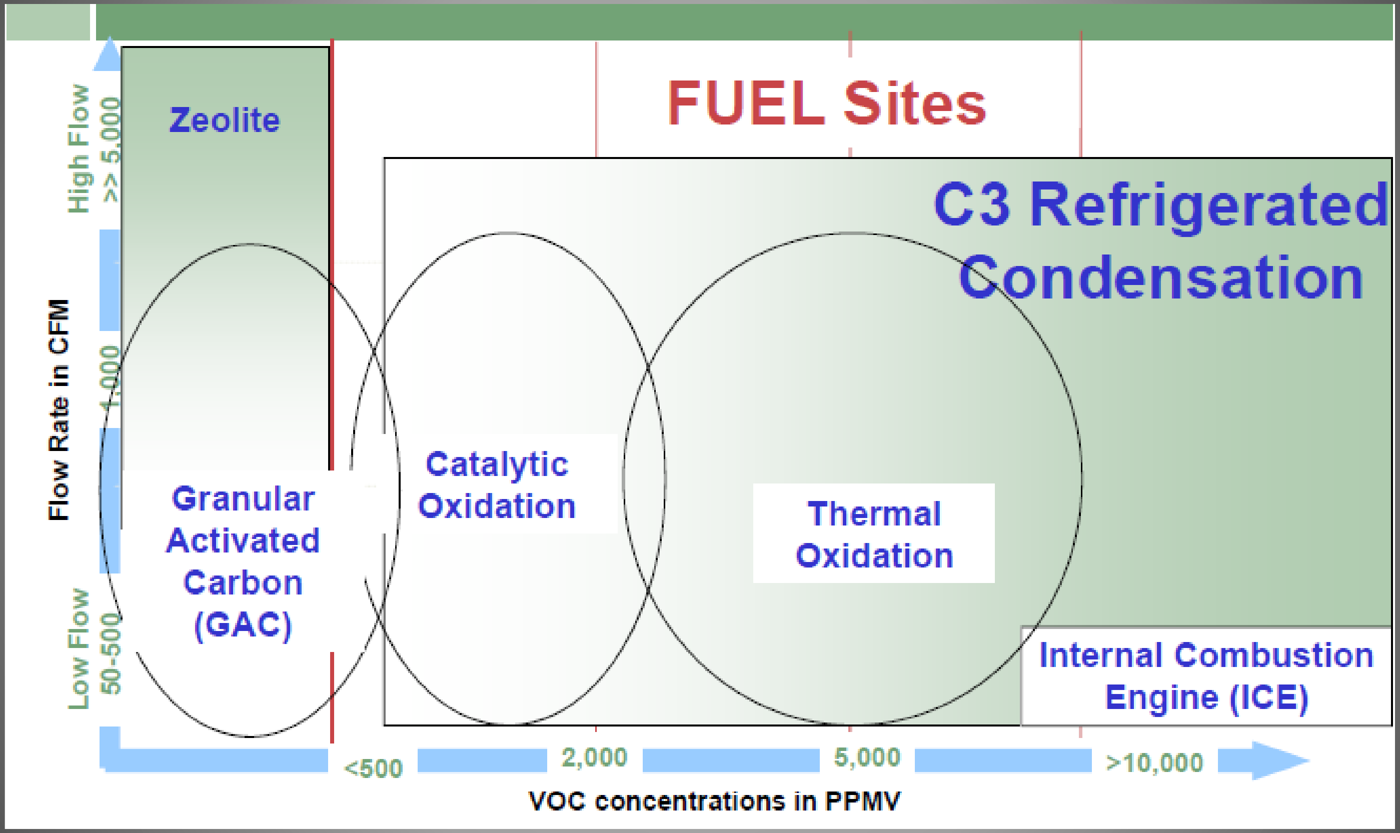
Method 4: C3

- Refrigerated cooling compression and condensation combined with regenerative adsorption
- NO UPPER LIMIT of VOC concentration
- NO INLET DILUTION!
- >100 projects completed
- >20,000,000 pounds of VOCs treated
- 28 years in service!

