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smoldering solutions

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safe, and
better for the
environment

STARx (Ex Situ Smouldering) for the Treatment of Contaminated Soils and Liquid Organic Wastes

Case Studies from Around the Globe

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Overview

- **Smouldering Combustion Basics**
- **STARx Case Studies**
  - Case Study 1: Canada
  - Case Study 2: China
  - Case Study 3: Taiwan
  - Case Study 4: Southeast Asia (Site 1)
  - Case Study 5: Southeast Asia (Site 2)
- **STARx Projects In Progress**
  - Upcoming Pilots: Brazil, Africa, United States, Australia
  - Full Scale Design: Middle East
- **Summary and Questions**

Smouldering Combustion

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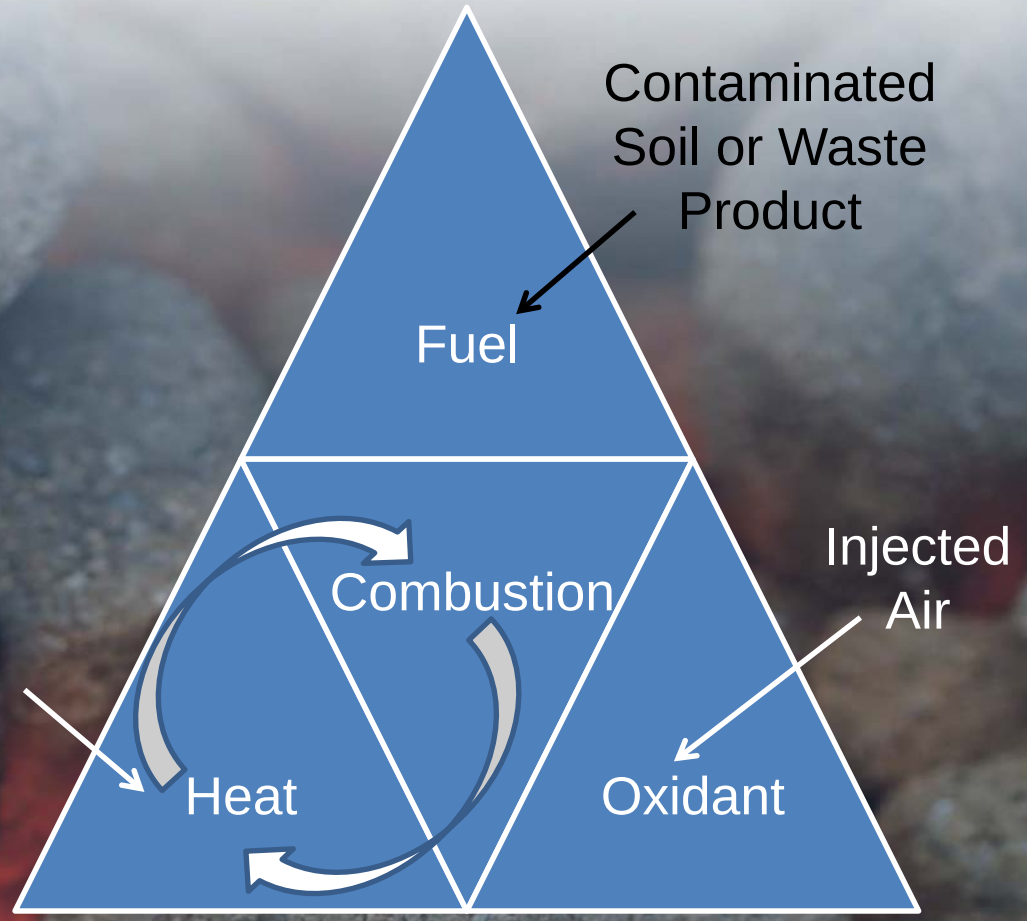
Smouldering Combustion

STAR and STARx are based on the process of smouldering combustion:

