



consultants

engineers | scientists | innovators



Brant Smith, PhD, PE
PeroxyChem
Technical Applications Manager



Chris Robb, PE
Geosyntec
Principal Engineer

WEBINAR

Wednesday, October 30th
11 AM and 2 PM EDT

**Fundamentals of Combining In Situ
Solidification and Stabilization (ISS)
with ISCO**

Dr. Brant Smith of PeroxyChem and
Chris Robb of Geosyntec will present the
fundamentals of *combining in situ*
solidification and stabilization with *in situ*
chemical oxidation.

Welcome!

Questions



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Fundamentals of Combining In Situ Solidifi...
Webinar ID: 336-331-619

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<http://www.peroxychem.com/remediationwebinars>

remediation@peroxychem.com

The screenshot shows the 'Webinars' page on the PeroxyChem website. The page features a navigation bar with 'MARKETS', 'CHEMISTRIES', 'ABOUT US', 'NEWS & EVENTS', and 'CONTACT'. Below the navigation bar is a banner with the word 'Environment' and various icons representing environmental remediation. The main content area is titled 'Webinars' and includes a brief introduction: 'As part of our commitment to the soil and groundwater remediation market, we offer a series of free webinars. The educational webinars, led by individuals from our experienced team of technical professionals, focus on a variety of topics on the science behind some of today's most innovative remedial treatments.' Below this is a subscription box with a camera icon and the text: 'To receive notifications of other upcoming webinars, we welcome you to subscribe to the Environmental Solutions mailing list. Subscribe here.' The main list of webinars includes:

- Klozur® KP Applications Experience: Extended Release Chemical Oxidation**
Since being launched in 2016, Klozur KP has been bench tested and applied at numerous sites around the world. With its unique extended release characteristics, Klozur KP is ideal for...
- Introducing Klozur® One: An All-in-One Fully Soluble Activated Persulfate Reagent**
Dr. Brant Smith introduces Klozur® One, a new addition to PeroxyChem's Klozur product portfolio of powerful oxidants.
- Soil Mixing and In Situ Stabilization Using Klozur® Persulfate**
Dr. Brant Smith of PeroxyChem, Professor Dan Cassidy of Western Michigan University, and Tom Simpkin and Mike Perlmutter of CH2M introduce strategies using in situ mixing to apply alkaline...
- Introducing Klozur® KP - an extended release ISCO persulfate reagent**
Dr. Brant Smith introduces Klozur® KP, a new addition to PeroxyChem's Klozur product portfolio of powerful oxidants.
- PFAS Emerging Issues and Potential Remediation Methods**
Dr. Ian Ross of ARCADIS provides an overview of the emerging issues surrounding poly-perfluoroalkyl substances (PFAS) including PFOS and PFOA.
- Monitoring Programs for Klozur® Persulfate Applications: Information Needed Before, During and After an Application**
Dr. Brant Smith discusses the monitoring programs necessary for a remedial approach using Klozur Persulfate, as well as best practices for assessing its effectiveness.
- In Situ Treatment of Pesticide-impacted Soil to Attain Residential Remediation Standards**
Dr. Alan Seech reviews the chemistry of ISCR for treatment of pesticides using a cycled, anaerobic/aerobic approach. A key advantage of this ISCR treatment is its ability to attain even...
- Heavy Metals Treatment Theory and MetaFix® Reagents**
Dr. Alan Seech reviews heavy metal treatment theory and introduces MetaFix® reagents. MetaFix reagents are site specific formulations of ZVI, other reducing agents, reactive minerals...
- Bench Testing for the Successful Implementation of Remediation Technologies**

On the right side of the page, there is a sidebar with the heading 'In Soil and Groundwater' and a list of links: 'Free Site Evaluation', 'Case Studies', 'Contaminants Treated', 'Webinars', 'Sample Requests', and 'Technical Document Search'.

Field-Proven Portfolio of Remediation Technologies

Chemical Oxidation

- Klozur® Persulfate Portfolio
- Hydrogen Peroxide

Chemical Reduction

- EHC® Reagent
- EHC® Liquid
- Daramend® Reagent
- Zero Valent Iron
- GeoForm™ Reagents

Aerobic Bioremediation

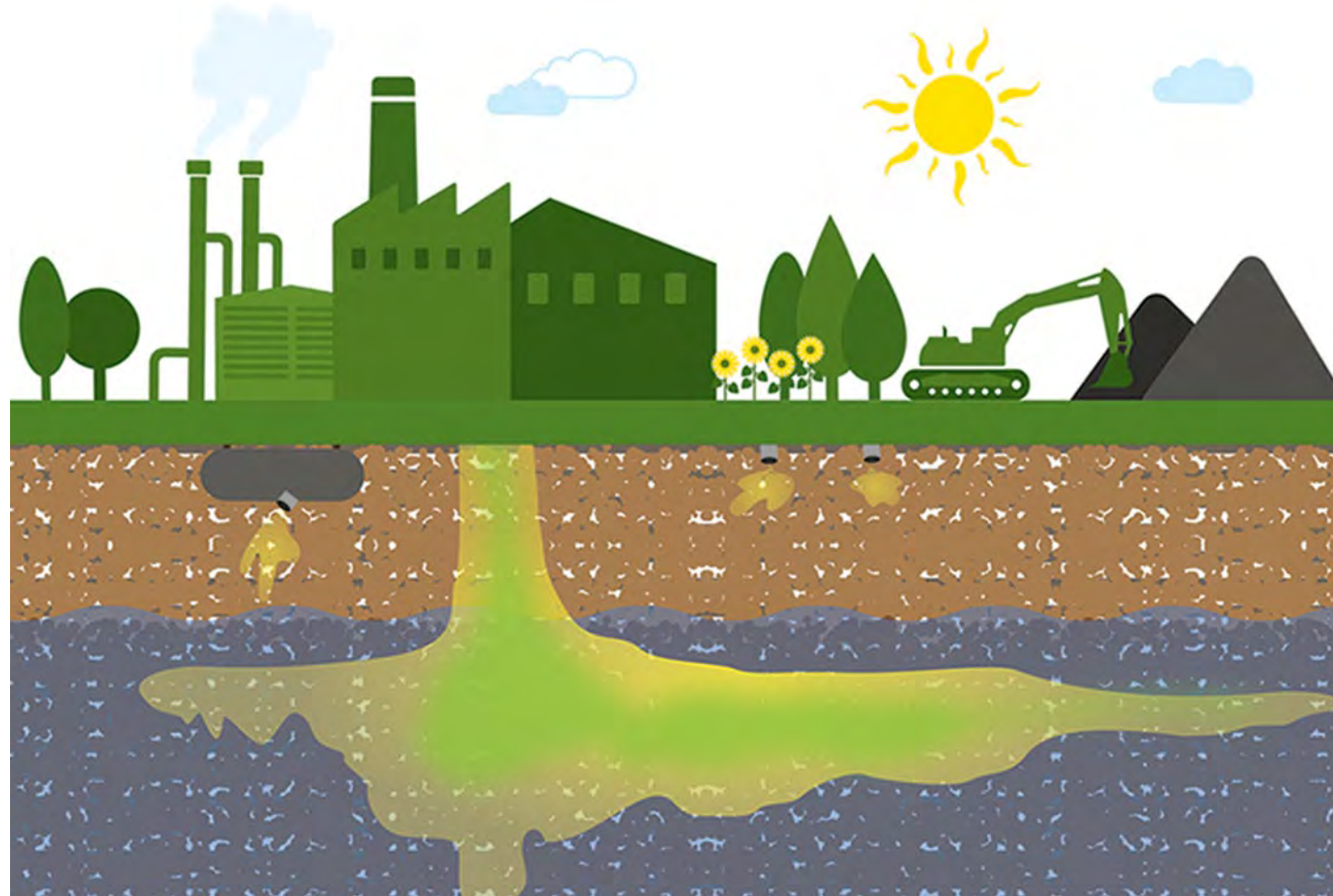
- Terramend® Reagent
- PermeOx® Ultra

Enhanced Reductive Dechlorination

- ELS® Microemulsion
- ELS® Concentrate

Metals Remediation

- MetaFix® Reagents





Previous Soil Mixing Webinar

- Overview of soil mixing
- Bench testing
 - ISCO-ISS
- Case Study
 - Site now closed

January 2017 Speakers

- **Tom Simpkin, Ph.D, P.E.**
 - Remediation Technology Leader and Senior Technologist for CH2M-Denver
 - Ph.D. University of Wisconsin-Madison
 - Over 30 years of experience
- **Dan Cassidy, Ph.D., P.E.**
 - Associate Professor at Western Michigan University
 - Over 400 Bench Scale Treatability Studies
 - 37 peer-reviewed publications
- **Mike Perlmutter, P.E.**
 - Senior Technologist CH2M - Atlanta
 - M.S. University of Texas-Austin
 - Over 20 years experience



<http://www.peroxychem.com/remediationwebinars>



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fundamentals of *combining in situ*
solidification and stabilization with *in situ*
chemical oxidation.