Method 2-4: which methods



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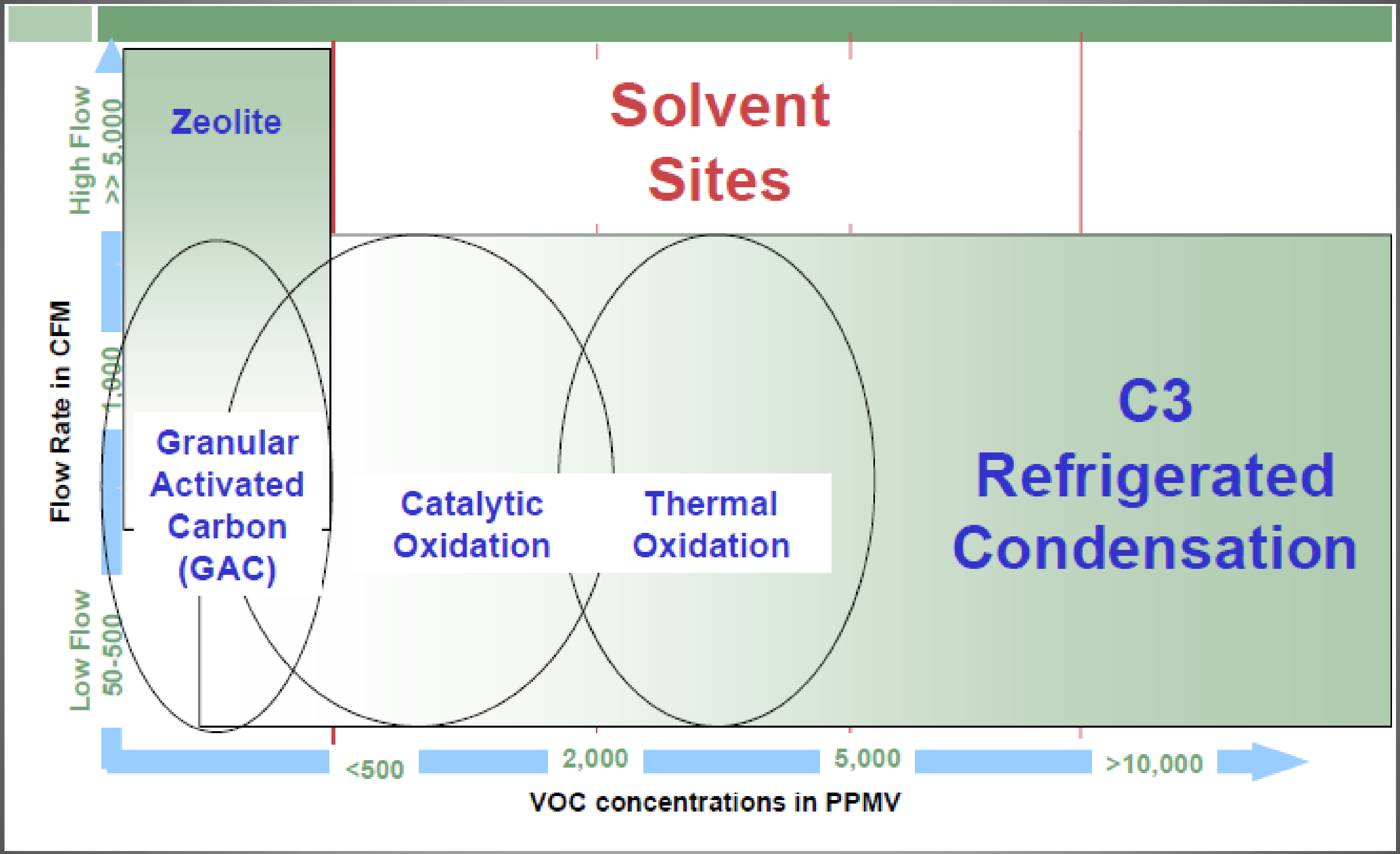
Method 2-4: which methods



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Method 4: C3 application in Thermal remediation

