



Coupling of chemical and biological treatment: the advantages and risks

Nora Sutton
Environmental Technology
Wageningen University


And WP 3 team from: Tecnalía, Deltares, IETU, Enacon, Powiz, and Biutec



What is Bioremediation?

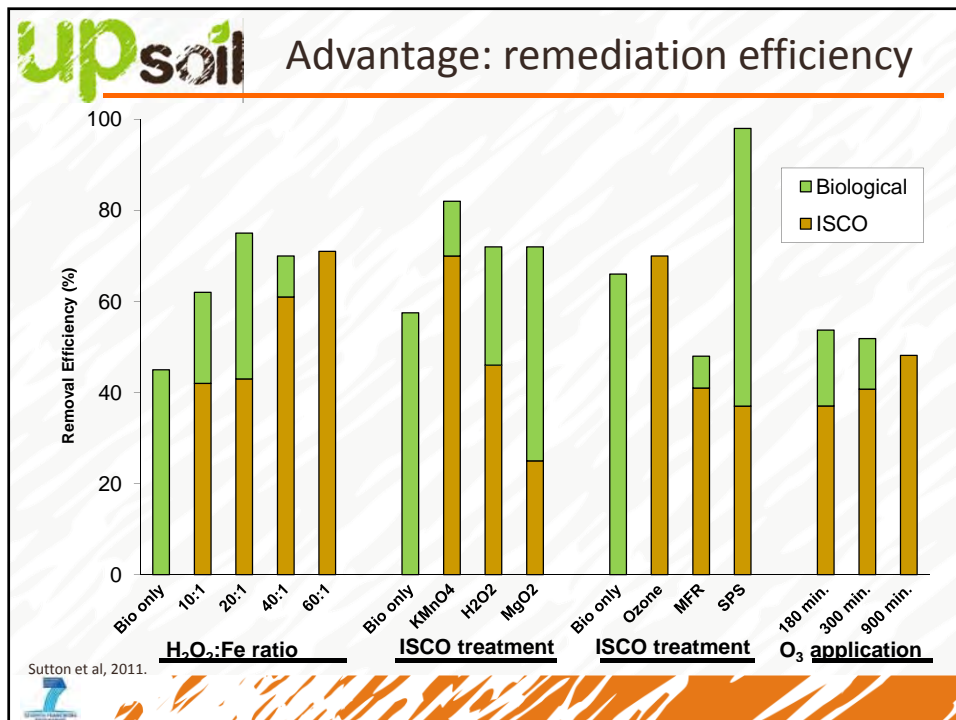
Bioremediation: Use of microbial metabolism to degrade contaminants