Chris Robb, 23 years experience; 17+ with ISS technologies

- B.S. Civil Professional Engineer (WI, FL)
- Remediation design and construction – “Develop Constructible Designs”
- In situ stabilization/solidification (ISS)
 - Engineer of record, remedial action coordination, constructability review, and senior technical expertise for over 500,000 cubic yards of ISS/DSM implementations across more than 20 project sites in US, Europe and Australia
 - Led design and implementation of first successful ISCO/ISS application in Denmark
 - ISS Experience on CVOC, MGP, CERCLA, SAS, Sediment, and CCR Sites
- Significant Contributions to the Practice:
 - **Featured Presenter/Instructor:** *Theme Day 1 - Soil Mixing as A Remediation Method*, Winter Meeting 2019, ATV Jord of Grundvand, Vejle, DK
 - **Principal Investigator/Author:** *Corrective Action Technology Profile: Practical Feasibility of In Situ Stabilization/Solidification as a Source Control for Coal Combustion Residuals*, EPRI Report 3002008475, December 2016
 - **Contributing Author:** *Development of Performance Specifications for Solidification/Stabilization*, Interstate Technology & Regulatory Council (ITRC), July 2011
 - **Inventor:** United States Patent No. US 9,909,277 B2, "IN SITU WASTE REMEDIATION METHODS AND SYSTEMS" March 6, 2018





Outline

- Technology overview
 - ISS
 - ISCO-ISS
- Benefits of a combined Remedy
- Case study
- Lessons learned
- Summary

TREATMENT

- Mixing of contaminated materials with cementitious/pozzolanic reagents:
 - ***Reduces contaminant migration via Advection, Hydrodynamic Dispersion and Diffusion***

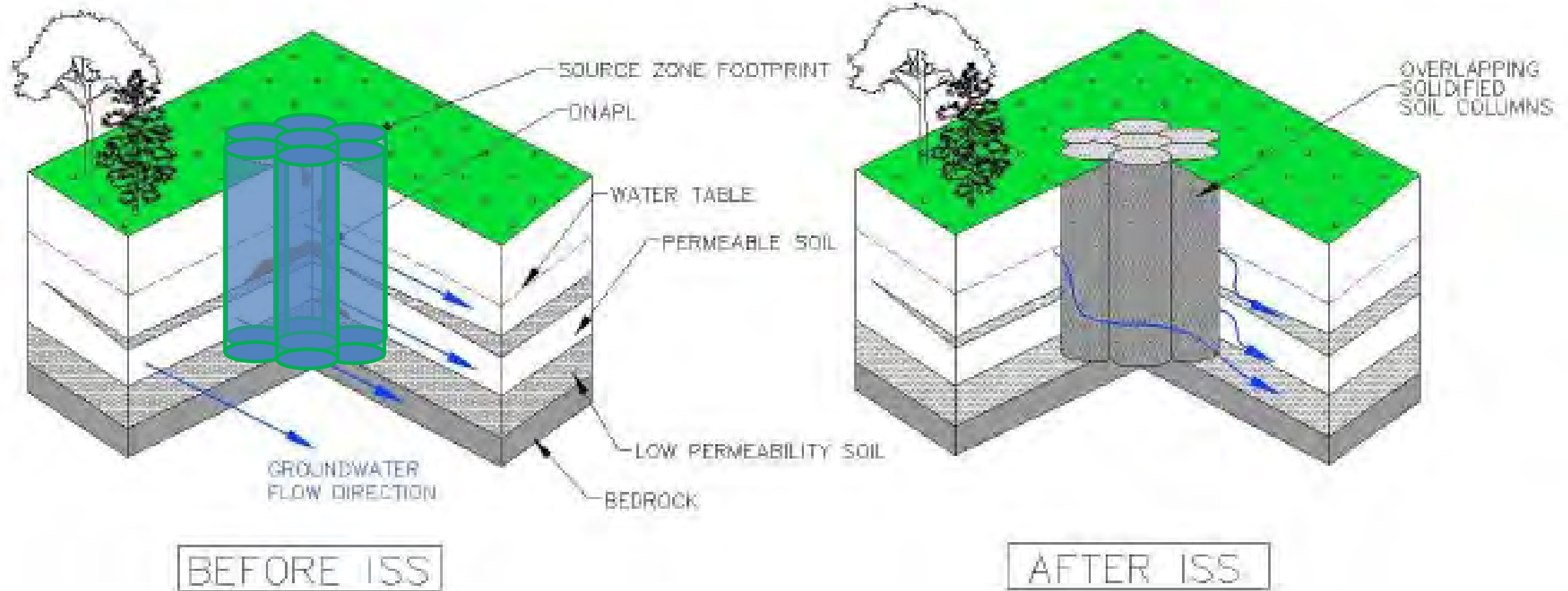
STABILIZATION

- Chemical reaction between reagents and contaminated materials - designed to reduce the leachability of targeted contaminants by:
 - ***Binding free liquids***
 - ***Immobilizing targeted contaminants***
 - ***Reducing solubility of the contaminated material***

SOLIDIFICATION

- Contaminated materials are encapsulated (physically trapped) to form a solid material that restricts contaminant migration by:
 - ***Reduction of permeability and effective porosity***
 - ***Increasing compressive strength and media durability***

In Situ Stabilization/Solidification (ISS) Conceptual Model



Source: *Development of Performance Specifications for Solidification/Stabilization*, Interstate Technology & Regulatory Council (ITRC), July 2011

ISS as a Treatment Technology



Why In Situ Chemical Oxidation (ISCO) + In Situ Stabilization / Solidification (ISS)?

- ✓ Treats all waste on-site.
- ✓ Rapid implementation.
- ✓ In U.S.A., ISS typically is applied alone. ISS is a mature technology used at hundreds of sites.
- ✓ At Søllerød, proximity of downgradient municipal supply well prompted need for destructive treatment (ISCO) as well as ISS.
- ✓ Published laboratory studies show promise for ISCO + ISS.



Where can ISCO aide ISS?

- Contaminants are not destroyed or removed
- Effectiveness for some contaminants (e.g., HVOCs) may require additional design measures
- Uncertainty in long term behavior / protection of sensitive receptors

Where can ISS aide ISCO?

- Contact and distribution of ISCO using LDA techniques
- Alleviate soft ground after treatment
- Residual contaminants rendered immobile

Combining technologies to capitalize on attributes

- LDA Mixing Key Attributes
 - Overcomes heterogeneities
 - Complete mixing/contact
 - Overcomes contact/distribution challenge
- ISCO Key Attributes
 - In situ technology that results in contaminant destruction
 - Chemistry is proven - contaminants such as gasworks residuals and chlorinated solvents can be oxidized/reduced, etc.
- Combined ISS/ISCO Concept
 - Contaminant sequestration/destruction followed by solidification/stabilization
 - Useful **when contamination destruction and greater leaching reduction is needed**
 - Commingled plume applications
 - Overcomes soft ground challenges
 - ISS components can be used to heat / activate reactants (e.g., persulfate activated by cement heat of hydration and high pH)



Drum Mixer Based ISCO-ISS

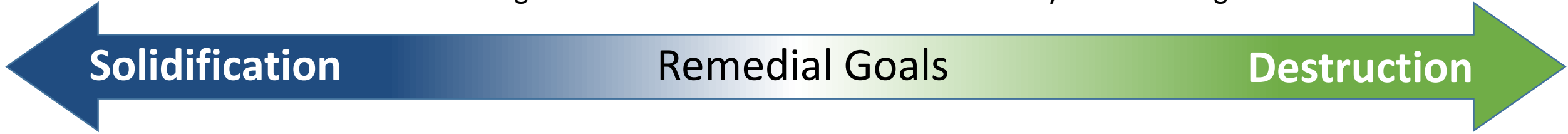


ISCO-ISS
Indiana
Courtesy of
SME and Lang
Tool



Remedial Goals and Reagent Ranges

ISCO and ISS reagent doses can be varied to achieve a variety of remedial goals





Reagents

- Binder plus Klozur[®] SP (sodium persulfate).
 - ISS with ISCO
 - 3-8% Portland cement
 - 0.5-2% Klozur SP
 - ISCO with ISS
 - 1-6% Portland cement
 - 1-5% 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

* PeroxyChem LLC (“PeroxyChem”) is the owner of U.S. Patents No: 7,576,254, US App 62/890,098 and their foreign equivalents. The purchase of PeroxyChem’s Klozur[®] persulfate includes with it, the grant of a limited license under the foregoing patent at no additional cost to the buyer.

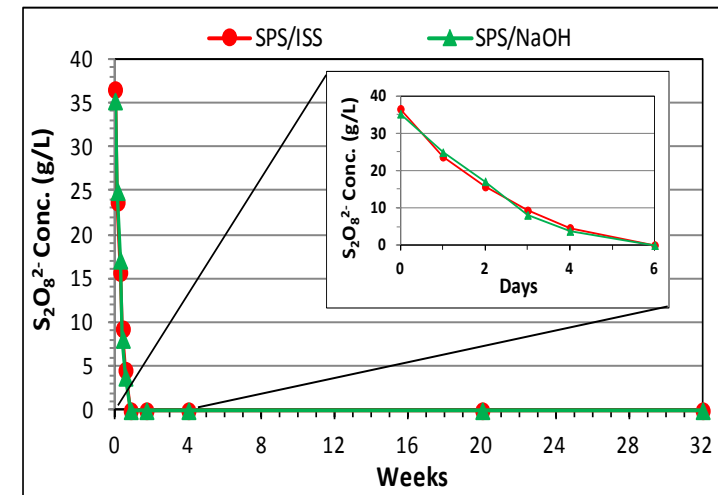


ISCO Perspective (w/ISS)

- Remedial Goal:
 - Destruction
- Application:
 - Soil mixing
- Soils need some post application strength
 - Clays

• Strategies

- Reagents combined in single application



Dan Cassidy (2017)

- Reagents applied in sequence
 1. ISCO technologies
 2. ISCO/ISS or ISS only



ISS Perspective: Common Objectives

- Reduced hydraulic conductivity
 - 2-3 orders of magnitude below native soils
 - 1×10^{-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	