Exothermic reaction converting carbon compounds to $CO_2 + H_2O$

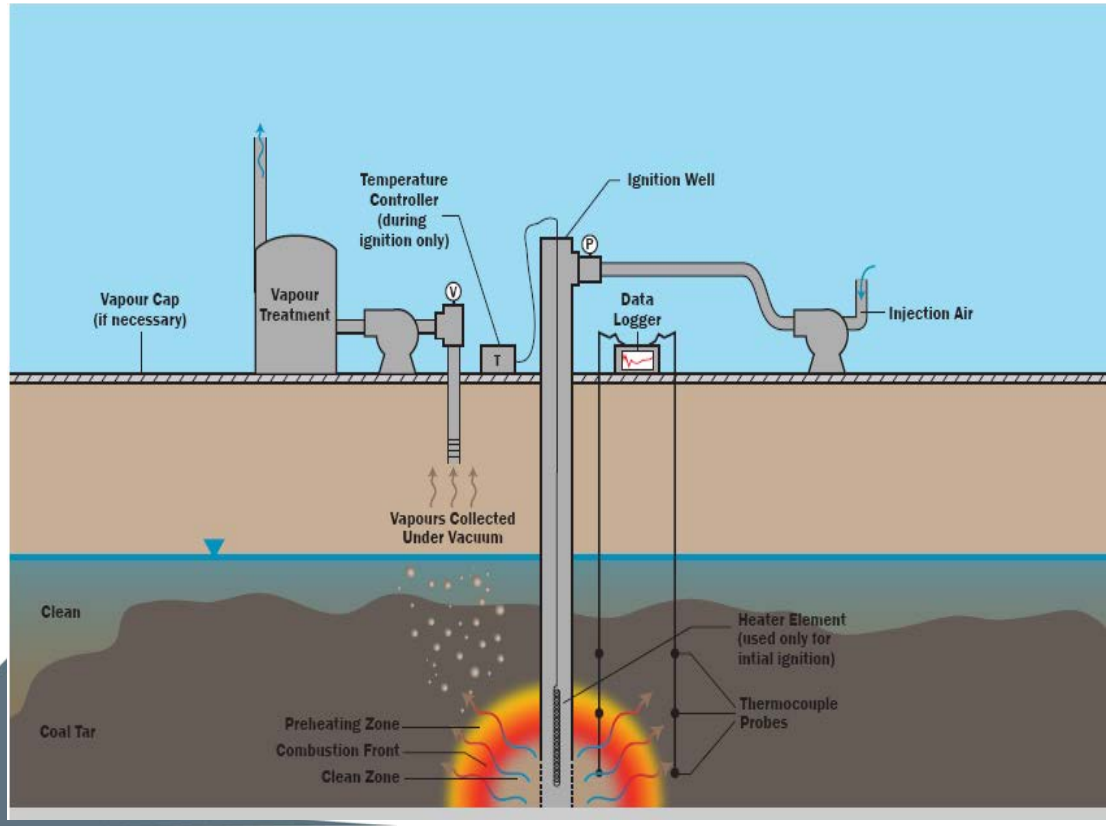


Smouldering possible due to large surface area of organic liquids (e.g., NAPL) within the presence of a porous matrix (e.g., aquifer)

Modes of Application

STAR

- **In situ (below water table)**
  - Applied via wells in portable in-well heaters



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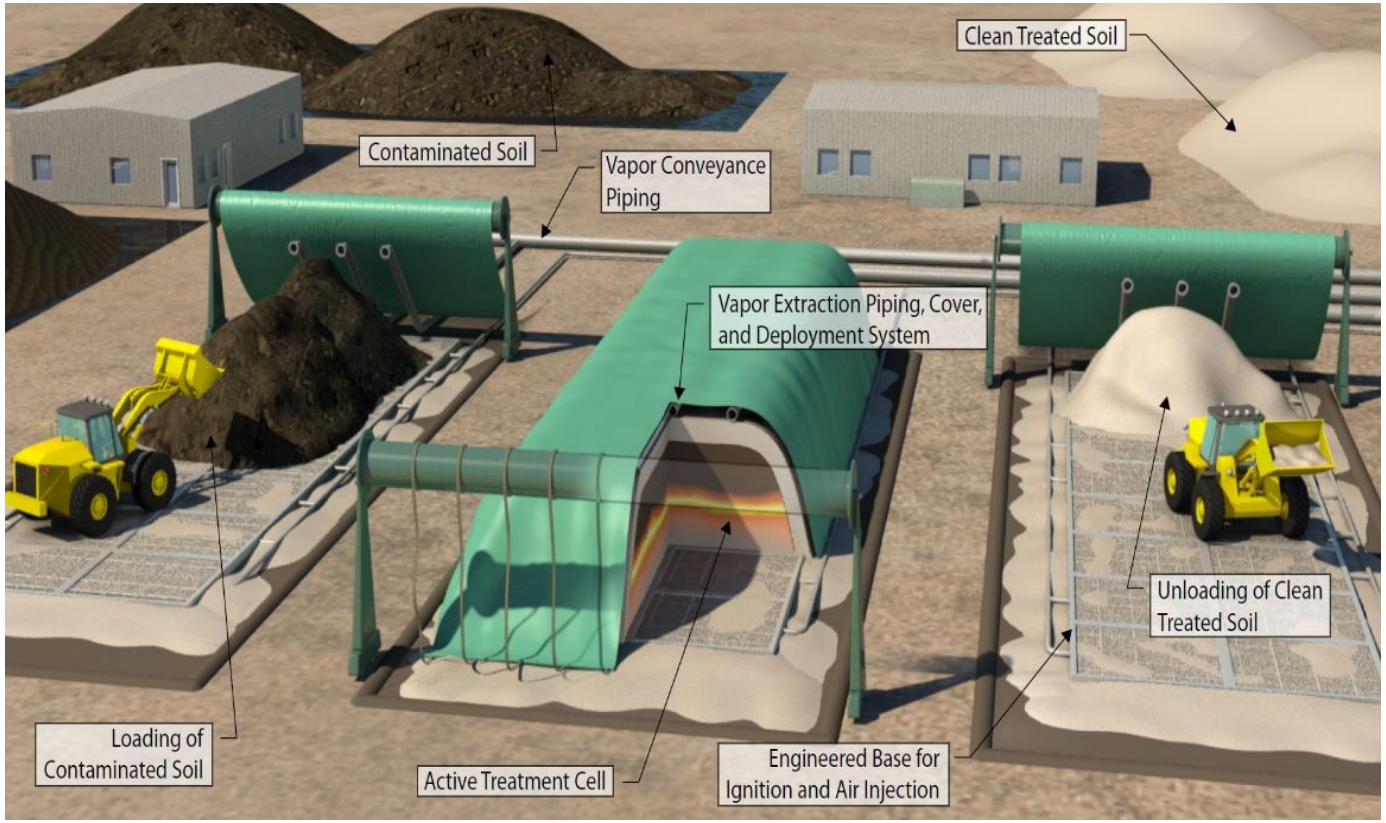
- **Ex situ (above ground)**
  - Soil piles placed on “Hottpad” system



