



**Remediation Strategy for Soil and Groundwater Pollution
RemS – A decision Support Tool**

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NIRAS Remediation Strategy for Soil and Groundwater Pollution - RemS

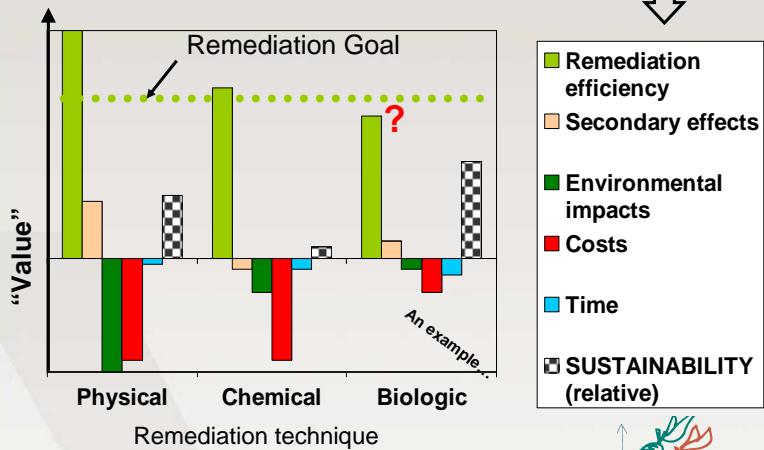
Project holders....

-  The Capital Region of Denmark
-  DANISH MINISTRY OF THE ENVIRONMENT
Environmental Protection Agency
-  Information Centre on Contaminated Sites
DANISH REGIONS

This presentation is about....

- Decision support parameters
- A tutorial through RemS
- Perspectives

Sustainability as aggregated parameters



What to choose???

A site specific tool

Decision support parameters:



- Remediation efficiency and secondary effects



- Costs

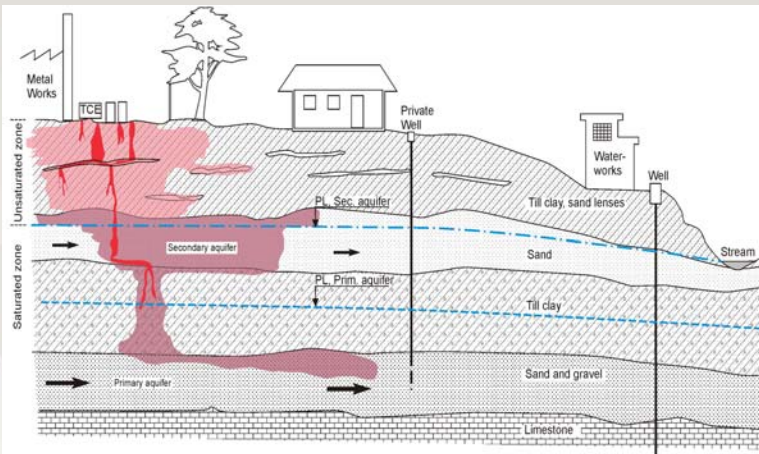


- Environmental impact (LCA)



- Time

Case: Industrial pollution with TCE



Conceptual model for geology, hydrogeology and pollution

Input data

Source zone	
Constituent	VC
Ranking of constituent	2
Area	1
Depth interval	1
Free phase?	Indication
Conc. max.	480.0
Conc. mean	8.308
Mass of pollution in soil	831.6
Free phase?	50,000

Unsat. zone	
Constituent	VC
Ranking of constituent	2
Area	1
Depth interval	1
Free phase?	Indication
Conc. max.	480.0
Conc. mean	8.308
Mass of pollution in soil	831.6
Free phase?	50,000

Saturated zone	
Constituent	VC
Ranking of constituent	2
Area	1
Depth interval	1
Free phase?	Indication
Conc. max.	125.0
Conc. mean	18.0
Mass of pollution in soil	241.9
Free phase?	1,000