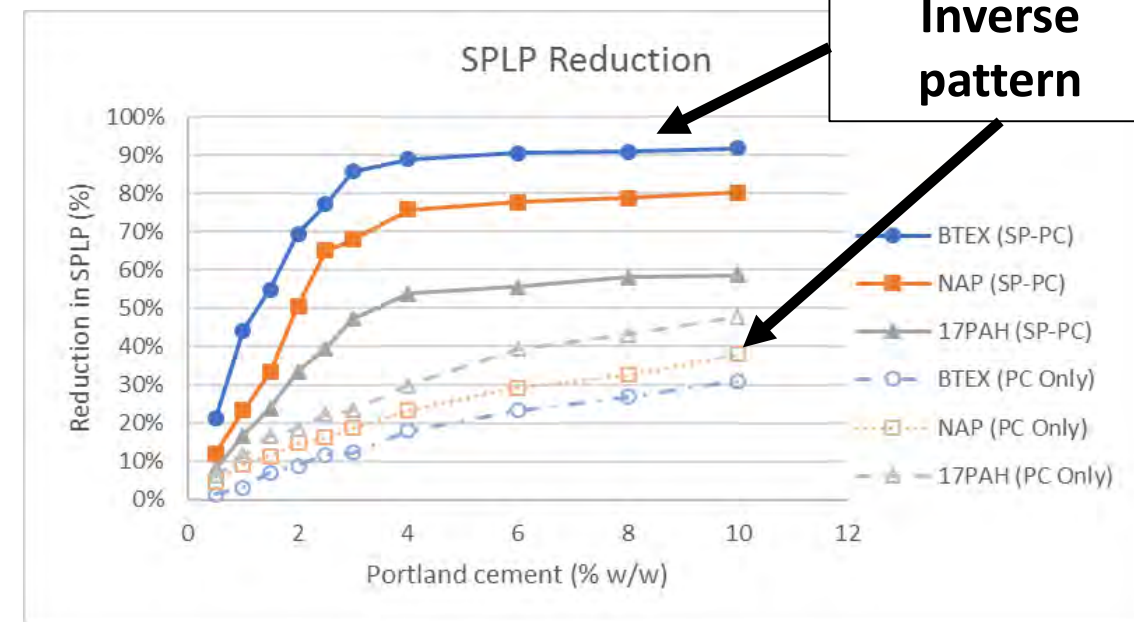
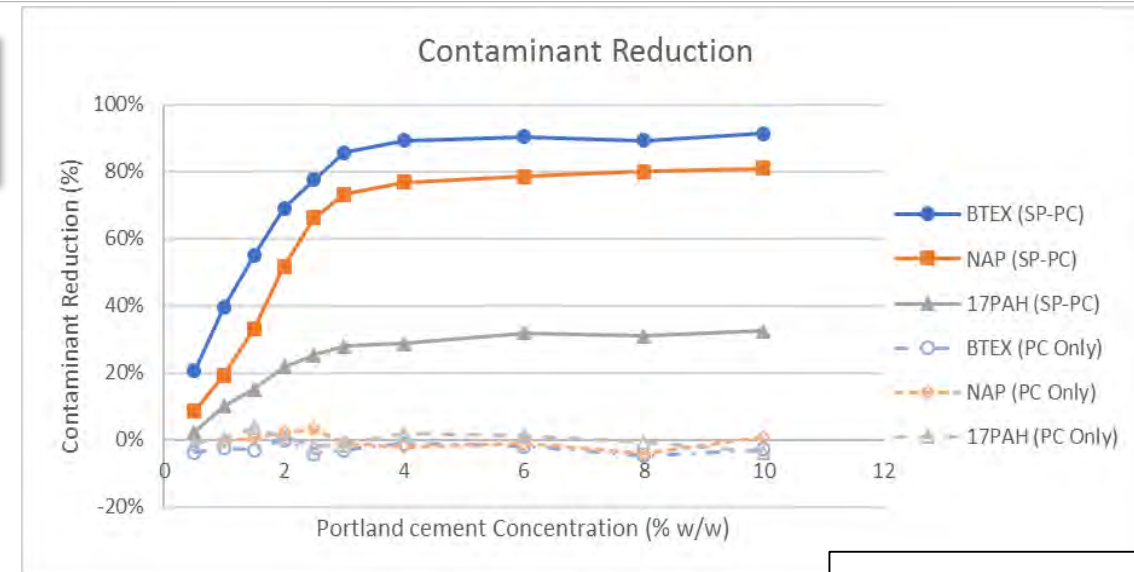
Typical target range for “workable” soils
~20-60 psi



1) Contaminant Destruction: Lower Leachate Concentrations

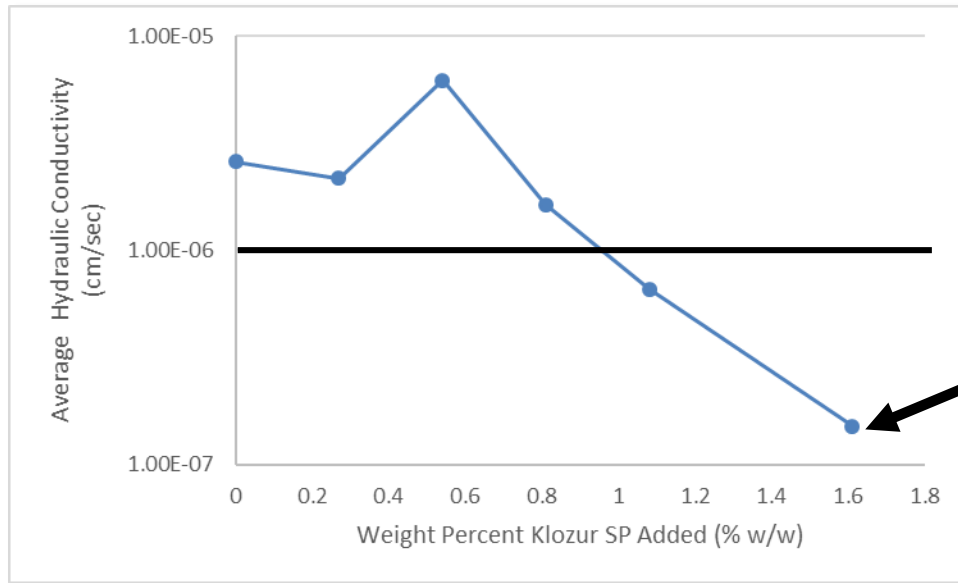
Srivastava et al (2016), J. Environ Chem. Engineering, 4, 2857-2864

- 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)
- Klozur SP: Portland Cement (PC) ratio (1:2 w/w)
 - CaO in PC facilitates alkaline persulfate activation
- ISCO:
 - Persulfate underdosed for complete treatment of TPH
 - Preferential treatment of soluble contaminants