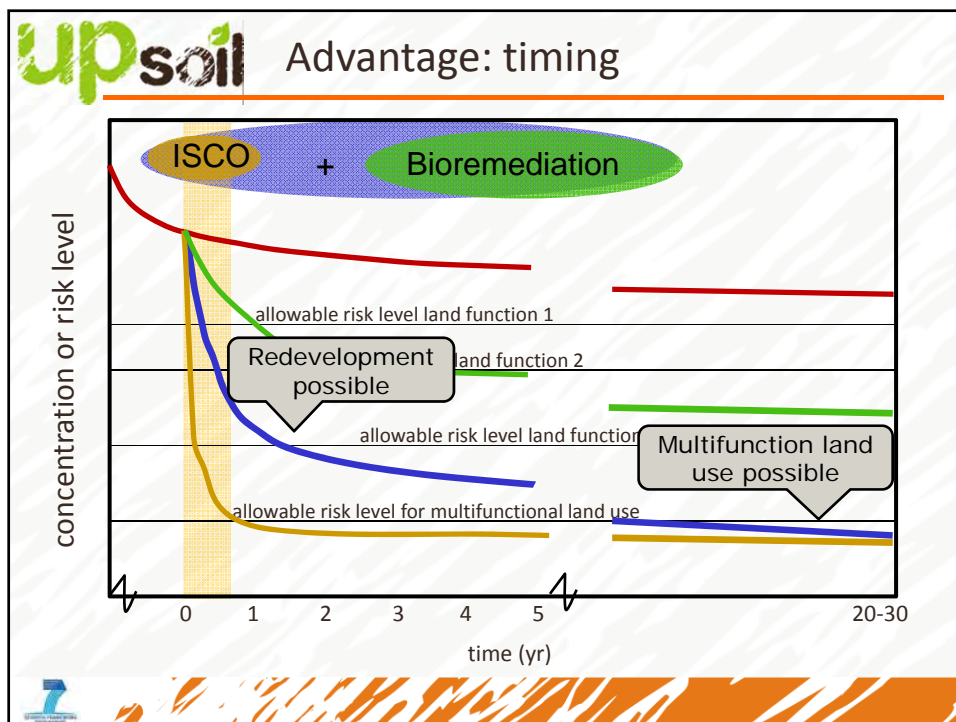
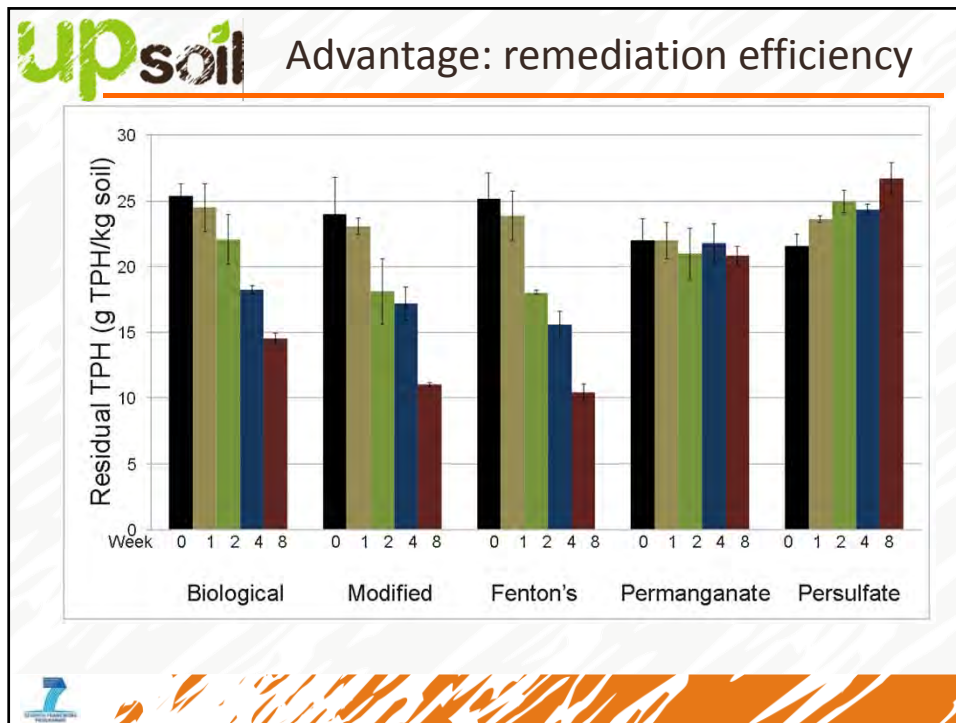
<u>Ex-situ</u>	<u>In Situ</u>
<ul style="list-style-type: none">• Pump-and-Treat• Landfarming	<ul style="list-style-type: none">• Natural Attenuation (NA): natural degradation capacity of indigenous microorganisms• Monitored Natural Attenuation (MNA): extensive monitoring performed to ensure degradation• Enhanced Natural Attenuation (ENA): manipulation of subsurface conditions to encourage biodegradation