STARx Hottpad

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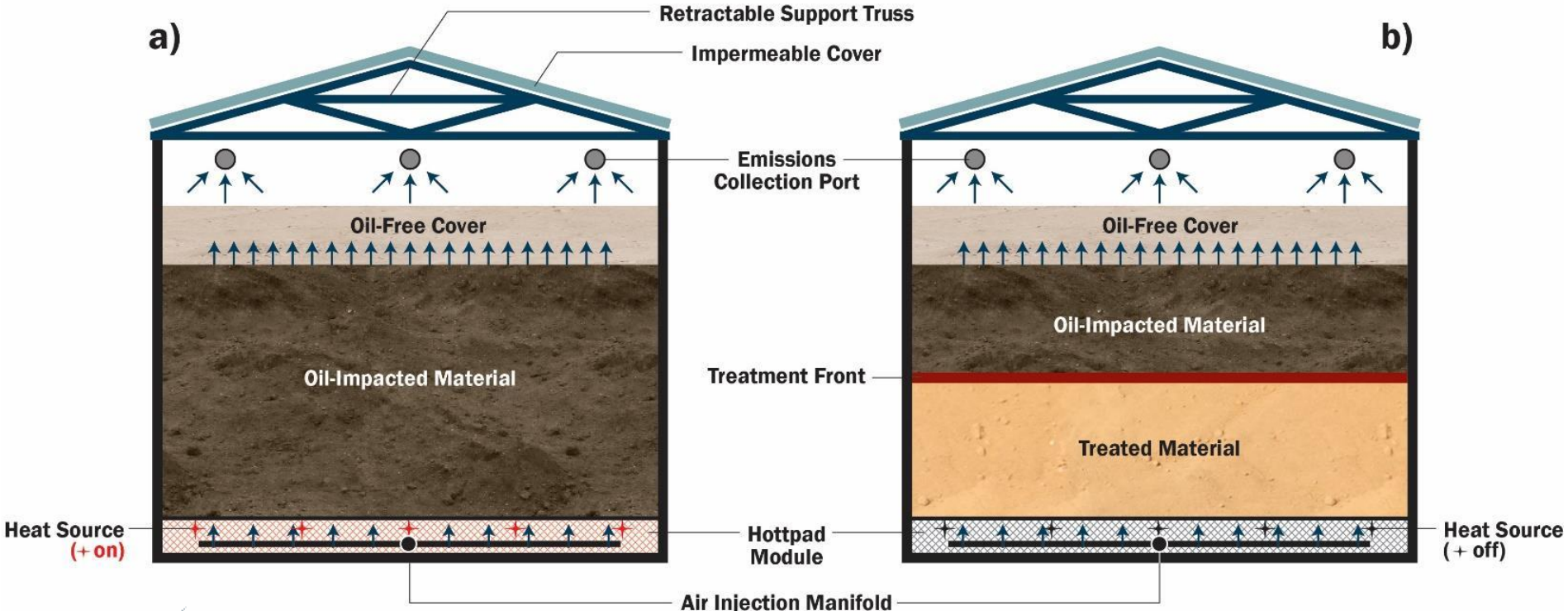
Overview of Hottpad Treatment



Video accelerated 50 times

Typical transformation of soil undergoing STARx process:

Hottpad Field Scales

Rapid Screening

- 1.5-2m^3 batches
- Rapid screening tests
- Multiple tests / fast deployment

Pilot Scale

- 6-10m^3 batches
- Full scale design parameters

Full Scale – Base System

- 150-200m^3 batches
- Multiple Base Systems integrated into larger plants to meet throughput

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Case Studies from Around the Globe

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Case Study 1: Toronto, Canada

WATERFRONToronto

STARx

Case Study 1:
Waterfront Toronto
Toronto, Canada

Site Background

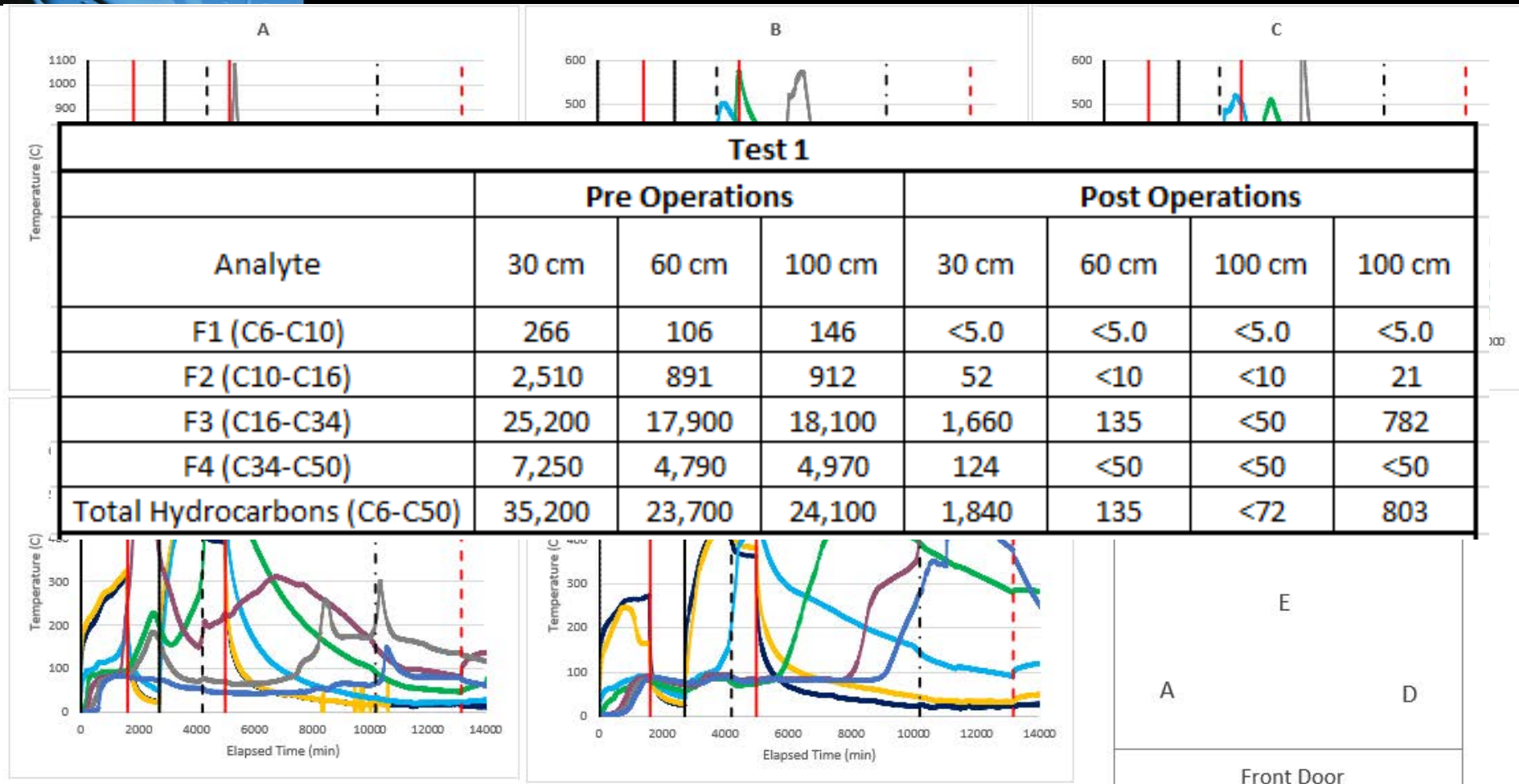
- The Port Lands Area is an 880 acre brownfield site, 715 acres of that are high-risk flood area
- In June 2017, WFT announced $1.25 billion in funding to naturalize the mouth of the Don River, provide flood protection and lay the groundwork for new communities
- Soil quality: widespread impacts across the site, with petroleum hydrocarbons (PHCs) being the predominant contaminant of concern