Pollution setting design criteria in each sub environment

RemS - Identification of alternative remediation strategies

Alternative remediation strategies	Source area					
	Major source		Secondary source		Priority source	
	Topsoil	Uncontaminated zone / "Soil 1"	Secondary water	Uncontaminated zone / "Soil 2"	Secondary water	Priority water
Guidance						
Land use						
Geology						
Soil pollution						
Air pollution (indoor)						
Groundwater pollution						
Area (m ²)	700		700		700	
Max. depth (m)	6		10		20	
Exceeding factor	25.000		400.000		5.000.000	
Free phase?	Indication		Indication		No	
Remediation needed?	X	X	X	X	X	X
Only one technique per strategy!						
Strategy A	ok	ok	ok	ok	-	-
1 Thermal - ISTD		X	X			
2 Soil Vapour Extraction	X		X			
3 Pumping				X		
4 Treatment (air/water)				X		
5 -						
Strategy B	-	ok	ok	ok	-	-
1 Excavation		X				
2 Chemical Oxidation ISCO			X	X		
3 -						
4 -						
5 -						
Strategy C	-	ok	ok	ok	-	-
1 Excavation		X	X			
2 Stimulated Dechlorination				X		
3 -						

Summary of conceptual model:

- geology,
- pollution,
- threshold limits..

Remediation needed?

Identification of remediation strategy A! (treatment train)

Alternative strategy...B!

Alternative strategy...C!

LCA calculations based technique inventories

Techniques included in RemS so far:

- Excavation and off site treatment (light oils)
- Sheet piling (trapeze wall and H profiles)
- Pumping - P
- Treatment – T (water and air, GAC)
- Dual Phase Extraction - DPE
- In Situ Chemical Oxidation - ISCO (potassium permanganate)
- Natural Attenuation - NA
- Stimulated Reductive Dechlorination – SRD (EOS, lactate, KB1)
- In Situ Thermal Desorption – ISTD (conductive heating)
- Soil Vapor Extraction - SVE
- Passive Soil Vapor Extraction – PSVE
- Soil mixing with zero valent iron - ZVI (planned)
- Thermal - Steam (planned)

NIRAS RemS – Assessment of remediation efficiency and secondary effects

Alternative remediation strategies

Guidance

Land use
Geology
Soil pollution
Air pollution (indoor)
Groundwater pollution
Area (m²)
Max. depth (m)
Exceeding factor
Free phase?
Remediation needed?

Source area

Remediation effect	Function	Secondary effects
Positive	Negative	Neighbour annoyances
<p>Mass removal reduction</p> <p>Security for effect</p> <p>Any other benefit (over vents)</p>	<p>Eliminate value of hydrocarbons</p> <p>Terrestrial aquatic ecosystem</p> <p>Terrestrial: E.g. mobilization</p> <p>(Microbial) Fertilisation (control)</p> <p>Other (over vents)</p>	<p>Eliminate value of hydrocarbons</p> <p>Terrestrial aquatic ecosystem</p> <p>Terrestrial: E.g. mobilization</p> <p>(Microbial) Fertilisation (control)</p> <p>Other (over vents)</p> <p>Noise and vibrations</p> <p>Dust and smell</p> <p>Traffic (accidental risk)</p> <p>Other (over vents)</p>
High efficiency: -3 (0-1-2-3)*	No effects: -0 (0-1-2-3)*	No effects: -0 (0-1-2-3)*
Score	Score	Score

Only one technique per strategy!!!

Strategy A

1 Thermal - ISTD	ok	ok	ok	ok	-	3	3	3	3,0	3	0	0	0,8	0	0	2	2	2,2	2	2	1	3	1,0	
2 Soil Vapour Extraction	x		x																					Container for treatment will be present for many years
3 Pumping																								
4 Treatment (air/water)				x																				
5 -																								

Strategy B

1 Excavation	-	ok	ok	ok	-	-	3	2	3	2,0	2	0	2	1,2	0	0	3	0	2,4	3	1	1	1	1,1
2 Chemical Oxidation ISCO		x			x																			
3 -																								
4 -																								
5 -																								

Strategy C

1 Excavation	-	ok	ok	ok	-	-	3	3	3	3,0	3	2	0	3	1,6	0	0	3	0	2,4	3	1	1	1,1
2 Stimulated Declorination		x	x																					
3 -																								
4 -																								
5 -																								

NIRAS RemS – Remediation efficiency and secondary effects

Assessment of remediation efficiency

Needs can be:

- Mass removal
- Reduction in massflux

It is mandatory to determine what success criteria are!!!
And to reach the goal in the most "cost"- effective way..