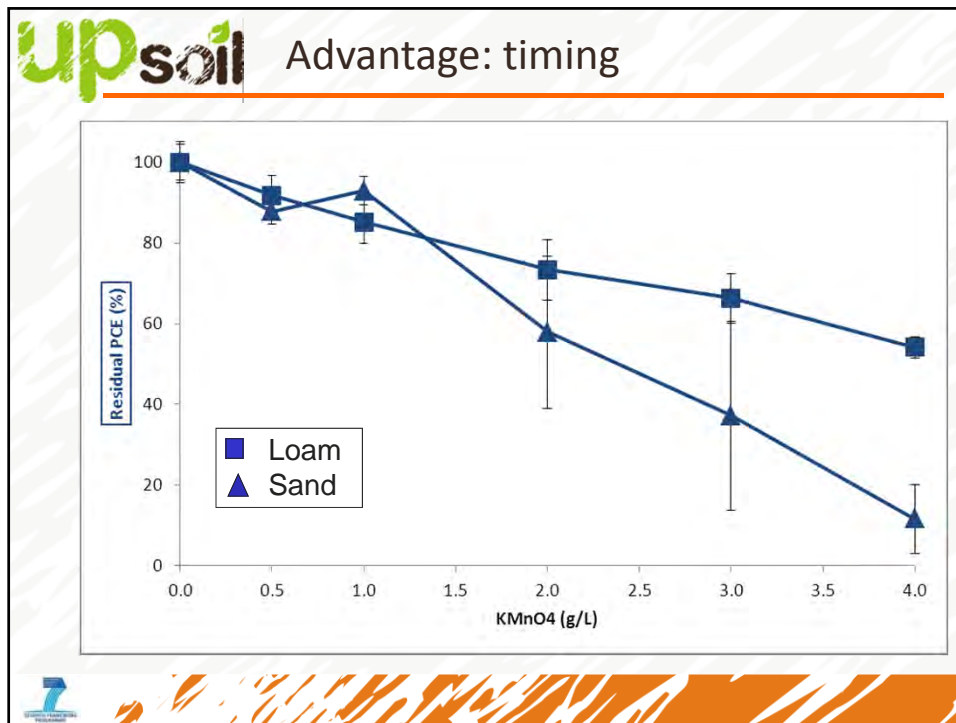


upsoil ISCO treatments

ISCO Treatment	Important Reactions	Optimal pH	Oxidation Potential (V)	Type of injection
Fenton's Reagent	$H_2O_2 + Fe^{2+} \rightarrow OH\cdot + OH^- + Fe^{3+}$	3-4	2.8 Hydroxyl radical (OH \cdot)	Liquid
Modified Fenton's Reagent	$H_2O_2 + OH\cdot \rightarrow HO_2\cdot + H_2O$ $HO_2\cdot \rightarrow O_2\cdot^- + H^+$ $2H_2O_2 \rightarrow 2H_2O + O_2$	neutral		
Activated Persulfate: Metal Activated Heat Activated Alkaline Activated	$M^{n+} + S_2O_8^{2-} \rightarrow SO_4\cdot^- + SO_4^{2-} + M^{n+1}$ $S_2O_8^{2-} + heat \rightarrow 2SO_4\cdot^-$ Reaction unknown	3-4 neutral >10.5	2.6 Sulfate radical (SO $_4\cdot^-$)	Solution
Ozone	$O_3 + OH^- \rightarrow O_2 + OH\cdot$	neutral	2.1	Gas
Permanganate	$MnO_4^- + 2H_2O + 3e^- \rightarrow MnO_2(s) + 4OH^-$ $2KMnO_4 + C_2HCl_3 \rightarrow 2CO_2 + 2MnO_2(s) + 3Cl^- + H^+ + 2K^+$	neutral	1.7	Solution

