REMTECH EXPO

REMTECH Europe

In Situ Stabilization and Solidification (ISS) The Optimized Benefits of Sodium Persulfate

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Outline

- ISS-ISCO Technology Overview
- ISS-ISCO Case Studies
- Summary

In Situ Solidification-Stabilization

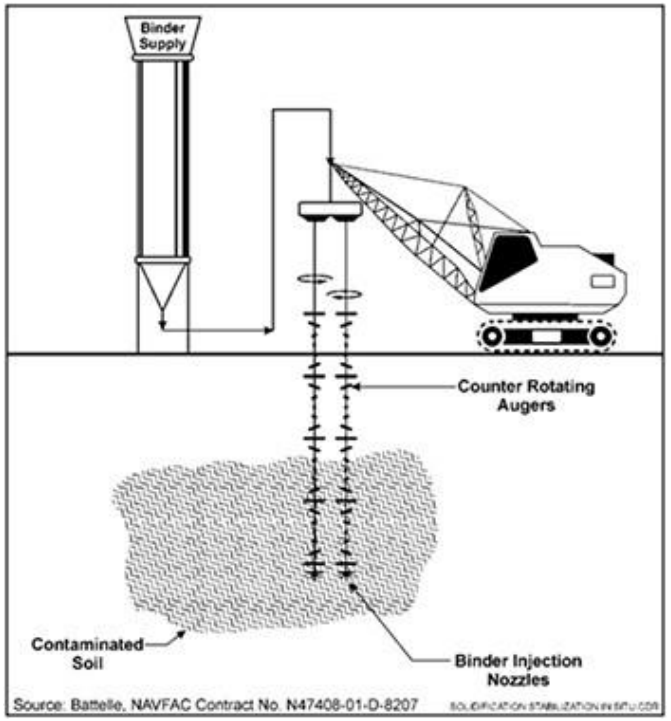
In Situ Solidification-Stabilization (ISS)

- Contaminant ***immobilization or mass flux reduction***
- Decreases the hydraulic conductivity of soils
- Compressive soil strength influenced by type and dose of reagents
- Applied via soil mixing/blending

ISS is commonly used to immobilize highly contaminated petroleum hydrocarbon sites (MGP sites, etc.)

ISS

- Common applications:
  - 10-40% w/w binder addition
    - Ex: Portland cement
  - Proportional water added
  - A single binder is common



Common Objectives of ISS

- Reduced hydraulic conductivity
  - 2-3 orders of magnitude below native soils
  - 1 x 10^{-6} cm/sec
- Unconfined Compressive Strength (UCS)
  - "Workable" ~20-60 psi
  - Hardened
- Lower contaminant flux and leachate concentrations

General Relationship between Soil Consistency and Unconfined Compressive Strength

Consistency	Unconfined Compressive Strength (UCS) Ranges			
	psi		kPa (KN/m^2)	
	Low	High	Low	High
Very soft	0	3	0	24
Soft	3	7	24	48
Medium	7	14	48	96
Stiff	14	28	96	192
Very Stiff	28	56	192	383
Hard	>56		>383	

Typical target range for "workable" soils ~20-60 psi

ISCO can help resolve ISS Challenges

ISS	ISCO/ISS
• No contaminant destruction	• Contaminate destruction
• Disposal of contaminated soils	• Reduced binder and water volume result in less disposal
• High carbon footprint	• Lower carbon footprint (less binder)

ISCO-ISS

- Binder plus Klozur® SP (sodium persulfate).
  - 1-10% Portland Cement
  - 0.5-5% Klozur SP
- Common ISS binder reagents can also create alkaline activated conditions for persulfate
- Typically less binder material is needed to achieve ISS goals when combined with sodium persulfate
  - Reduced handling and disposal of excess soils

Common ISS reagents

Portland cement (~65% CaO)

- Calcium hydroxide [$Ca(OH)_2$]
- Calcium oxide (CaO)
- Fly Ash (Class C & F)
- Blast furnace slag
- Lime kiln dust
- Cement kiln dust
- Pozzolans
- Bentonite