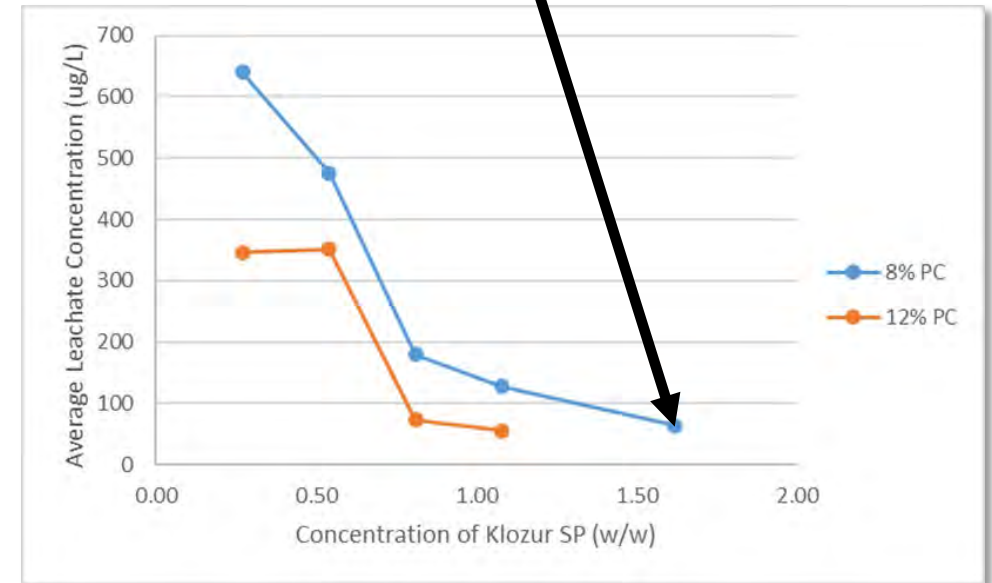




2) Lower Hydraulic Conductivity: Lower Leachate Concentrations



**1.6% Klozur
SP**



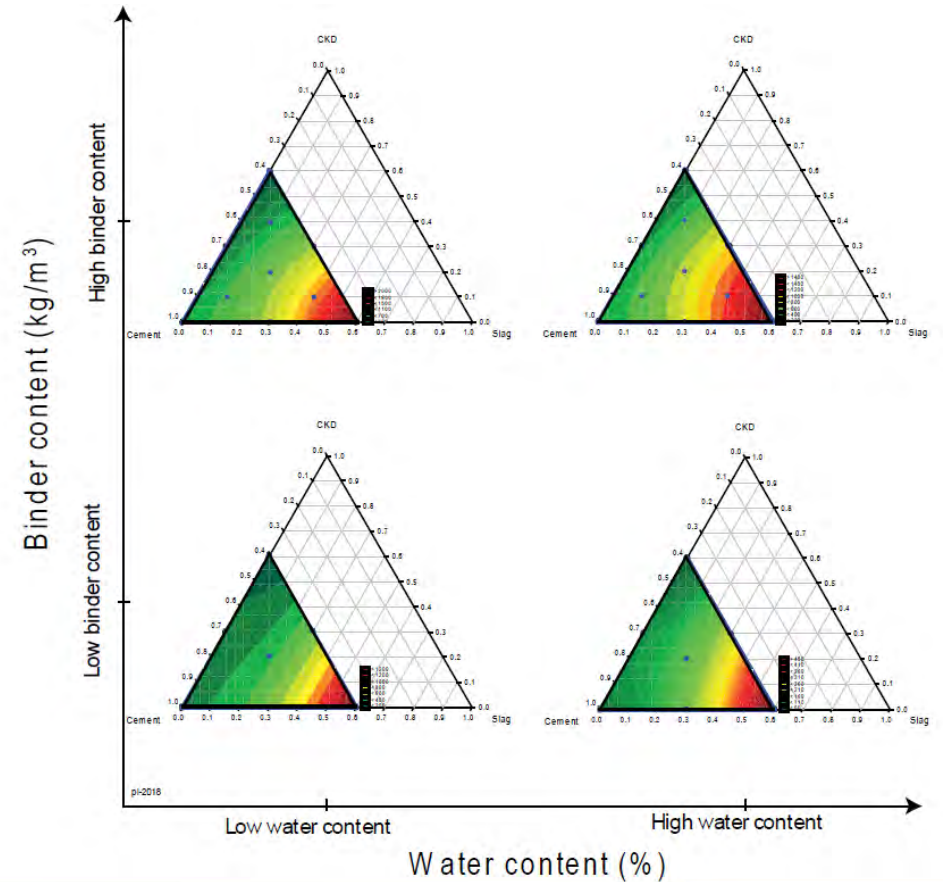
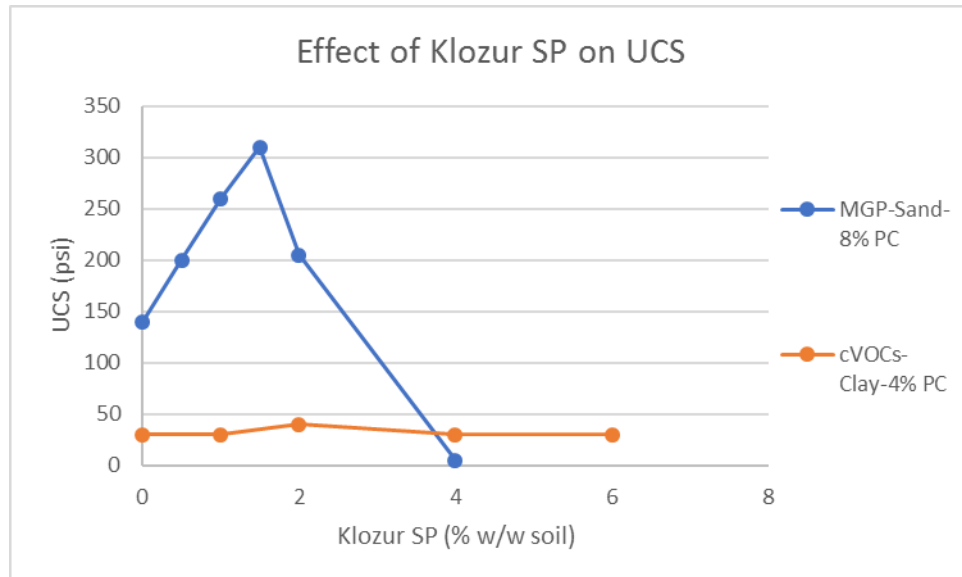
Theory: Organic matter can impede cementitious process. Oxidizing organic matter can help the cementitious process.

Courtesy of Brasfond (Isabel Peter Rando/Worley)
Geosolutions (Tony Moran/Entact)



3) Greater UCS/Control over UCS

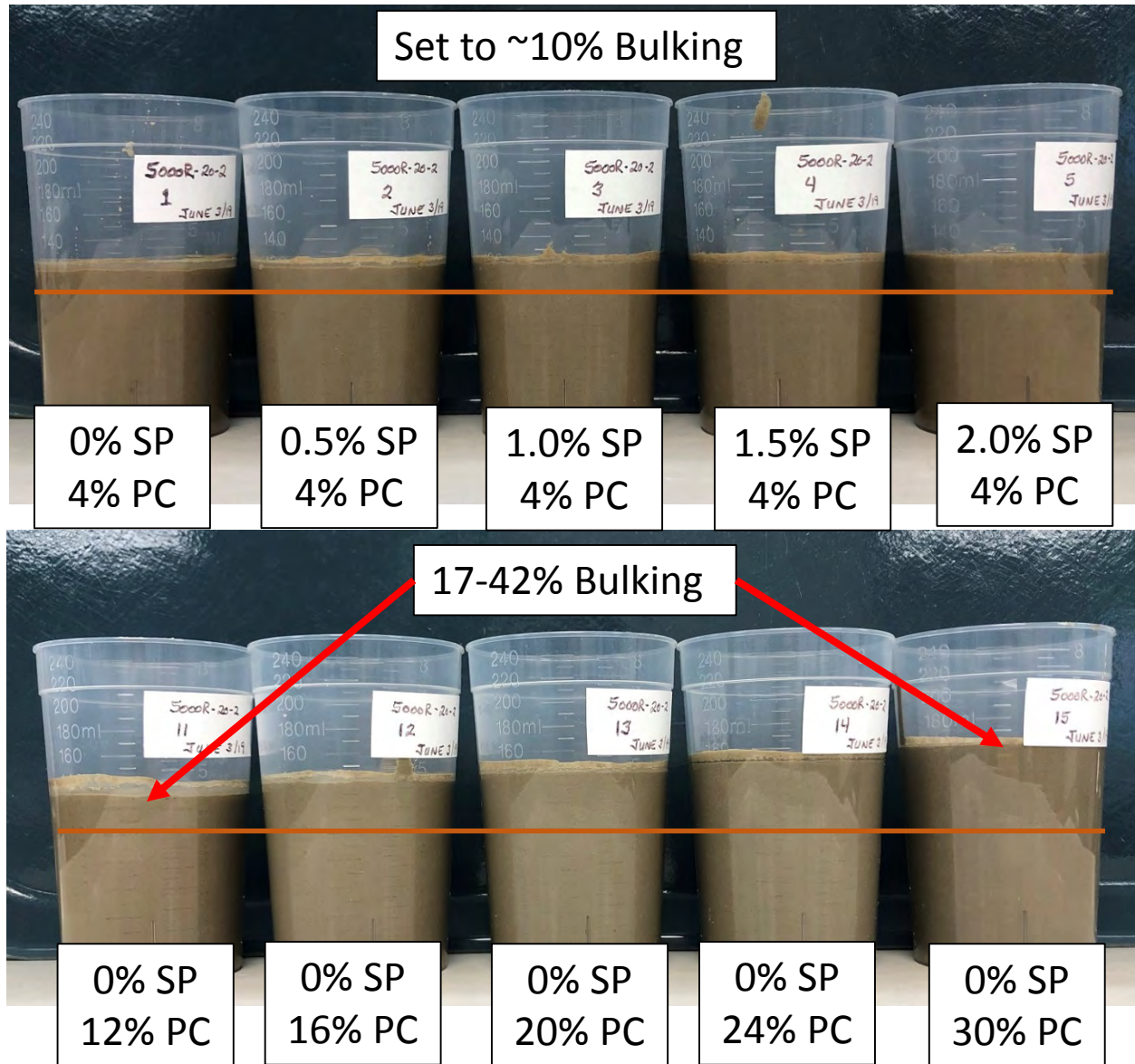
- Klozur SP can impact UCS
 - Potential break point
- Final UCS is a function of more than one variable



Courtesy of Per Lindh, Vintermode 2019, Temadag om Soil Mixing som afvaergemetode



4) Less Binder: Less Displaced Soils



- Minimizing binder and water needed
- Minimizes soil bulking
- Lower carbon footprint
- Less material handled and disposed of results in cost savings

CASE STUDY: SØLLERØD GASVÆRK SITE

Holte,
Capital Region of
Denmark

October 30, 2019

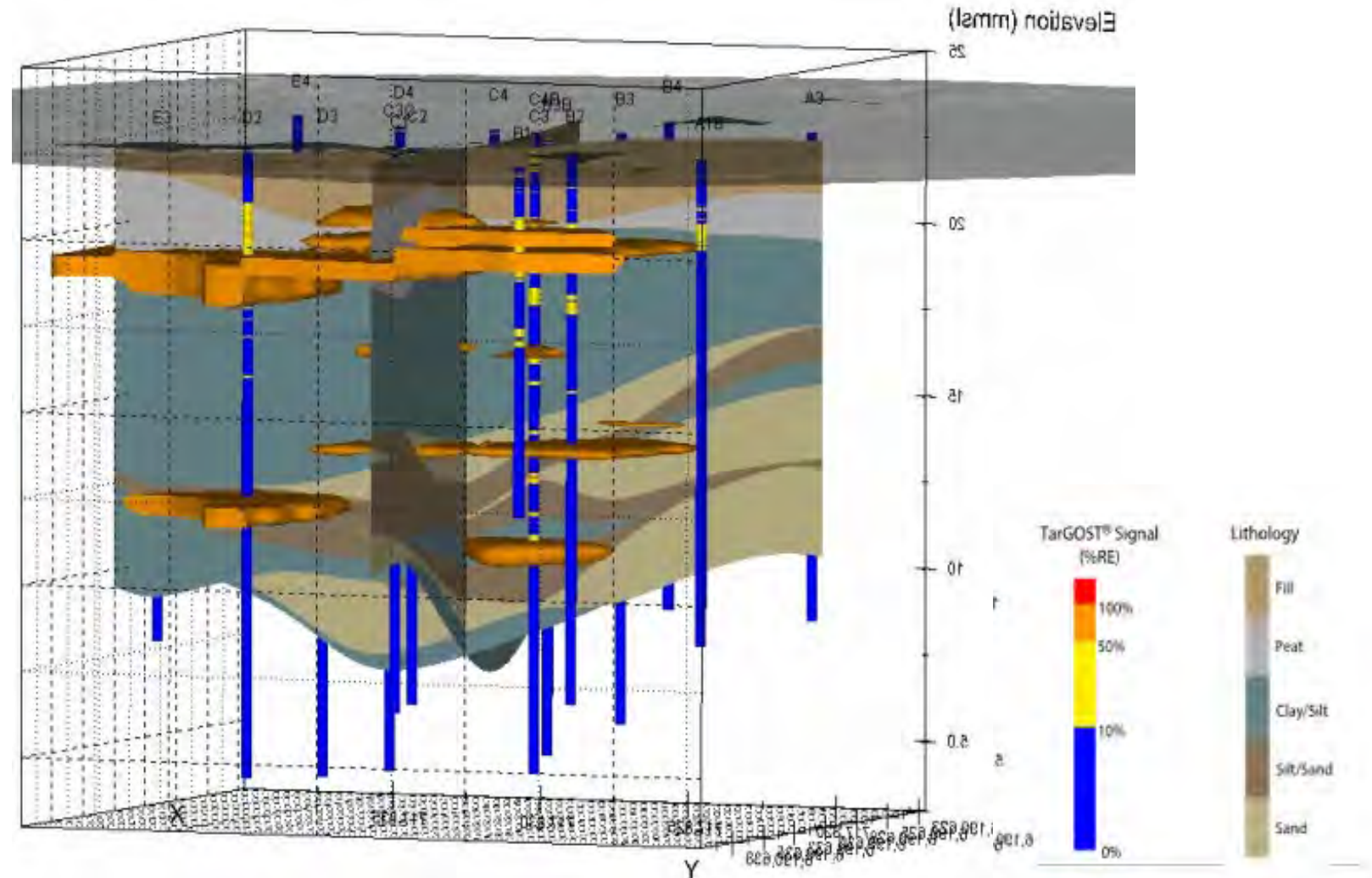
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 **PeroxyChem**