Uncertainties on techniques could be depending on:

- Access to site
- Remaining pollutants after remediation
- In situ contact problems when biological or chemical techniques are used
- Experiences for the involved parties
- Technology transfer between different geological and climatic conditions

Assessment of local secondary effects



Positive or negative effects:

- Esthetic value of area/landscape
- Terrestrial or aquatic changes of ecosystem
- Geochemical changes (fixation or mobilization of constituents)
- Geotechnical changes (foundation conditions)

Neighbour annoyances during construction and remediation:

- Noise and vibrations
- Smell
- Traffic



Successive calculation to determine effects of uncertainties on unit prices and operation time

Net Present Values of costs for alternative remediation strategies

Guidance: Single calculation, Successive calculation

3.0% Discounting rate p.a.

2010 Calculation year (YYYY)

Automatic cost estimate

Net present value calculation on future costs

	Construction				Operation				Dismantling		Grand total costs				
	Investigation s. pilottests	Projecting and tender (consultancy)	Construction and run in	Construction total costs	Start	Time of operation	Costs per year	Operation total costs	Works	Dismantling total costs					
	1 000 DKK	1 000 DKK	1 000 DKK	1 000 DKK	Years	Years	1 000 DKK	1 000 DKK	1 000 DKK	1 000 DKK	1 000 DKK	1 000 DKK			
	Likely	Likely	Likely	Mean		Likely	Likely	Mean	Likely	Mean	Mean	Mean			
				SD				SD		SD		SD			
Strategy A	Genskab strategi														
1 Thermal - ISTD	526	958	4.555	6.140	0	2.009	1	8.417	3.128	0	398	352	0	9.618	0
2 Soil Vapour Extraction	290	145	970	1.405	31	2.009	2	340	646	0	290	271	0	2.322	31
3 Pumping	500	550	1.350	2.400	37	2.009	30	200	3.878	0	200	71	0	6.150	37
4 Treatment (air/water)	0	0	0	0	0	2.009	0	0	0	0	0	0	0	0	0
5 -	0	0	0	0	0	2.009	0	0	0	0	0	0	0	0	0
Consultancy (% of construction sum)	50%		20%	2.083	0	20%		1.291	0	20%	60	0	2.535	0	
Total +/- standard deviation (SD)	2.125	1.653	8.250	12.028	48			8.348	8.842	0	1.017	754	0	21.624	48
Strategy B	Genskab strategi														
1 Excavation	473	210	2.438	3.120	0	2.009	1	135	130	0	270	281	0	3.511	0
2 Chemical Oxidation ISCO	120	85	1.040	1.245	32	2.009	0	0	0	0	0	0	0	1.245	32
3 -	0	0	0	0	0	2.009	0	0	0	0	0	0	0	0	0
4 -	0	0	0	0	0	2.009	0	0	0	0	0	0	0	0	0
5 -	0	0	0	0	0	2.009	0	0	0	0	0	0	0	0	0
Rådgraving (% af anlægssum)	50%		20%	992	0	20%		26	0	20%	52	0	1.070	0	
Total +/- spredning	889	295	4.173	5.357	32			162	157	0	324	313	0	5.826	32
Strategi C															

Cost estimates



- Comparing alternative remediation strategies:
- Each strategy can have several techniques
 - Different payment schedules

Back discounting of future costs to a Net Present Value - NPV

Management of uncertainties on:

- Unitprices
- Amounts, e.g. m³ soil
- Operation period

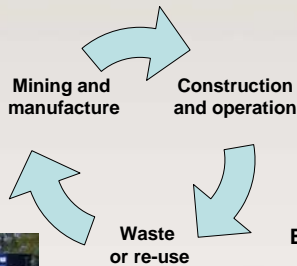
Successive calculations based on estimates of minimum, most likely and maximum values.