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ISS and ISCO

Srivastava et al (2016), J. Environ Chem. Engineering, 4, 2857-2864

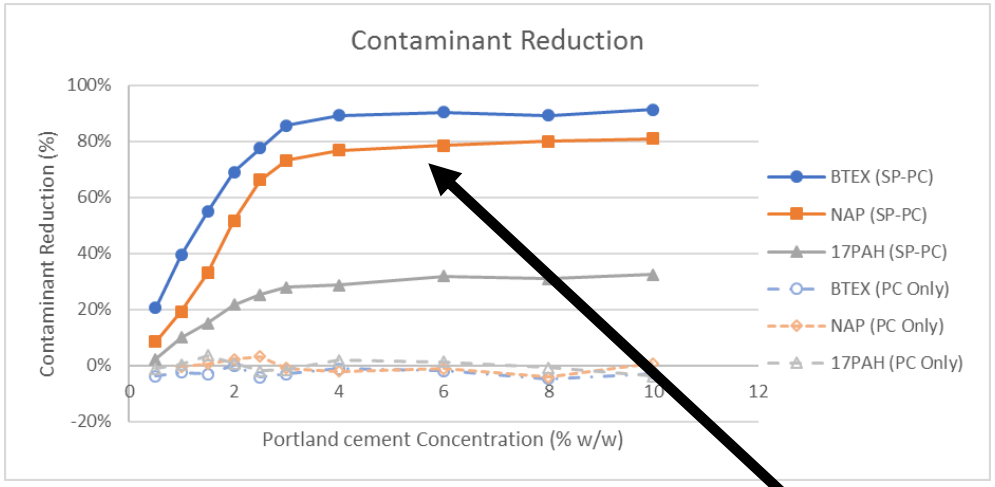
- Highly contaminated soils (MGP residuals)
  - >36,900 mg/Kg TPH
  - ~6,800 mg/Kg BTEX
  - ~13,400 mg/Kg Naphthalene (Nap)
  - ~16,900 mg/Kg 17 PAHs (not including Nap)

- Portland Cement (PC) : Klozur SP ratio (2:1 w/w)
  - **CaO in PC facilitates alkaline persulfate activation**

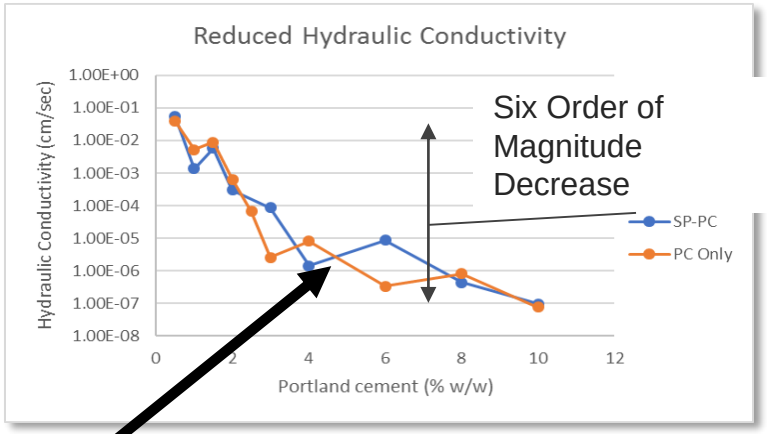
- ISCO:
  - Persulfate loading underdosed for complete treatment of TPH
  - Preferential treatment of soluble contaminants

Combining ISS and ISCO

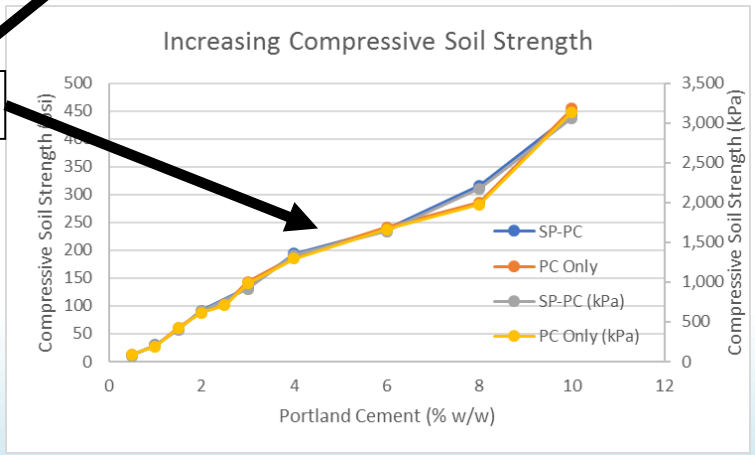
Srivastava et al (2016), J. Environ Chem. Engineering, 4, 2857-2864