Camp Pendleton, CA

Method 4: C3

Flow Rate	100 SCFM Pilot test unit	200 SCFM	300 SCFM	500 SCFM
Power	480 VAC 3-ph 100 A & 240 VAC 70 A	480 VAC 3-ph 150 A & 240 VAC 70 A	480 VAC 3-ph 200A & 240 VAC 70 A	480 VAC 3-ph 300 A & 240 VAC 70 A
KVA/Hr	45 KVA	75 KVA	105 KVA	170 KVA

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Vapor Treatment Development

(1) Cooling
(2) VGAC Polishing

(1) Cooling
(2) Therm Oxidation
(3) VGAC Polishing

or

(1) Cooling
(2) Catalytic Oxidation
(3) VGAC Polishing

(1) Cooling
(2) C3
(3) VGAC polishing

(1) Cooling
(2) GTR-O
(3) VGAC polishing

Method 5: GTR-O (Case #3)

Used GTR as Oxidzer

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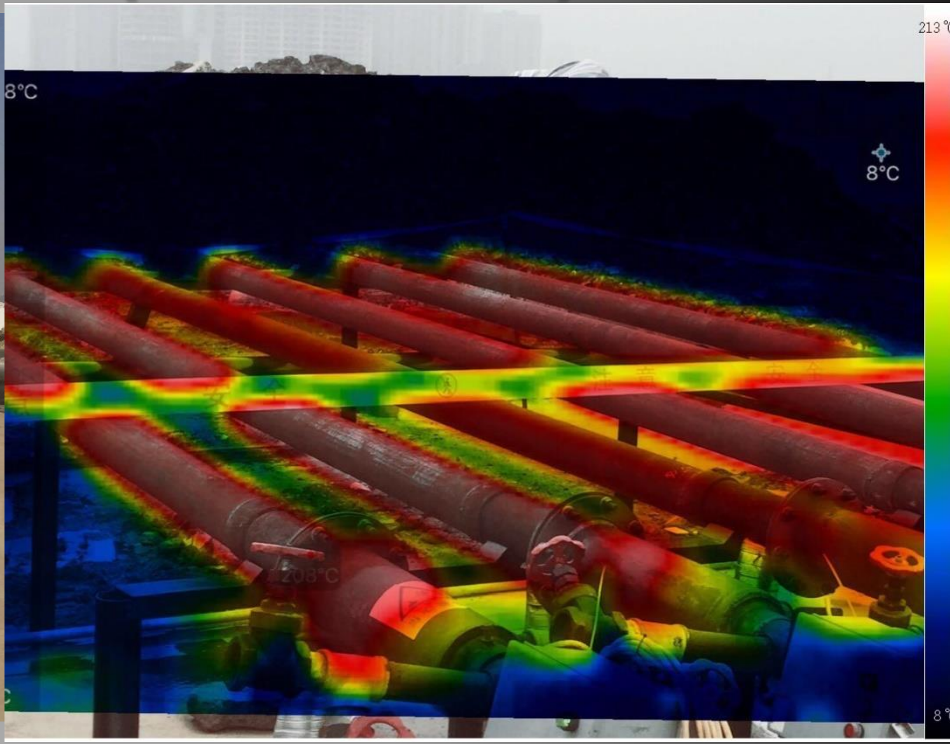
Method 5: GTR-O (Case #3)



- 800C ~300C
- Retention time is double of most thermal oxidizer
- VOCs from >15,000 ppmv to 120 ppmv