- Free phase tar (up to 15 m deep)
- Alternating geology
- Non-coherent pollution distribution



- Assess *in situ* solidification/stabilization (ISS) with *in situ* chemical oxidation (ISCO) for treating source area coal tar contamination in soils at the former Søllerød Gasværk Site in Holte, Denmark
- Performance Targets:
 - Oxidation and **reduction in leaching** of dissolved phase coal tar constituents (i.e., BTEX, sVOCs, and phenolic compounds),
 - Acceptable values of fresh slurry density, viscosity, and pH (API RP13B-2);
 - Average **hydraulic conductivity** $< 1 \times 10^{-6}$ cm/s with no more than 10% of the samples $> 1 \times 10^{-5}$ cm/s with the least quantity of additional reagents
 - **Unconfined compressive strength** > 0.15 MPa at 28-day curing

■ Study:

- ✓ Phase 0 - Soil Compositing and Geotechnical Index Testing
- ✓ Phase 1A – assess ISCO reactant dosage (base activated sodium persulfate) performance
- ✓ Phase 1B – assess ISS reagent dosage (CEM III/B and CEM I 42,5 N – SR5)
- ✓ Phase 2 - assess combined ISS/ISCO

Phase 0 - Baseline Geologic Material Homogenization and Sampling

```
graph TD; A[Phase 0 - Baseline Geologic Material Homogenization and Sampling] --> B[Phase 1A - ISCO Optimization]; B --> C[Phase 1B - ISS Optimization]; C --> D[Phase 2 - ISS + ISCO]; D --> E[Select ISS/ISCO Mix Design for Pilot Scale Testing];
```

Phase 1A – ISCO Optimization

Phase 1B – ISS Optimization

Phase 2 – ISS + ISCO

Select ISS/ISCO Mix Design for Pilot Scale Testing

Laboratory Study Results

	Unit	Phase /10/	ISCO	ISS	ISS+ISCO - One step	ISS + ISCO- Two step	Target value
Geotechnical test							
Geotechnical structure (soil strenght)	MPa	Phase 1B; Table 2-2, 3-5	NA	3.8	0.59	2.92	0,15 Mpa (> 24 psi)
Average hydraulic conductivity	cm/s	Phase 1B; Table 2-2(ISS); Table 3-5 (Step 1 and step 2?)	NA	1.9×10^{-5} *	2.7×10^{-7}	1.8×10^{-8}	< 1×10^{-6} cm/s with no more than 10% of the samples > 1×10^{-5} cm/s with the least amount of additional reagents
Swell of geologic materials	%	Phase 2; Table 2-1, 3-1	NA	14-22	23-31	24-33	Not defined
Mass destruction	%	Phase 1A; Table 1-2; Phase 2; Table 3-2					Not defined
Benzene			99	NA	100	100	
Phenol			100	NA	83	83	
TPH			26	NA	39	37	
Naphthalene			-19	NA	58	77	
Leach reduction	%	Phase 2 - Annex M					>75
Benzene			NA	>99	>99	>99	
Phenol			NA	>99	>99	>98	
TPH			NA	NA	NA	NA	
Naphtalene			NA	93	80-98	80-84	

Notes:

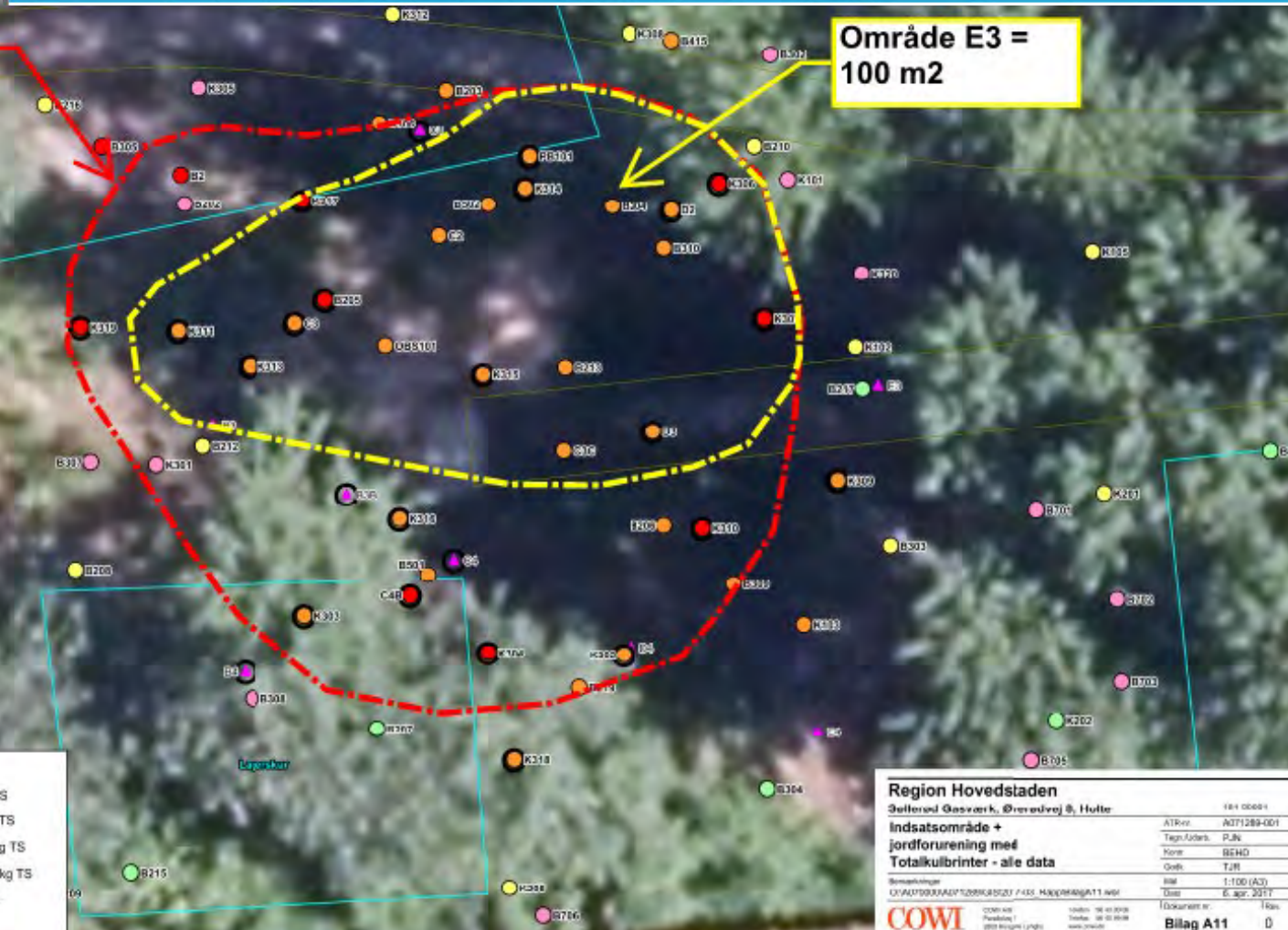
* - Hydraulic conductivity samples may have been influenced by channeling due to a difference in the mold diameter and test cell diameter.