Scope of Work

- Treatability Study on Site soils
- STAR single ignition point pilot test
- STARx Hottpad pilot test (2 x 10 m^3 tests)

STARx Pilot Test

STARx Results



Test 1

	Pre Operations			Post Operations			
Analyte	30 cm	60 cm	100 cm	30 cm	60 cm	100 cm	100 cm
F1 (C6-C10)	266	106	146	<5.0	<5.0	<5.0	<5.0
F2 (C10-C16)	2,510	891	912	52	<10	<10	21
F3 (C16-C34)	25,200	17,900	18,100	1,660	135	<50	782
F4 (C34-C50)	7,250	4,790	4,970	124	<50	<50	<50
Total Hydrocarbons (C6-C50)	35,200	23,700	24,100	1,840	135	<72	803

Legend:

- 0 cm
- 10 cm
- 25 cm
- 50 cm
- 100 cm
- 140 cm
- 170 cm (clean cap)
- Heaters ON
- Air increased to 195 m³/min
- Air decreased to 119 m³/min
- Air increased to 229 m³/min
- Air increased to 382 m³/min
- Heater OFF
- Air OFF

Notes:

Thermocouple bundles A, B, C and D offset 60 cm from each corner.

Thermocouple bundle E located in the centre of the Hottpad™.

Thermocouple heights (i.e., 0 cm, 10 cm, 25 cm, 50 cm, 100 cm, 140 cm, and 170 cm) reported as distances above the screen at the base of the soil pile.

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STARx Results

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Case Study 2: Shaanxi, China

DADI BENESOURCE

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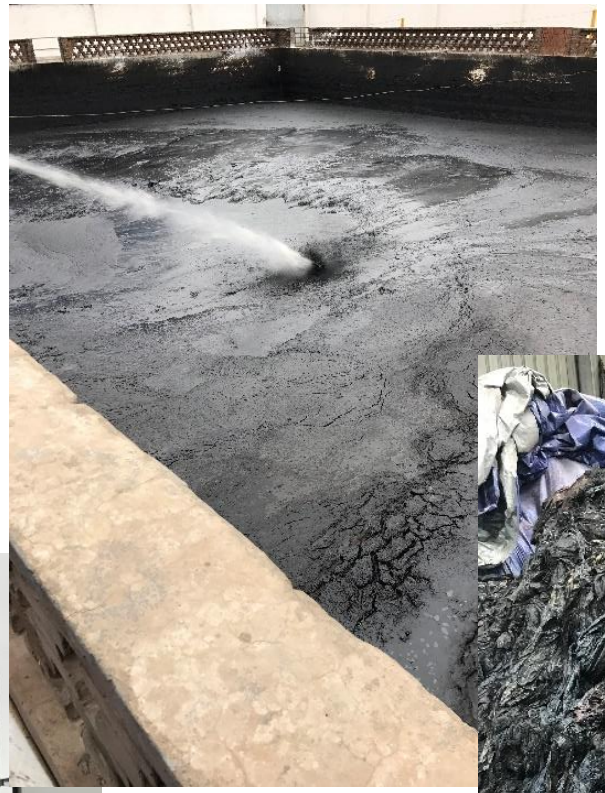
Case Study 2:
Sludge Disposal
Facility

Shaanxi, China

Sludge Disposal, Shaanxi, China

- **Sludge disposal and brick manufacturing facility**
- **Sludge waste (3 types)**
  - Plus oil-soaked bags
- **Dual-unit rapid screening system**



Sludge Disposal, Shaanxi, China

Test No.	Soil Type	Soil:Sludge: Shredded Bag Ratio	Sludge Type	Propagation Rate (m/d)	Total Petroleum Hydrocarbon Concentrations (mg/kg)	
					Pre-STARx	Post-STARx
1	Quartz sand	13:1:0	Pond #1	0.43	3,360*	7*
2	Site soil	13:1:0	Pond #1	0.37	7,830*	7*
3	Site soil	6:1:0	Pond #1	0.15	13,000*	79
4	Site soil	8:1:0	Pond #2	0.22	5,510*	ND
5	Site soil	4:1:0	Centrifuge	0.15	16,800*	ND
6	Site soil	4:3:0	Pond #2	0.13	30,600*	ND
7	Site soil	2:1:0	Centrifuge	0.17	25,300*	167
8	Site soil	1:1:1	Pond #2	0.12	66,300*	ND

