



**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

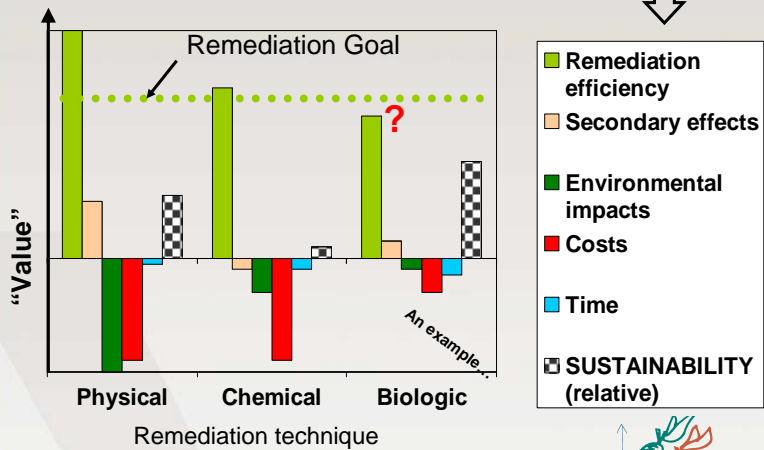
Project holders....

-  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

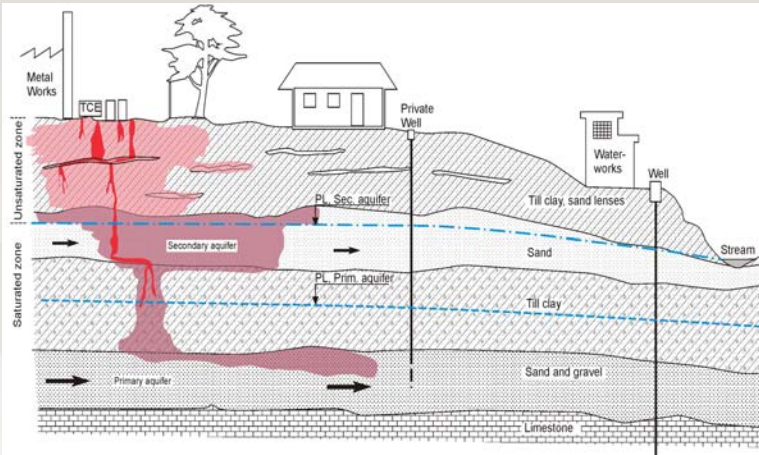


- Environmental impact (LCA)



- Time

Case: Industrial pollution with TCE



Conceptual model for geology, hydrogeology and pollution

Input data

Source zone		Air pollution		
Constituent	Ranking of constituent	TCE	VC	Benzene
Mean conc.		0,00050	0,00000	0,00020 mg/m3
Max. conc.		0,00010	0,00000	0,00007 mg/m3
Min. conc.		0,00000	0,00000	0,00000 mg/m3
Mean conc.		0,00400	0,00004	0,00040 mg/m3

Soil pollution		TCE			VC			PHE		
Ranking of constituent	Area	1	2	3	1	2	3	1	2	3
Area	m ²	700	500	200						
Depth interval	m	10,0	10,0	10,0						
Free phase?		Indication	Indication	Indication						
Conc. max.	mg/kg	480,0	320,0	2,0						
Conc. mean	mg/kg	8,308	50,0	0,1						
Mass of pollution in soil	kg	831,6	247,5	0,0						
Free phase?		50,000	20,000							

Geowater pollution		SAND			CLAYTLL		
Ranking of constituent	Area	1	2	3	1	2	3
Area	m ²	700	500	200			
Depth interval	m	8,0	5,0	1,4			
Free phase?		Indication	Indication	Indication			
Conc. max.	µg/l	9,900,0	2,290,0	0,9			
Conc. mean	µg/l	1,200,0	160,0				
Mass of pollution in soil	kg	5,504	0,045	0,000			
Free phase?		2,000	1,000				

Pollution setting design criteria in each sub environment

RemS - Identification of alternative remediation strategies

Alternative remediation strategies	Source area					
	Major source	Uncontaminated zone / "Source 1"		Secondary source	Contaminated zone / "Source 2"	
	Topsoil	CLAY/SAND	CLAY/CLAY	SAND	CLAY/CLAY	SAND
Guidance						
Land use	VC					
Geology		YCL	TCL		TCL	
Soil pollution						
Air pollution (indoor)				TCL		TCL
Groundwater pollution						
Area (m ²)		700	700	700	700	700
Max depth (m)		0.5	6	10	10	20
Exceeding factor	05	25.000	400.000	5.000.000	05.000	0
Free phase?		Indication	Indication	Indication	Indication	Indication
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?