Transition of Laboratory Results to Pilot Scale

- Pilot Test Challenges
 - First-time use in Denmark (learning)
 - Process scale up from bench to field
 - Residential neighborhood, spatial constraints above ground, proximity to houses
 - Challenging Geology: 3m to 5m peat – stability concerns, highly plastic clay, confined aquifer, tight site logistics
 - Verification of treatment performance
 - Handling and mixing of potentially corrosive materials

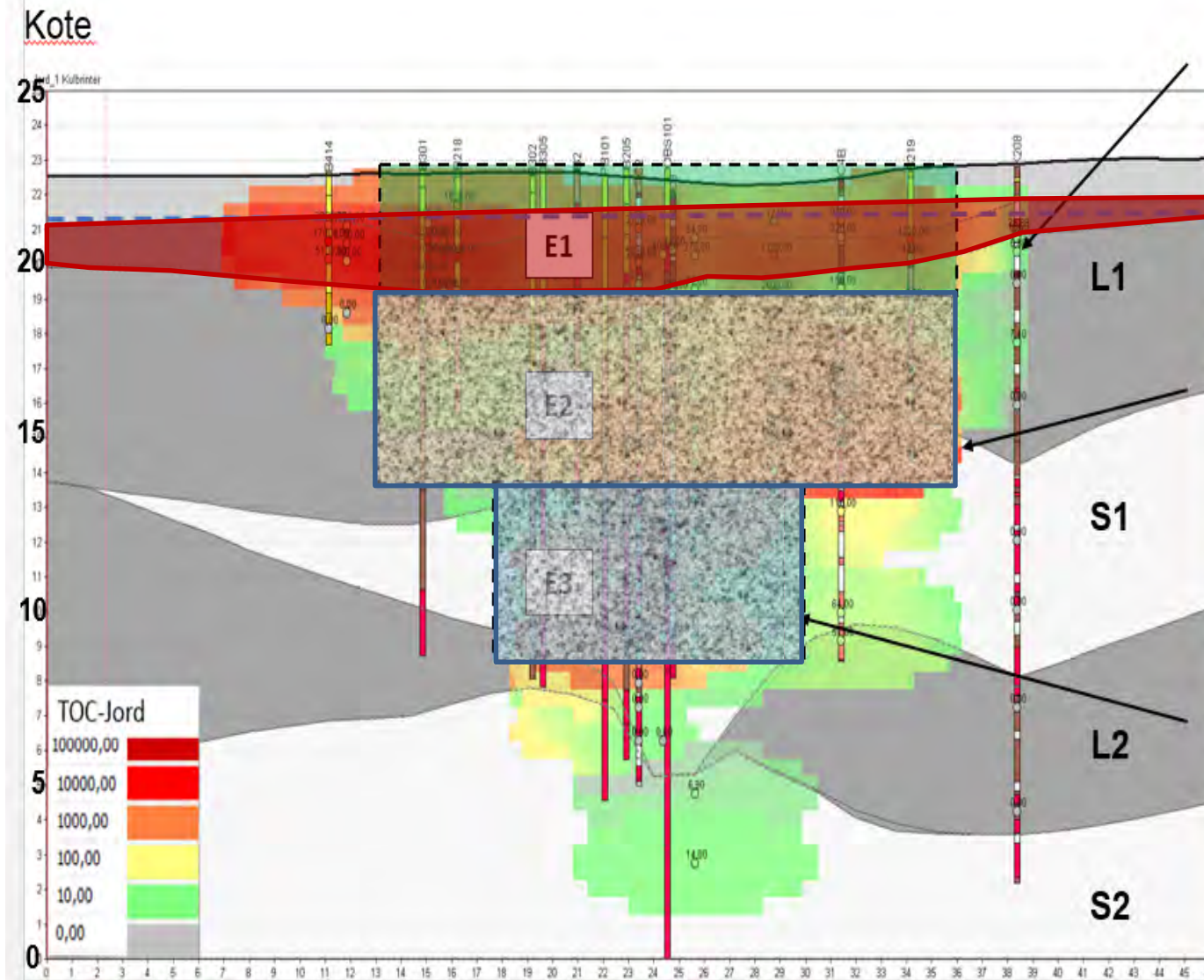


Conceptual Full-Scale Layout of ISS Columns



Design	
Slag Cement (CEM II/B)	8 % dw
Persulfate	3 % dw
Auger diameter	2 m
Auger Mixing area	3.14 m ²
Total target treatment area	188 m ²
Number of columns	75
Area of all columns	235.5 m ²
Column overlap	35 m ²
Overlap %	17.5

10 DEPTH OF ISS/ISCO (mbs)



Område E.1:

Areal: 185 m²
 Dybde: 0 - 2/5 m u.t.
 Volumen: ca. 700 m³
 Geologi: Fyld/tørvt/silt
 Hydrogeologi: Mættet fra ca. 2 m u.t.

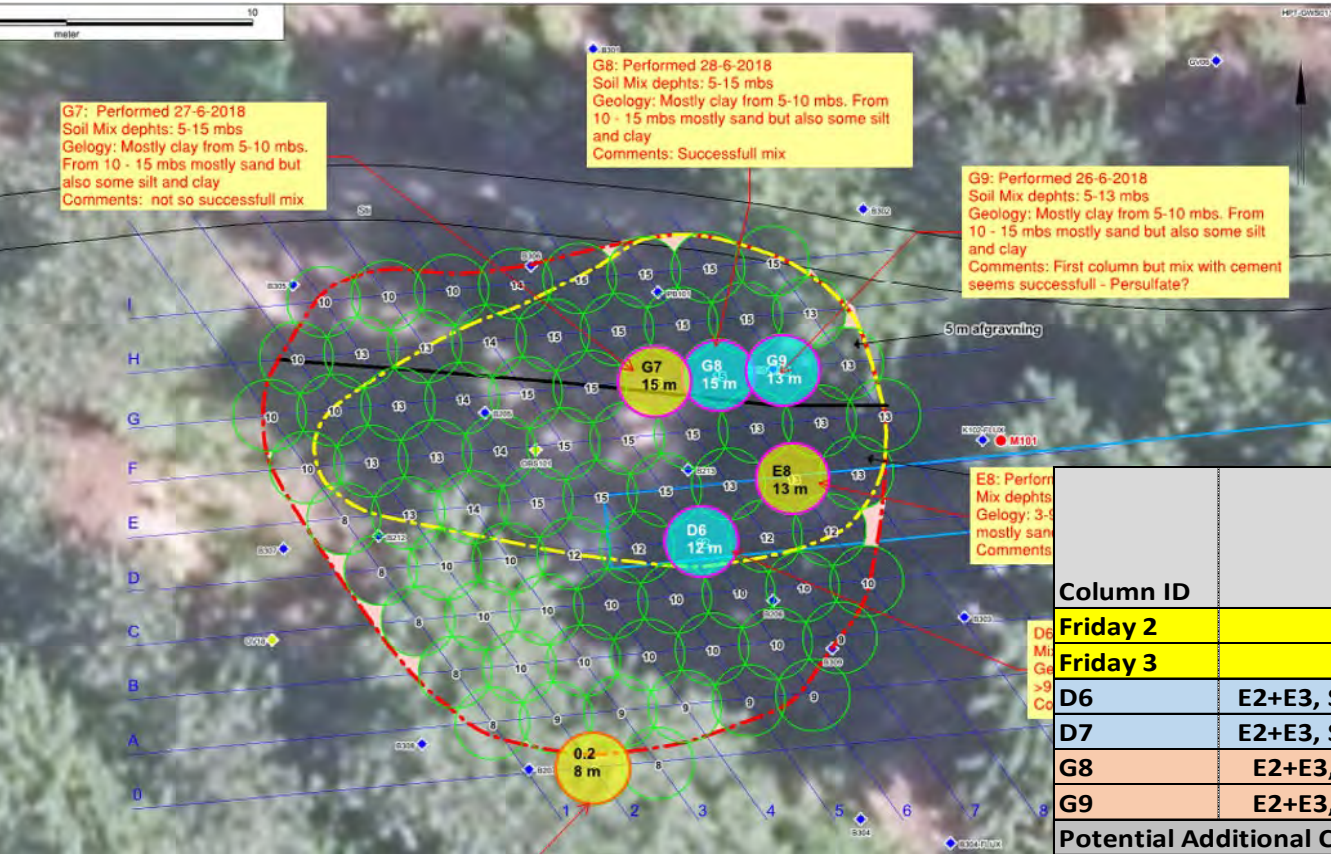
Område E.2:

Areal: 185 m²
 Dybde: 2/5-8/10 m u.t.
 Volumen: ca. 1150 m³
 Geologi: Ler og silt med sandstriber
 Hydrogeologi: Mættet

Område E.3:

Areal: 100 m²
 Dybde: 10-12/15 m u.t.
 Volumen: ca. 400 m³
 Geologi: Sand med silt-/lerindslag
 Hydrogeologi: Mættet, spændt

Design of Pilot Scale Study



Column ID	Area	Mix Design	Top El. (m El.)	Start Treatment Depth (m El.)	Bottom El. (m El.)	Design Depth (mbs)	Treatment Thickness (m)
Friday 2		1	22.8	19.8	14.8	8	5
Friday 3		1	22.8	19.8	14.8	8	5
D6	E2+E3, Shallow Bench	1	22.3	19.3	9.3	13	10
D7	E2+E3, Shallow Bench	1	22.3	19.3	9.3	13	10
G8	E2+E3, Deep Bench	1	22.3	17.3	7.3	15	10
G9	E2+E3, Deep Bench	1	22.3	17.3	9.3	13	8
Potential Additional Columns							
G7	E2+E3, Deep Bench	TBD	22.4	17.4	7.4	15	10
E7	E2+E3, Shallow Bench	TBD	22.3	19.3	10.3	12	9
E8	E2+E3, Shallow Bench	TBD	22.3	19.3	10.3	12	9

- **K_h** . All QA/QC samples met criterion of $\leq 1 \times 10^{-6}$ cm/sec.
- **UCS**. 8 of 13 samples exceeded 0.35 MPa and 10 of 13 samples exceeded minimum criteria of 0.15 Mpa. (3 samples failed initially but cured later in time)
- UCS improved by optimizing blade rotation / mixing energy, sealing leaks, reducing slurry water content
- **Contaminant destruction** – reduction in benzene concentrations ranged from 6x to 133x.