Sludge Disposal, Shaanxi, China

Before



After



Case Study 3: Kaohsiung, Taiwan

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Case Study 3:
PHC-Impacted Soil
Kaohsiung, Taiwan

PHC-Impacted Soil, Kaohsiung, Taiwan

- **Former base oil and lubricant blending plant**
- **Range of soil types:**
  - Silt, sand, and gravelly sand
- **Focus on finding lower concentration threshold of SS smouldering**
- **Rapid screening system**

PHC-Impacted Soil, Kaohsiung, Taiwan

- **Site silts and gravelly sands successfully treated**
  - SS smouldering achieved with initial concentrations as low as ~4,000 mg/kg TPH
  - Lower initial concentrations possible if amended with surrogate fuel

Case Study 4: Southeast Asia (Site 1)

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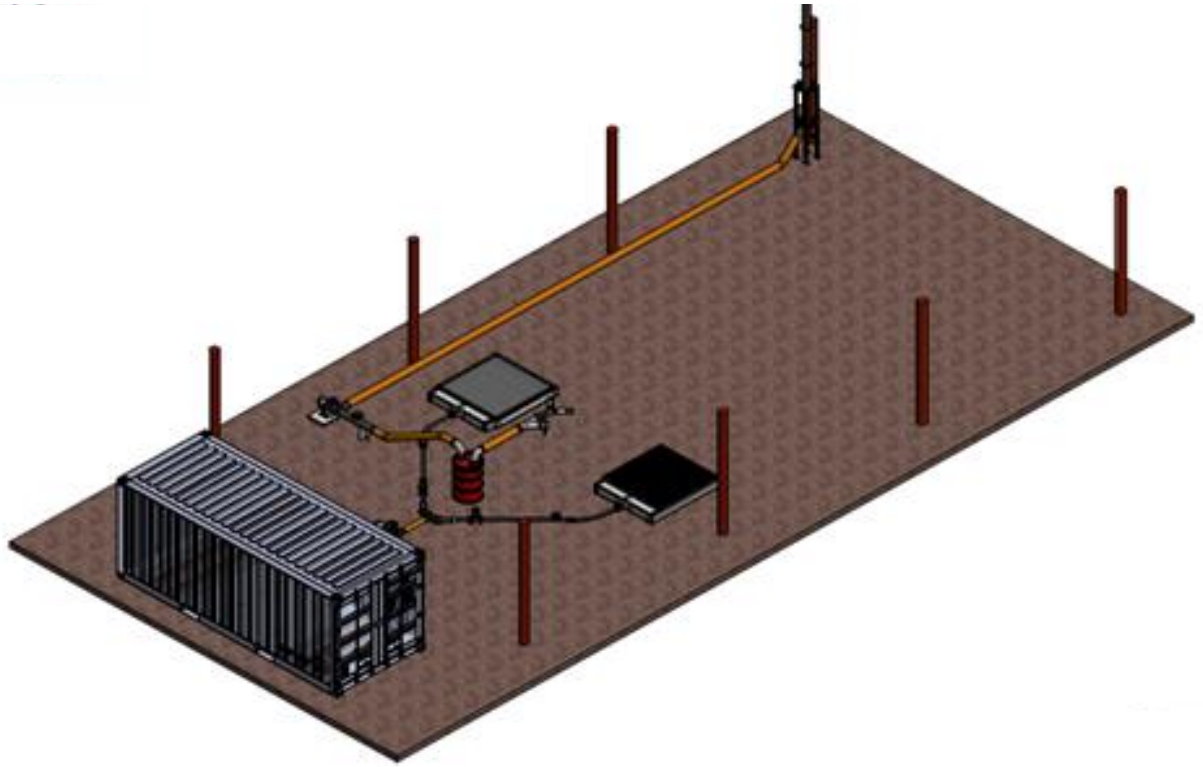
Case Study 4: Fine Grained Materials and Revegetation of Treated Soils *Southeast Asia (Site 1)*

Pilot Test Overview

- **Treat oil-impacted soil (OIS)**
  - Confirm treatment via STARx
- **Assess operational envelope**
  - Oil content, moisture content, clay content
- **Develop information to support system design**
  - Full-scale systems (fixed and mobile)
- **Field study of revegetation potential**



Hottpad Rapid Screening System Set up

Soils Tested

- **High clay and silt content (70 – 80%)**
- **Moderate to High moisture content (15 – 40%)**
- **Variable oil content (1 – 4.5%)**
  - Non-uniform distribution

Combustion Results

- **Completed 12 test runs**
  - **All** runs successfully treated OIS
  - The treatment process is very robust
  - Clay, water, and oil content
- **Soil mixing for more uniform oil distribution**
  - Does not require homogeneity
- **Improved performance at lower injection flow**
  - More uniform treatment
  - Less probability of fracturing the pile

Before Treatment

After Treatment

Revegetation Study

Clean Soil

Oil-Impacted Soil

Hottpad Treated Soil

Fertilizer

No Amendments

Case Study 5: Southeast Asia (Site 2)

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Case Study 5: Full-Scale Treatment of Oil-Water Separator Sludge
Southeast Asia (Site 2)

Site Background

- Active terminal facility in south east Asia
- Designed to treat 3,500 m^3 of stockpiled API separator sludge
- Co-treatment with oil-impacted site soils