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Method 5: GTR-O

Case #4

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Method 5: GTR-O

Case #4

3-methyl-6-nitrophenol

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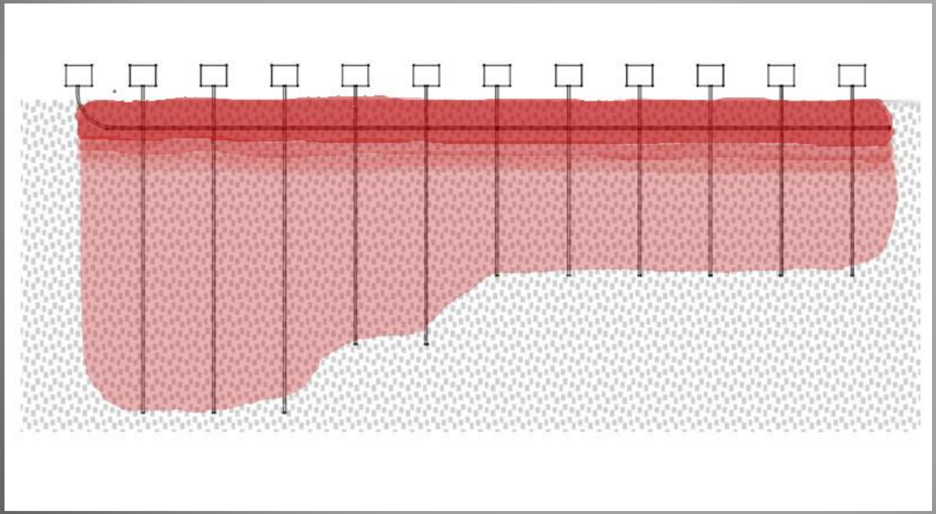
Method 5: GTR-O

Case #5

GTR-O: simultaneously heating the ground and treating vapor



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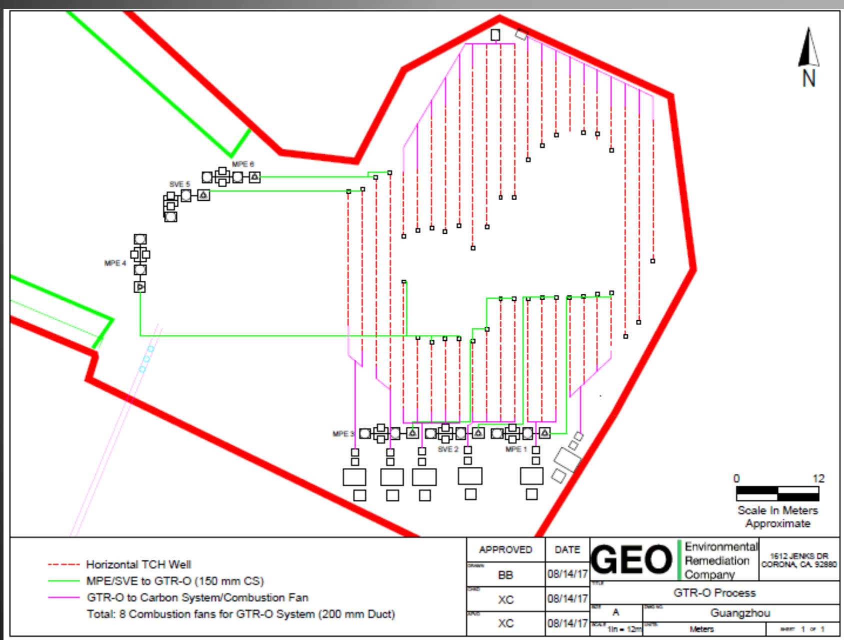
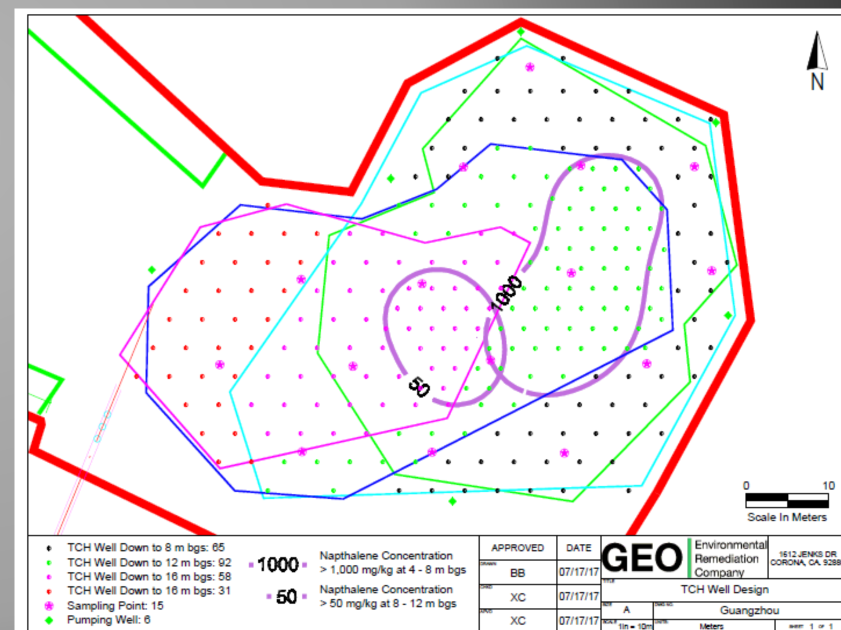
Method 5: GTR-O