Full-Scale Implementation

- Recommendation to proceed to full scale ISS/ISCO treatment of area E:
 - Strength results were indicative of the long term durability of the ISS/ISCO treatment and preventing long term soft ground conditions
 - Samples that did not exhibit adequate strength were located in the upper portions of the columns and correlated with high moisture content (> 35%)
 - Hydraulic conductivity reductions translated from laboratory to pilot scale implementation
 - Optimize LDA operations

2-m Diameter Mixing Auger, Column Casing

- **Geology/Stability Solution:**

- Excavated peat in 2m DIA steel casing to 3 to 5 mbs
- ISS through each casing
- 3 mixing passes – established optimum blade rotation number to mix plastic clay
- Cleaned augers after first mixing pass to remove accumulated clay



OPTIMIZE			Min/m		
Mixing total meter / volume			5	16.0	15.708
Cyklus nr.	Penetrering i meter/min	Samlet minutte	Rotation omdr/min	Bemærkning	BRN
1-DOWN	0.2	25	10	+ Tilsæt cementslurry	50
1-UP	0.3	17	32	Kun mixing	107
2-DOWN	0.5	10	32	+ Tilsæt 50% klorur	64
2-UP	0.5	10	32	+ Tilsæt 50% klorur	64
3-DOWN	0.5	10	32	Kun mixing	64
3-UP	0.6	8	32	Kun mixing	53
		Mixing Time:	80	Total BRN:	
					402

Full-Scale ISCO/ISS By the Numbers

- Treatment Area – 188 m²
- Treatment Volume ~ 1,865 m³
- 75 columns, 17% overlap
- Rate - 100 m³/day (10 m³/hr)
- Cement – 15 tons/day
- Water – 32 m³/day
- Persulfate – 6.5 tons / day
- Mixing cycles – 3 cycles; 300 m³/day



- Hydraulic Conductivity (K goal: 1×10^{-6} cm/s)
 - Average: 3.1×10^{-7} cm/s (Lab: 2.7×10^{-7} cm/s)
 - Range: 2.6×10^{-9} cm/s – 1.5×10^{-6} cm/s
 - 92% < 1×10^{-6} cm/s (1 of 14 > 1×10^{-6} cm/s)
- UCS (Min: 0.15 MPa; 90% \geq 0.35 MPa)
 - 36 samples; 22 \geq 0.35 MPa; 29 \geq 0.15 MPa
 - Direct correlation between the UCS and the water content average moisture content of 32 % - 6 samples < 0.15 Mpa
 - 3 samples < 0.05 MPa. Average moisture content of 36 %.
 - Follow up CPT and 365 day UCS tests performed

Category	Units	Benzene	Total hydrocarbons	Naphthalene	Phenols
Treatment Area	m ³	1,865	1,865	1,865	1,865
Treatment Area (assuming 2 tonnes/m ³)	Tonnes	3,730	3,730	3,730	3,730
Contamination Mass Before ISCO/ISS	Kg	50-100	2000-3000	400-600	Approx. 10 kg
Concentration after ISCO/ISS	mg/kg	0	321	23	0.04
Contamination Mass after ISS/ISCO	Kg	0	1,200	85	0.1
Pollution reduction after ISS/ISCO	%	Approx. 100%	40 - 60%	80 -85%	Approx. 99%

- Degradation measured in laboratory tests:
 - Benzene = 100%
 - Phenols = 83%
 - Total hydrocarbons = 39%
 - Naphthalene = 58%
- **Improved degradation in full-scale tests**

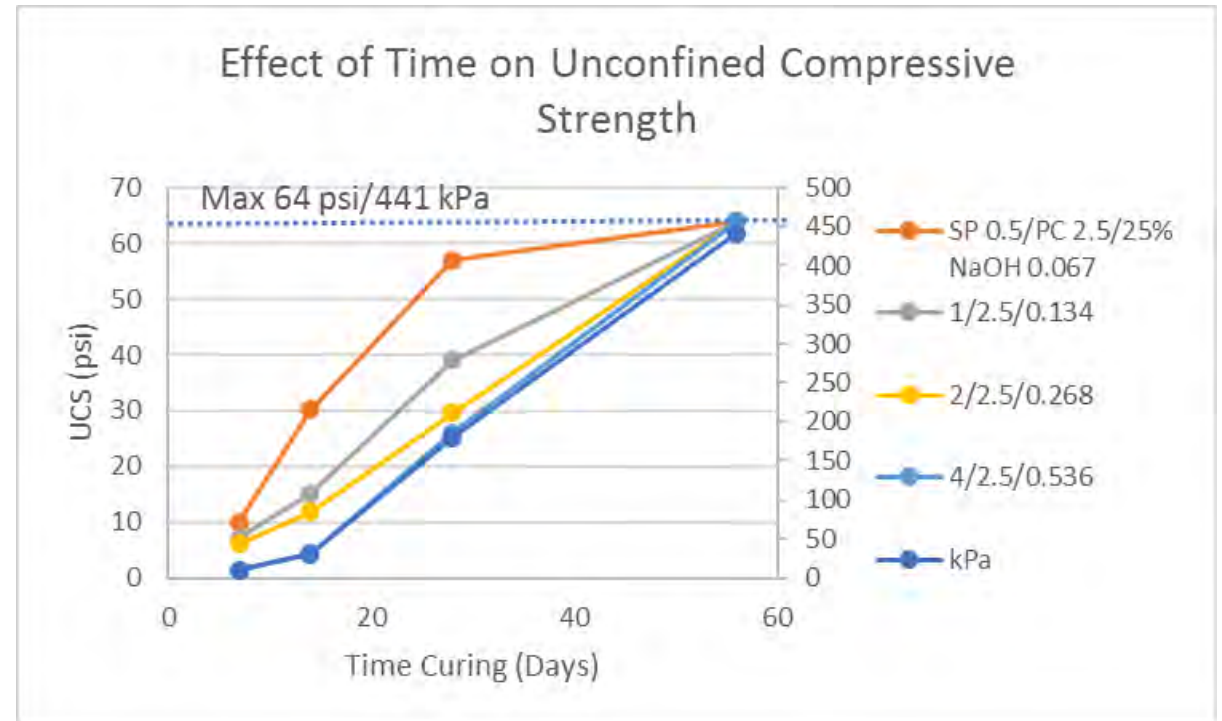


- Field verify strength development – multiple lines of evidence
- Best day – 36 m³/hr (113 m³)
- Many days – 0 m³
- Corrosivity of persulfate stock solution requires special handling
- Control of water content is critical – additional cement was added to some columns
- Mixing energy delivered to soils is critical – contractor experience



Lessons Learned: Set Up Time

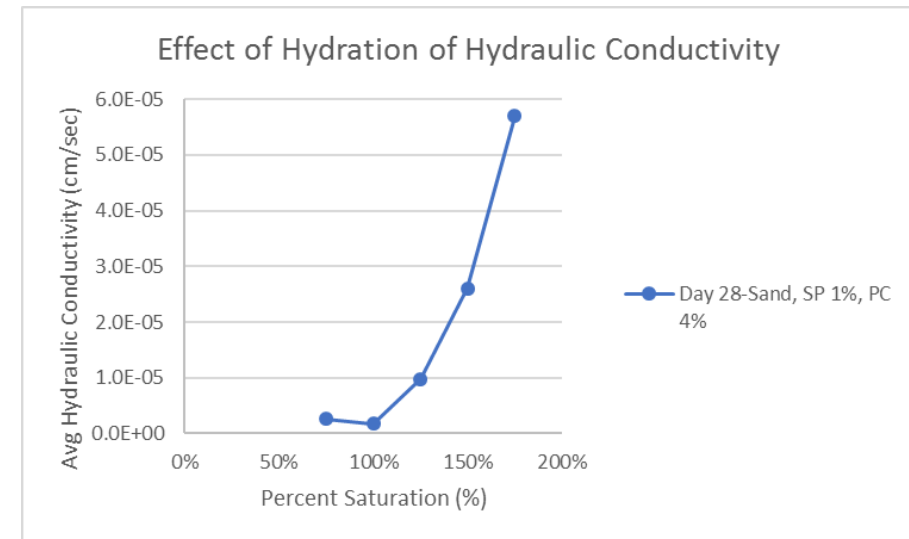
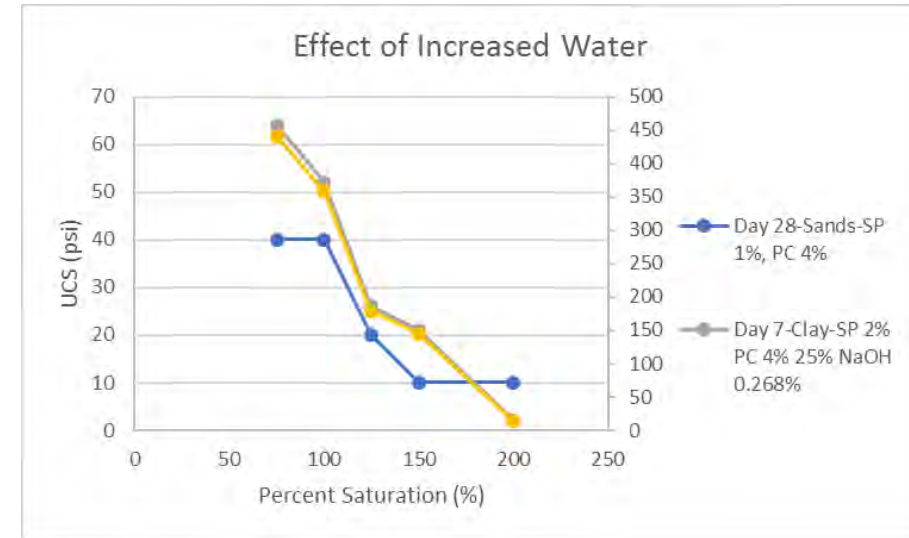
- Set up time is longer
 - CaSO_4 slows set up time
- Blast furnace slag may have better performance