Hottpad Full-Scale – Field Deployment

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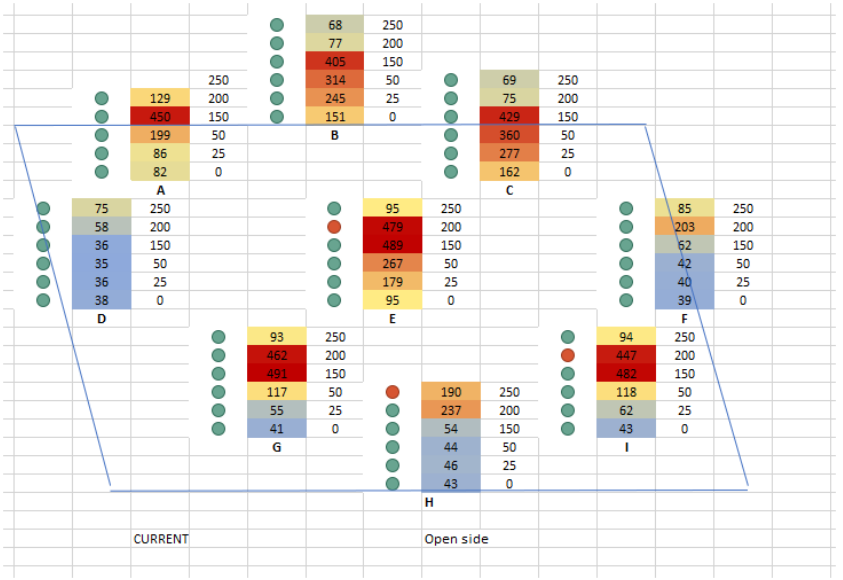
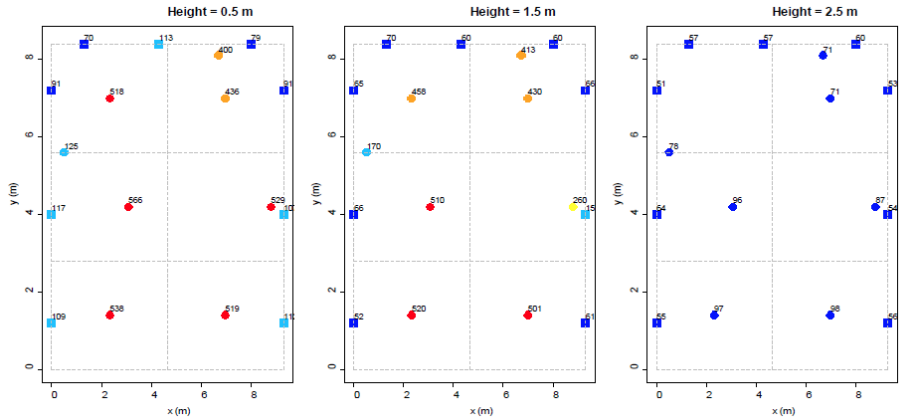
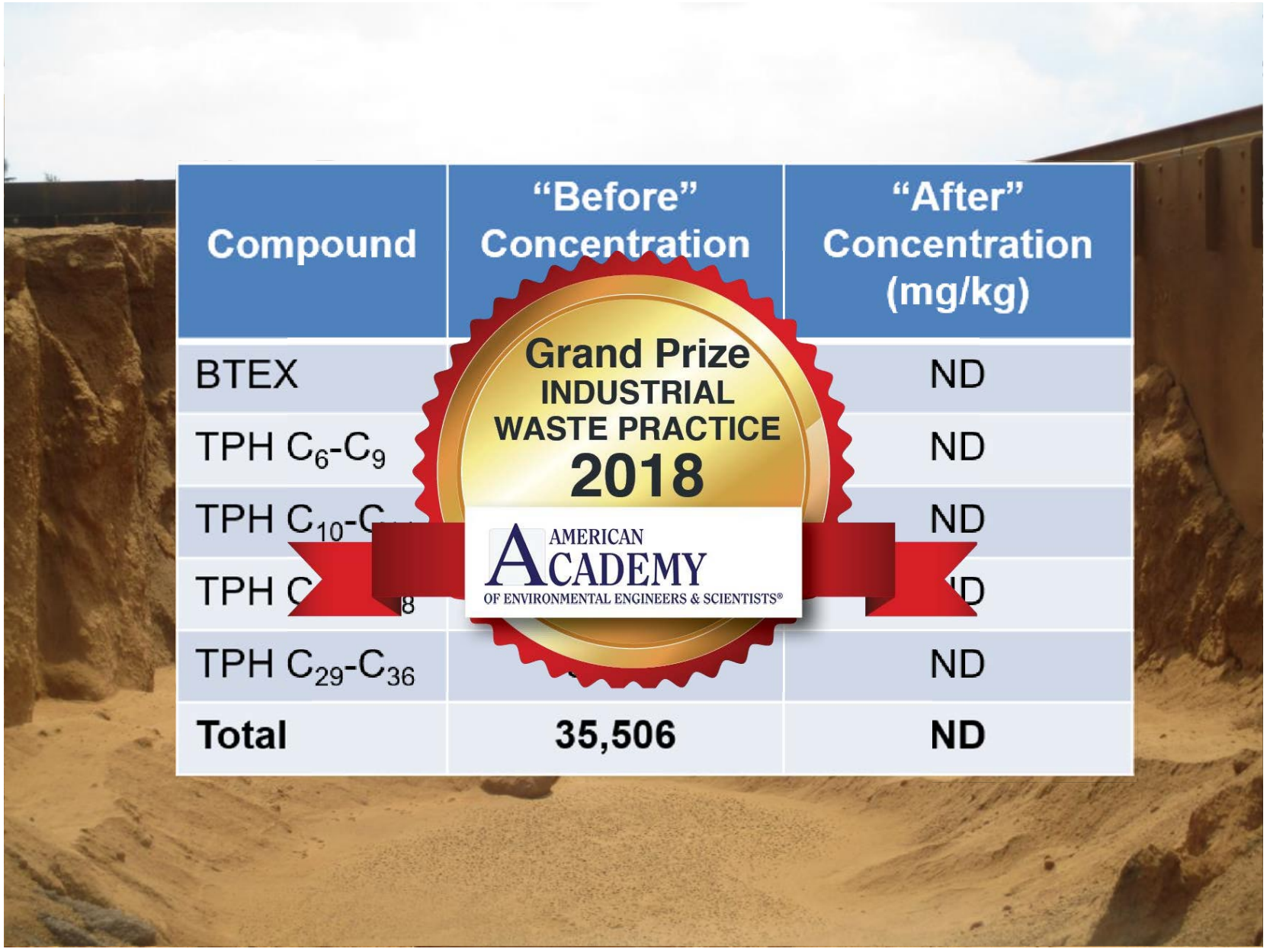
Hottpad Loading