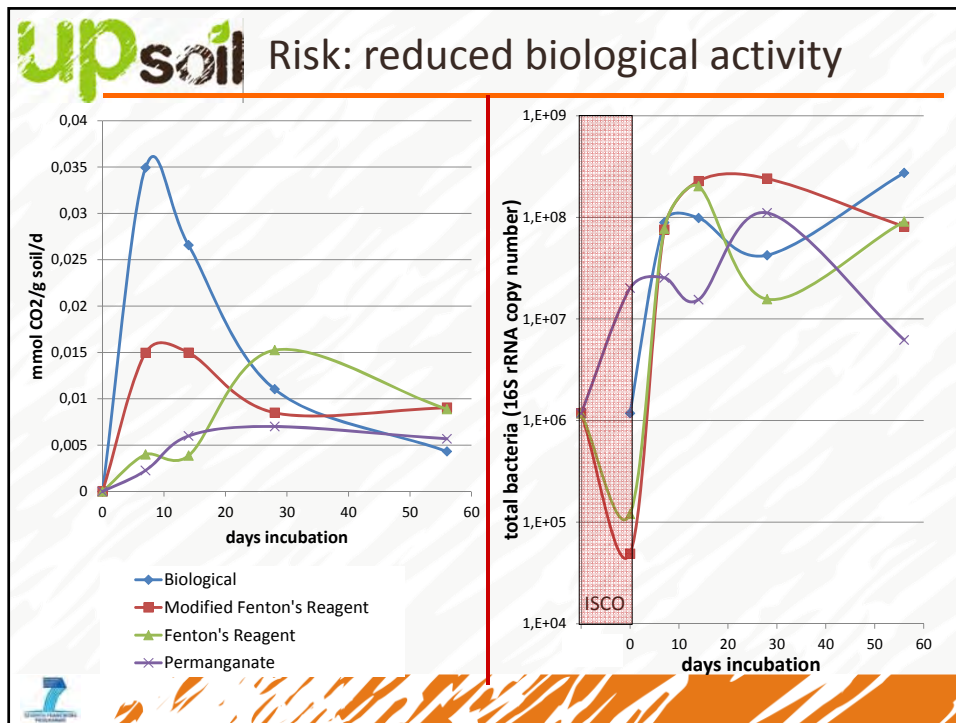






upsoil ISCO from a biological perspective

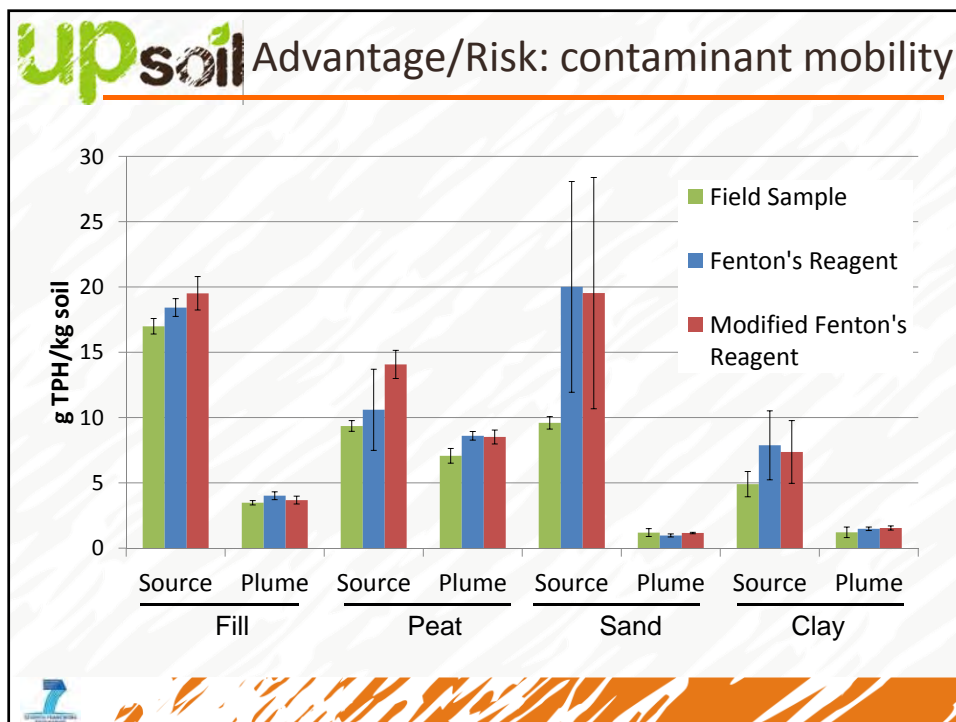
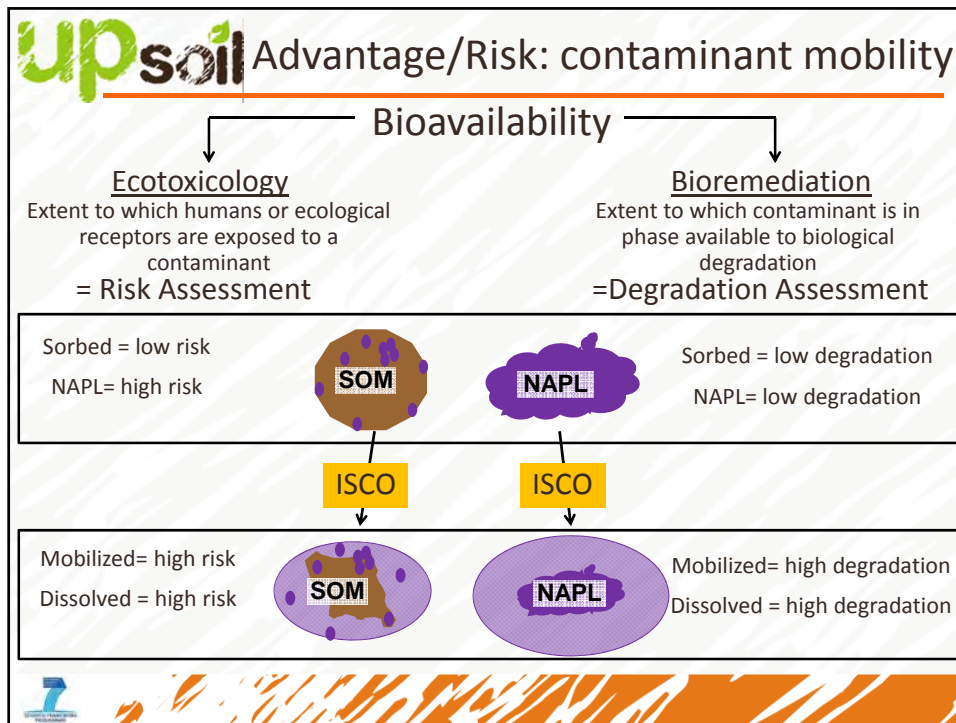
<p>••• Pros:</p> <ul style="list-style-type: none"> • Reduces toxic contaminant concentrations • Improves biodegradability of parent compound (s) • Increases temperature, mixes system • Can improve redox conditions for biological conversion • Improves bioavailability of residual contaminant 	<p>•• Cons:</p> <ul style="list-style-type: none"> • Harsh oxidizing conditions • Chemical oxidant catalysis or reaction yields alkaline or acidic pH • Can cause unfavorable redox conditions for biological conversion • Non-specific reaction degrades soil organic matter
--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------	-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