Lessons Learned: Hydration

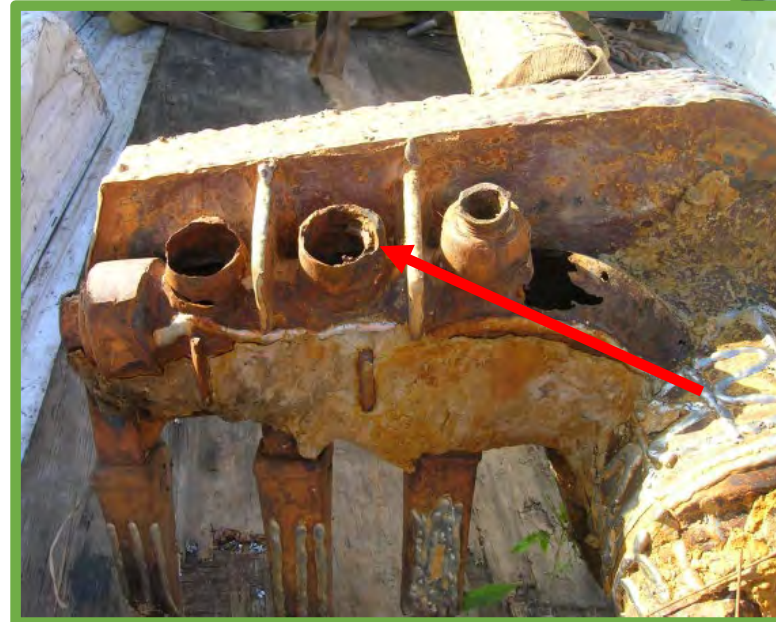
- Hydration impacts
 - UCS
 - Hydraulic conductivity
- Hydration
 - Present in subsurface
 - Used to dissolve reagents
 - Used to lubricate subsurface





Lessons Learned: Chemical Compatibility

- Neutral pH persulfate can be very corrosive to carbon steel
- Persulfate generates acid as it decomposes





Best Practices: Compatible Materials

Chemically compatible equipment needs to be used for all wetted equipment parts or parts that may come in contact with the reagents

- Compatible with persulfate:
 - 304 and 316 stainless steel, PVC, CPVC, polyethylene, Plexiglas®, glass, FRP (fiber reinforced plastic, e.g. Derakane®), Fiberglass – specifically vinyl ester resin, Polyester
 - Elastomers:
 - Long term duration: Teflon or PTFE, PVDF, or Gylon®
 - Short term duration: EPDM
 - Safety gear: butyl rubber, neoprene
- Corrosion rates increase at higher persulfate concentrations

Note: The pH of persulfate solutions can decrease over time and can become acidic

Table 4: Results for Alkaline Activated Klozur Persulfate Solutions, 20 wt% and 40 g / L at Room Temperature After 1 Month Exposure Time

mpy – milli-inches per year; ✓ - compatible material, ⊖ - non-compatible material

Material	20 wt% concentration	40 g / L	Comments
Stainless steels (304L, 316L)	✓	✓	< 1 mpy. No noticeable corrosion over 1 month
Copper Brass	✓	✓	Negligible general corrosion (< 2 mpy). Black film formation observed.
Carbon steel	✓	✓	Negligible general corrosion (< 2 mpy). Isolated rust spots observed



Best Practices

- Combine and coordinate chemistries with applications method
 - Design with understanding of contractor abilities and requirements
 - Amount of hydration
 - Dry reagents
 - Aqueous phase dissolved reagents
- Bench test materials to be used in field



Courtesy of Cascade



Best Practices: Bench Tests

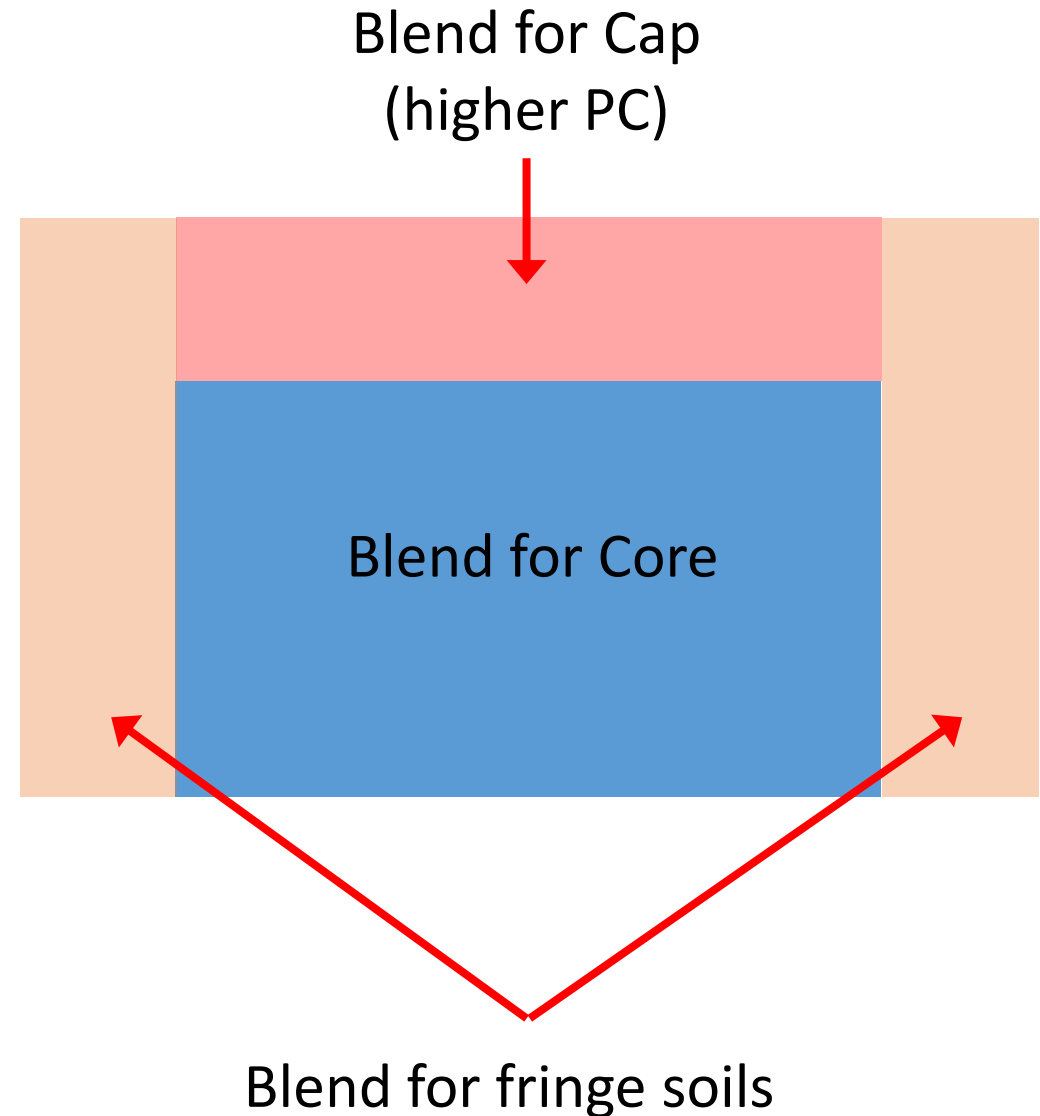
- Variables
 - Binder (test actual materials)
 - Portland cement
 - Type I or Type II
 - Blast furnace slag
 - Klozur SP
 - Water content
 - Multiple test conditions
 - Soil type
- Contact time
 - Contaminants: 14 days
 - Modified SPLP
 - UCS: 28 day and 56 to 80 days
 - Hydraulic conductivity (with final UCS)
- Experimental Design
 - Multiple test conditions
 - Contaminants: all
 - UCS and hydraulic conductivity
 - Based on contaminants treated



Different Blends for Different Areas

Several projects have developed custom approaches for different areas, favoring goals such as:

- Higher UCS in the cap
- More treatment in the core
- Lower permeability/leachate in the fringe soils





Summary

- Chemically compatible materials should be used
 - Decontamination procedure
- Coordination between contractor, labs, design engineer and chemical vendors
- Bench scale tests
 - Water content needs to be considered along with reagents
 - Curing time is expected to take significantly longer than normal concrete



Summary

- Two valid remedial technologies that can be combined
 - ISCO perspective (destructive remedial goal)
 - Control post soil mixing geotechnical characteristics
 - Can apply in sequence or combined
 - ISS perspective (solidification remedial goals)
 - Lower leachate concentrations
 - Lower hydraulic conductivity
 - More control over final geotechnical parameters (UCS)
 - Less binder
 - Less excess soils requiring handling and disposal
 - Cost savings
 - Fewer trucks in neighborhood
 - Smaller carbon footprint



Questions??

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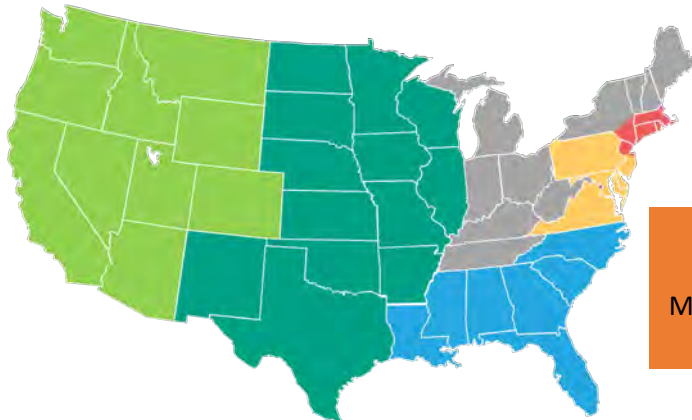
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