Process Monitoring





Additional Post-Treatment Results



Compound	"Before" Concentration	"After" Concentration (mg/kg)
BTEX		ND
TPH C_6-C_9		ND
TPH C_{10}-C		ND
TPH C		ND
TPH C_{29}-C_{36}		ND
Total	**35,506**	**ND**

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STARx (Upcoming Projects)

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Upcoming Projects

Brazil

- STARx Pilot on Chloronitrobenzene compounds in soil (Q3 2019)
- Former Chemical manufacturing facility in Brazil
- Multiple 10m^3 test runs to optimize full scale operating parameters

Africa

- STARx Pilot to test hydrocarbon paraffin sludges (Q1 2019)
- Active oil terminal facility in Western Africa

Upcoming Pilot Projects

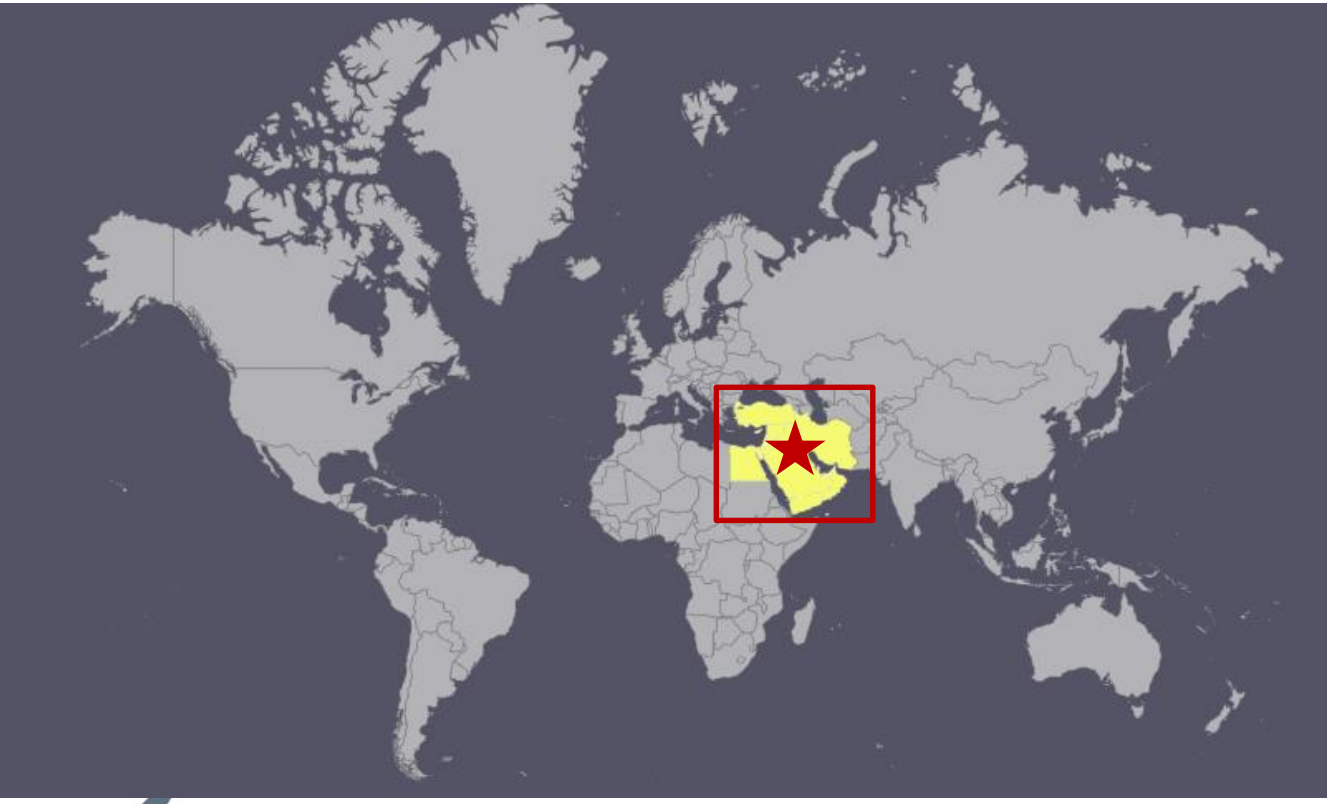
United States

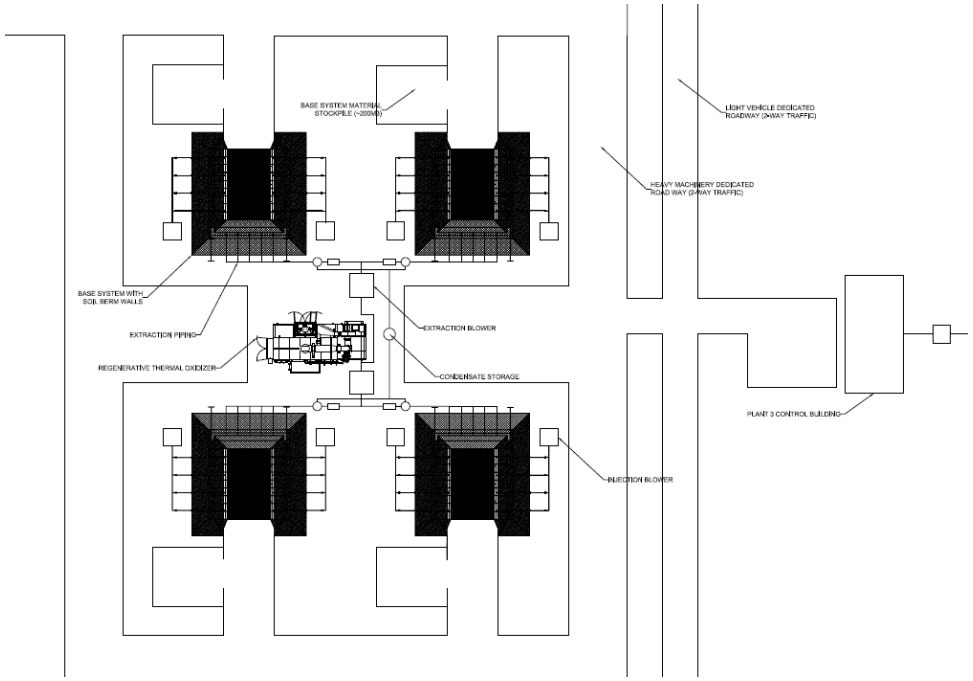
- Active oil field in western United States
- Treat hydrocarbon sludge and impacted soil
- Demonstrate technology with regulatory agencies

Australia

- Commercial waste processing facility in North Western Australia
- Full scale treatment of hydrocarbon sludge
- Trial emerging contaminants