Only one technique per strategy!!!

Remediation strategy	Source area						Function			Secondary effects					
	Mass removal	Reduction in massflux	High efficiency	Security for effect	Any other benefits	Score	Positive	Negative	Neighbour annoyances	Score	Score				
Strategy A	ok	ok	ok	ok	-	3.0	3	0	0	0.8	2	2	1	3	1.0
1 Thermal - ISTD															
2 Soil Vapour Extraction	x														Container for treatment will be present for many years
3 Pumping															
4 Treatment (air/water)															
5 -															
Strategy B	-	ok	ok	ok	-	2.0	2	0	2	1.2	0	0	3	0	2.4
1 Excavation															
2 Chemical Oxidation ISCO															
3 -															
4 -															
5 -															
Strategy C	-	ok	ok	ok	-	3.0	3	0	3	1.6	0	0	3	0	2.4
1 Excavation															
2 Stimulated Declorination															
3 -															

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	NPV				
	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	SD	Mean	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)



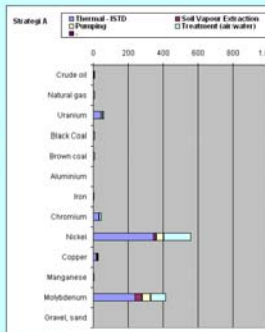
Environmental Impact: Resource consumption, emissions, toxicity and waste

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

Factors
 Techniques

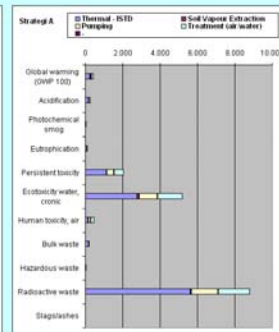
Resource Consumption

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



Potential Environmental Effects

Weighted data, Person Equivalent
 Targeted reduction goals (PET)

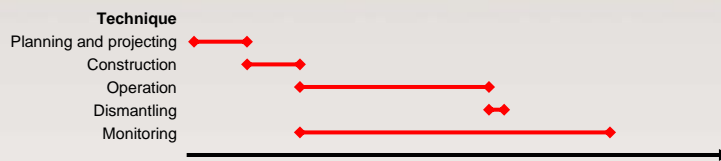


Units: Impacts in person equivalents - PE

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 effects)
- 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 between groups (%)																	
1	80%	20%	20%	40%	40%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%
Strategi A																	
1	Thermal - ISTD				Container for treatment will be present for many years	703	416	3.980	5.778	6.140	4.523	520	11.183		15		
2	Sol Vapour Extraction					83	16	205	75	1.405	640	123	2.176		15		
3	Pumping					123	147	1.548	1.495	852	3.556	112	4.520		9		
4	Treatment (air/water)					293	206	2.020	1.746	2.400	3.740	130	6.270		9		
5	Electricity EU 220V Low-volt. at grid					4.109	993	7.054	9.994	19.738	13.460	805	24.948	4.864	60	29	0,3
Total	0,190	3,0	0,8	2,2	1,0	0,0	0,0	0,0	0,0	0,0	1,7	1,5	2,0	9,0	0,0	0,8	0,8
Strategi B																	
1	Excavation				Excavation and re-establishment of vegetation area a facelift	83	79	510	3.291	8.445			8.445		11		
2	Chemical Oxidation ISCO					30	35	368	182	4.888	356	236	5.280		18		
3																	
4																	
5																	
Electricity DK Low-volt. at grid						112	114	872	3.484	13.133	356	226	12.725	3.422	18	7	1,5
Total	0,865	2,0	1,2	3,4	1,8	2,7	2,6	2,7	1,9	2,5	1,4	3,0	3,0	1,3	1,3	0,3	2,3
Strategi C																	
1	Excavation				Excavation and re-establishment of vegetation area a facelift	83	79	510	3.291	14.551			14.551		13		
2	Simulated Declorination					9	18	214	50	3.211	289	183	3.663		20		
3																	
4																	
5																	
Electricity DK Low-volt. at grid						90	81	734	7.111	17.762	289	183	18.234	4.833	20	12	1,1
Total	0,503	1,3	1,6	2,4	1,8	2,0	2,6	2,7	1,5	2,6	0,0	3,0	3,0	4,7	0,7	0,6	1,8

Weighting

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...