Environmental impacts in a life cycle perspective



Consumption of resources

- Energy
- Metals
- Sand and gravel



Environmental impacts

- Emissions to air
- Toxic effects
- Waste generation



LCA calculation is visualized in person equivalents (PE)



Environmental Impact: Resource consumption, emissions, toxicity and waste

Normalized data (PE)
 Weighted data (PE, PET)
 Manual weighting

Factors
 Techniques

Resource Consumption

Weighted data, scarcity (reciprocal supply horizon)
 Person equivalent Reserve (PR)

Potential Environmental Effects

Weighted data, Person Equivalent
 Targeted reduction goals (PET)

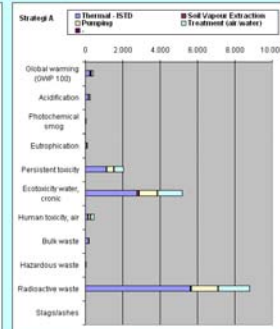
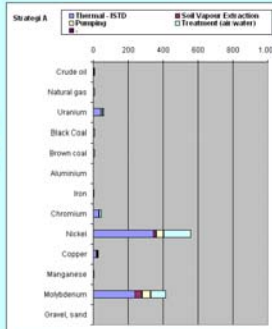
Strategy A

- 1 Thermal - 100%
- 2 Soil Vapour Extraction
- 3 Pumping
- 4 Treatment (air/water)
- 5 -

Type of electricity

Electricity EU2? Low vol. at grid

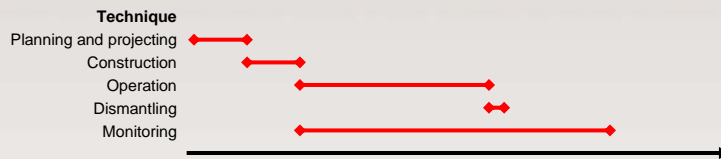
Vis udsikt/udskriv "Påvirninger"



Units: Impacts in person equivalents - PE

RemS – Time schedule

Time – a scarce resource?



Time schedules can be constrained due to:

- Limited time to reach success criteria
- Availability of the site for the owner/future land use
- Limitations on annoyances periods (secondary effekts)
- Preference to promote site closure (political)

Summary of decision parameters and scoring

Summary of decision parameters

Function	Local secondary effects				Risk environmental impact - weighted (LCA)				Costs					Time			
	Efficiency	Positive (0-3)	Negative (0-3)	Labour annoyances (0-5)	Resource consumption	Emissions	Toxicity	Waste	Construction	Operation	Commissioning	SUM	+	SD	Project start week no, year	SD	
Score (0-3)	Score (0-3)	Score (0-3)	Score (0-3)	PK	PE1	PE2	PE3	KDKK	KDKK	KDKK	KDKK	+	KDKK	Months	Months	+	Years
Weighting Weighting between groups (0)																	
Strategi A 1 Thermal - ISTD 2 Slot Vapour Extraction 3 Pumping 4 Treatment (air/water) 5 Electricity EU 220 Low volt. at grid Total 0.180																	
Strategi B 1 Excavation 2 Chemical Oxidation ISCO 3 4 5 Electricity DK Low volt. at grid Total 0.865																	
Strategi C 1 Excavation 2 Stimulated Declination 3 4 5 Electricity DK Low volt. at grid Total 0.503																	

Score as decision support

Perspectives for RemS...

Shall consider:

- Systematize and document the decision making process
- Overview of decision parameters
- Make alternatives comparable
- Analyze uncertainty on costs and sensibility of discounting
- Ranking based on user's weighting of decision parameters

In general a qualification of the decision making

- Transparency in decision making process
- Eases communication to politicians and other stakeholders

RemS is expected to be available in English primo 2010, kwe@niras.dk



Thank you for your attention

Carbon - footprint and soil remediation...