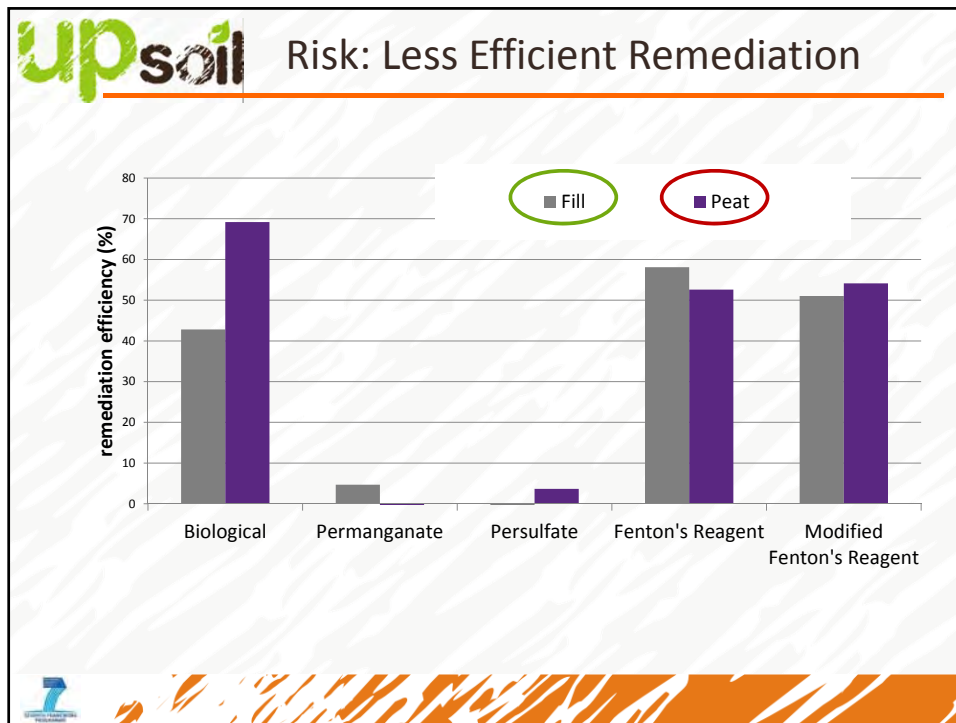


upsoil ISCO from a biological perspective

••• Pros:	•• Cons:
<ul style="list-style-type: none"> • Reduces toxic contaminant concentrations • Improves biodegradability of parent compound (s) • Increases temperature, mixes system • Can improve redox conditions for biological conversion • Improves bioavailability of residual contaminant 	<ul style="list-style-type: none"> • Harsh oxidizing conditions • Chemical oxidant catalysis or reaction yields alkaline or acidic pH • Can cause unfavorable redox conditions for biological conversion • Non-specific reaction degrades soil organic matter


Note: In the original image, the last two items in the Pros and Cons lists are circled and connected by a double-headed arrow.







The complex block, titled "Coupling ISCO and Bioremediation", is divided into two sections: Risks and Advantages. The Risks section lists three potential issues, and the Advantages section lists three benefits of the coupled process.

- Risks:**
 - Contaminant mobilization → environmental risk
 - Microbial inhibition → longer remediation time
 - Soil matrix and contaminant type → less efficient remediation
- Advantages:**
 - Rapid reduction in concentrations → fast redevelopment
 - Microbial stimulation → faster remediation
 - Soil matrix and contaminant type → more efficient remediation



Coupling ISCO and Bioremediation

•Risks: <ul style="list-style-type: none">•Contaminant mobilization → environmental risk•Microbial inhibition → longer remediation time•Soil matrix and contaminant type → less efficient remediation	•Advantages: <ul style="list-style-type: none">•Rapid reduction in concentrations → fast redevelopment•Microbial stimulation → faster remediation•Soil matrix and contaminant type → more efficient remediation	
•When? <ul style="list-style-type: none">•Rapid redevelopment•Low Bioavailability•Robust system	•How? <ul style="list-style-type: none">•Think biologically•Test in lab	
Contact: Nora Sutton Nora.Sutton@wur.nl	Funding:  	More Info: “Efforts to improve coupled in situ chemical oxidation with bioremediation: a review of optimization strategies” <i>Journal of Soils and Sediments</i> (2011) 11:129-140.

