# Enhancing In Situ Stabilization and Solidification (ISS) in Sediments by Adding Sodium Persulfate

Poster Group 2

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## ISCO and ISS

In Situ Chemical Oxidation (ISCO) and In situ Solidification and Stabilization (ISS) are two established technologies that can be combined in a single soil mixing application.

ISCO is a contaminant destruction technology that works by transforming targeted pollutants into harmless end products.

ISS is a contaminant immobilization technology where the contamination still exists but is trapped within a solidified matrix.

By combining these two technologies contaminant mass can be significantly reduced, with the residuals then immobilized in the matrix. This helps reduce site risks, including through vapor intrusion or contaminant migration in groundwater.

The most common blends include:

KLOZUR® SP plus Portland Cement
KLOZUR® SP plus Portland Cement / Blast Furnace Slag

ISCO-ISS being applied at former MGP site in Stockholm
Contractors: ARKIL A/S, PEAB
Consultant: Geomind, Golder, Elander

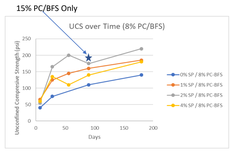
ISCO-ISS being applied at former MGP near Copenhagen
Contractor: ARKIL A/S
Consultants: COWI, Geosyntec

ISCO-ISS being applied at redevelopment site in Southern Sweden
Contractor: Soil Mixing Group AB (SMG)
Consultant: Rambøll

## Benefits of Adding Sodium Persulfate to ISS

ISCO-ISS can be applied as a combined remedy, benefits have also been observed to adding ISCO even when ISS is the selected remedy, and there are no remedial goals associated with contaminant destruction. These include:

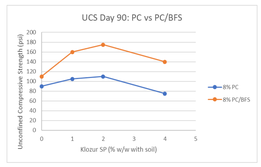
### Higher UCS



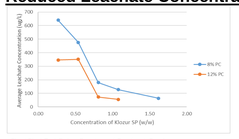

In the figure to the left, 8% SP/BFS with 1% SP had stronger UCS than 15% PC/BFS only.

In the figures below, adding sodium persulfate with the binders resulted in increased compressive strength of the matrix. This peaked at 2% SP added to 8% PC/BFS which was 160% the strength of 8% PC/BFS only.

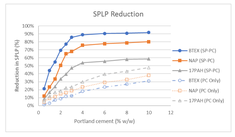
| Klozur SP (% w/w soil) | 8% PC | | 8% PC/BFS | |
|---|---|---|---|---|
| | Day 90 UCS (psi) | % of ISS only | Day 90 UCS (psi) | % of ISS only |
| 0 | 90 | 100% | 110 | 100% |
| 1 | 105 | 117% | 160 | 145% |
| 2 | 110 | 122% | 175 | 159% |
| 4 | 75 | 83% | 140 | 127% |




### Reduced Leachate Concentrations

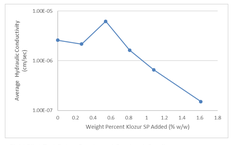



Field Pilot Test Data. Courtesy of Brasfond, Brazil




Srivastava et al (2016) Chemosphere

### Reduced Hydraulic Conductivity




Field Pilot Test Data. Courtesy of Brasfond, Brazil

By accomplishing the remedial goals of UCS and/or leachate concentrations with less reagent addition, adding sodium persulfate to ISS applications can reduce the mass of reagents added. This can result in less soil bulking (swell) which has to be disposed of after the application.

This has been observed to often result in significant cost savings.

## Effects of Water Content

Water is both present in site soils and is usually added with the reagents in a solid slurry blend.


Naturally present water can approach a full Pore Volume:

Specific Yield (%) + Specific Retention (%) = 100 % of a Pore Volume

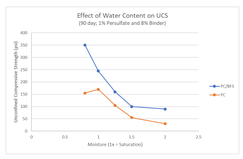
*Specific Yield*: % of Pore Volume that will drain by gravity
*Specific Retention*: % of Pore Volume that is retained by soils after gravity drainage

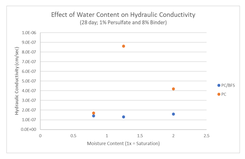
| Material | Avg Specific Yield | Avg Specific Retention |
|---|---|---|
| Clay | 2% | 98% |
| Sandy Clay | 7% | 93% |
| Sand | 21% to 27% | 73% to 79% |

Natural sands can hold 73 to 79% of a PV, whilst clays can hold up to 98% of a PV before gravity causes the water to drain.