Case #5





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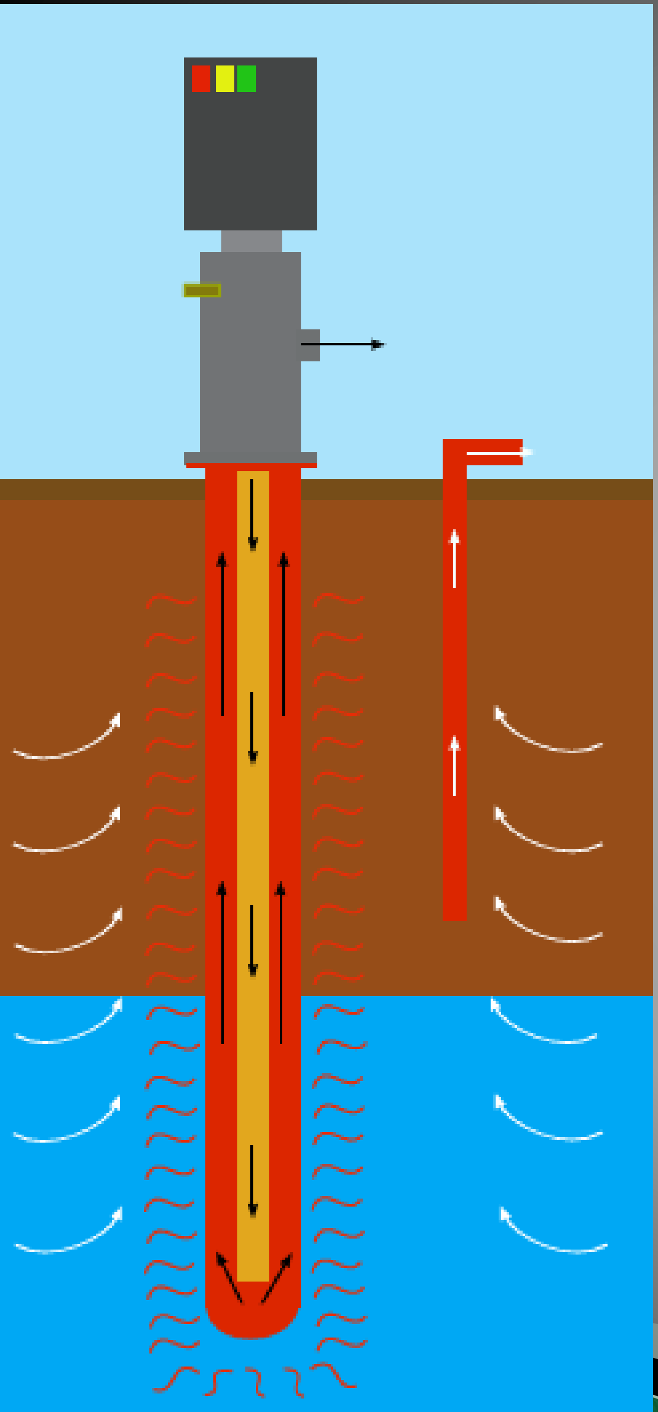

Questions?

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