Full Scale in Middle East





4 Base System Plant

- Designed to treat approximately 300,000m^3 of hydrocarbon sludge in 5 years
- Design underway, field deployment set to begin in 2019

Technology Cost Drivers

- **Capital**
  - Hottpad system
  - Emissions treatment system
- **Throughput**
  - Treatment propagation rate
  - Project duration
- **Energy Requirements**
  - Heaters
  - Blowers
  - Emissions treatment

Example Project

- 4-Base System Plant in North America to designed to treat ~ 200,000 tonnes of soil in 5 years
- CapEx of 40$/tonne (CDN)
- OpEx of 25$/tonne (CDN)

Summary

- **Effective and Robust**
  - Rapid on-site treatment
  - Complete destruction of contaminants
- **Reduced cost versus other technologies**
- **Safe and Sustainable**
  - Self-sustaining process = less energy use
- **Flexible**
  - Modular STARx systems fully expandable to meet target throughput
  - Deployable at source areas and remote locations all over the world

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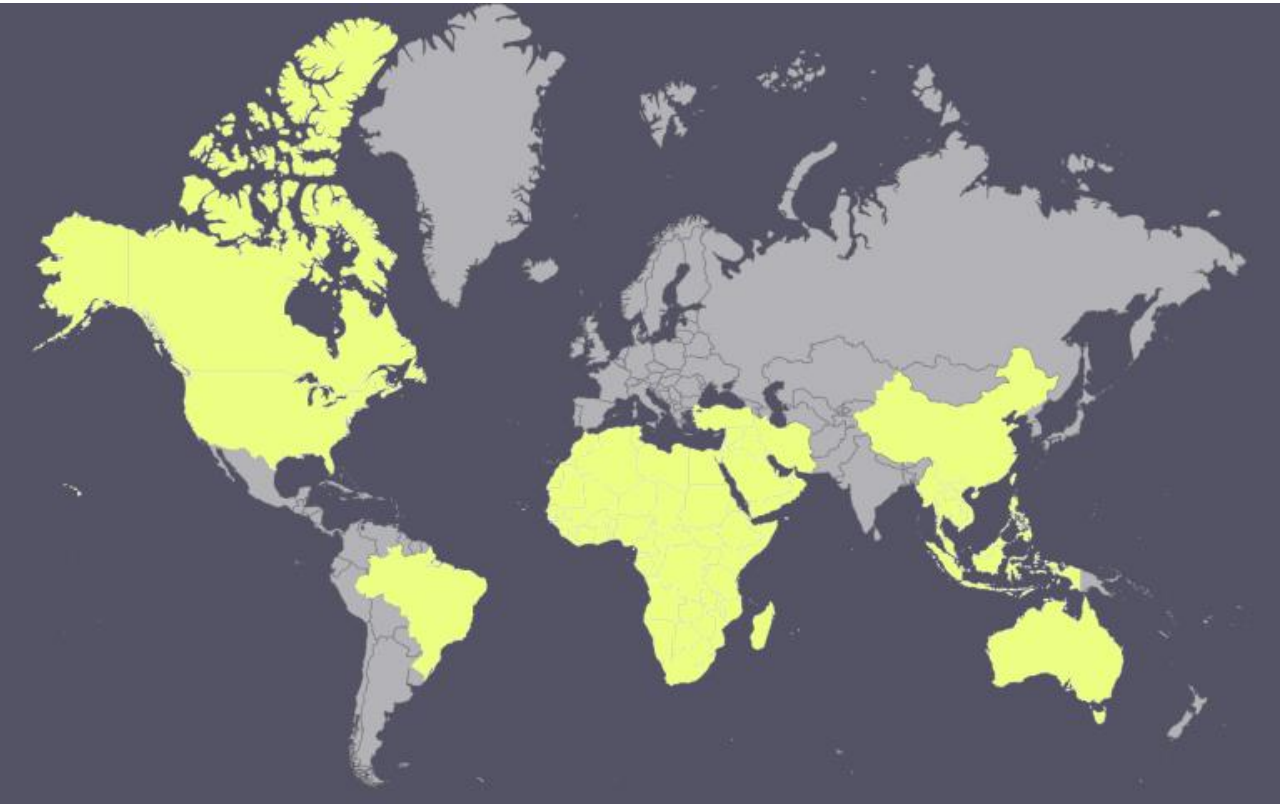

Questions?

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