ISCO

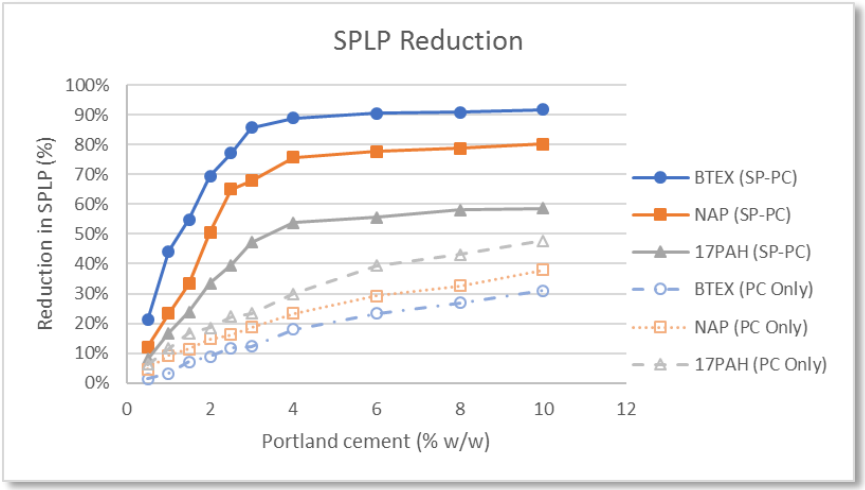


ISS



ISS Benefits: Leachate Concentrations

- Contaminant leachate reduction
  - Greater reduction in leachate concentrations with Persulfate and Portland cement than Portland cement only
  - ISCO preferentially reduced more soluble contaminants
  - Portland cement alone only preferentially reduced leachate concentrations of larger, less soluble compounds



SPLP (synthetic precipitation leaching procedure)

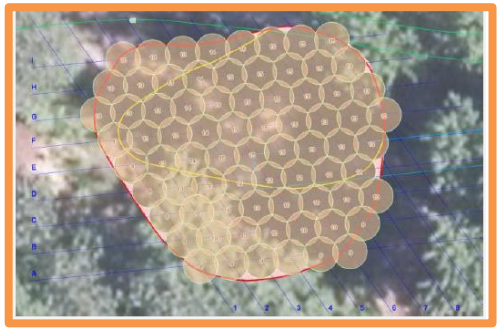
Srivastava et al (2016), J. Environ Chem. Engineering, 4, 2857-2864

Case Study: Søllerød Gasværk

- Former MGP Site Denmark
  - 3% Klozur SP
  - 8% Portland Cement/Slag
- ISS Goals:
  - UCS: 100% > 20 psi (150 kPa) after 80 days
  - Permeability:
    - Avg: 2.1 x 10^{-7} cm/sec
    - 100% of 26 samples ≤ 1 x 10^{-6} cm/sec

Compound	Baseline Concentration[1] (mg/Kg)	Post Application Concentration (mg/Kg)	Reduction due to Treatment (%)
Benzene	13 to 27	ND	>99
Naphthalene	100 to 160	23	80-85
Phenols	3	0.04	99
TOC	500 to 800	23	85-90

1. Based on conversion of contaminant mass estimates



Nissen L. et al, (2019), "Full Scale ISS/ISCO soil mixing Søllerød Gasværk," Vintermøde 2019, Temadag om Soil Mixing som afværgemetode

Case Study: Bolzano, Italy

- Treatment volume:
  - 3,500 m^3
- Depth:
  - 3 to 8 m bgs
- 556 columns
- Reagents
  - 0.7 - 1% Klozur SP
  - 4 to 8 percent Portland cement
- Treatment Goals:
  - Contaminant reduction
  - Waste minimization
  - Stable Compressive Soil Strength

Courtesy of Ladurner

Bolzano Results

ISS Remedial Goals:

- UCS:
  - 215 kPa to 470 kPa
  - ~30 psi to ~70 psi
- Permeability:
  - 2.8 x 10^{-6} cm/sec to 7.3 x 10^{-7} cm/sec

Less than 15% bulking of Soils

- ISCO Remedial Goals:
  - Benzene:
    - 100% sample locations below 2 mg/Kg remedial goal
  - TPH (C<12)
    - 100% sample locations below 250 mg/Kg remedial goal
  - TPH (C>12)
    - Some free product observed
    - Some TPH (C>12) above goals

Summary

- ISS can be enhanced by the addition of sodium persulfate
  - ISCO-ISS
- ISCO-ISS addresses several issues with ISS only
  - Less excess soil requiring disposal
  - Carbon footprint decreased
  - Contaminant destruction
    - Contributes to lower leachate concentrations
- ISCO-ISS still achieves common ISS goals (UCS, hydraulic conductivity, etc)
- Water content needs to be optimized along with reagents

Questions

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Project Teams for Case Studies

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- Kim Jensen/Arkil

Bolzano, Italy

Ladurner/Bauer

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