Even vadose zones can have significant existing water content.

### Effect of Water on UCS and Hydraulic Conductivity




Water content should be included as a design parameter for ISCO-ISS projects "from bench to field" to maintain predictable UCS results.

Moisture content of site soils should be determined in the field, and amount of moisture added during the application should be controlled.

Evonik typically sees 1.25 to 1.5 PVs of moisture added as a good target for both solidification and contaminant destruction.

## Redeveloping A Former Manufactured Gas Plant

**Background**
Site: Norra Djurgårdsstaden
Where: Stockholm, Sweden
Client: Stockholm Stad (City of Stockholm)
Contractor: PEAB

One of Europe's most extensive urban redevelopment areas. New homes, shops, recreational areas, and living spaces are planned.

Soil, groundwater, and sediments are contaminated with PAHs.

Overarching goal with soil and groundwater remediation is to limit vapor intrusion to new residential buildings.

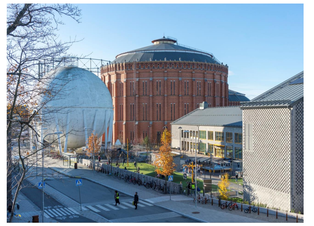
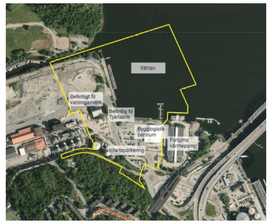


Photo credit: City of Stockholm, Eric Cung Dinh.




Pictured: An early-stage visionary illustration of the final Stockholm Royal Seaport district.

**"Uplands" Portion of the Site**

Actively being remediated with technologies including ISCO-ISS for clay soils and ISCO for moraine layer (~70,000 $m^3$).

ISCO-ISS: Initial Area (~50,000 $m^3$)
- Binder: 4-8%
- Klozur® SP: 1.8%
- Additional water: 4-7%

ISCO-ISS continuing in other areas. First application of ISCO treatment of moraine completed in 2022. Additional ISCO treatment of other areas is ongoing.

**Sediment Portion of the Site**

Bench studies completed comparing various technologies, including amending ISS reagents with Klozur® SP.

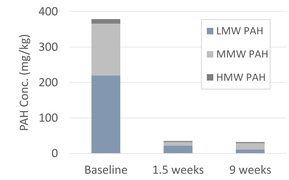
Bench Study Results

The data showed that UCS of greater than 350 kPa (~50 psi) and hydraulic conductivities of less than $10^{-8}$ m/sec were achieved with a variety of ISS reagent blends and persulfate additions of 15 $Kg/m^3$ (~1% w/w), 30 $Kg/m^3$ (~2% w/w), and 45 $Kg/m^3$ (~3% w/w). The data indicates that ISS blend formulations with higher ratios of blast furnace slag resulted in stronger soil cores at lower persulfate loadings but this transition to stronger soils cores with ISS blends with higher ratios of Portland cement with higher concentrations of sodium persulfate. Contaminant reduction was observed in the presence of sodium persulfate. The highest degree of contaminant reductions was observed in ISS blends that favored a blend of blast furnace slag and cement kiln dust. In addition, these studies correlated the non-destructive P-wave method of evaluating UCS with against destructive UCS sampling with a $R^2$ of 0.995.

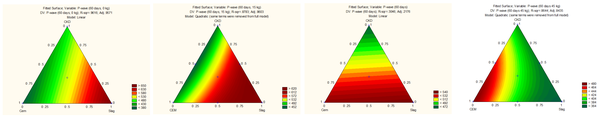
Remediation of sediments will be completed in the future.

ISCO-ISS Results

~95% reduction in light PAH
~90% reduction in medium PAH
~80% reduction in heavy PAH

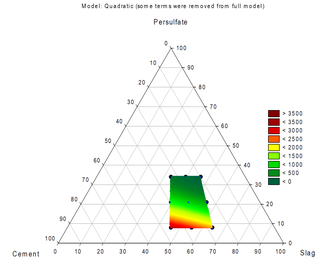



**Unconfined Compressive Strength (UCS; 60 days in kPa)**



0% Klozur® SP (w/w sediment) | 1% Klozur® SP | 2% Klozur® SP | 3% Klozur® SP

**Treatment of PAHs (ug/Kg)**




**UCS after 90 Days**