



Phytosanierung von schwermetall-belasteten Böden: Das GREENLAND-Projekt



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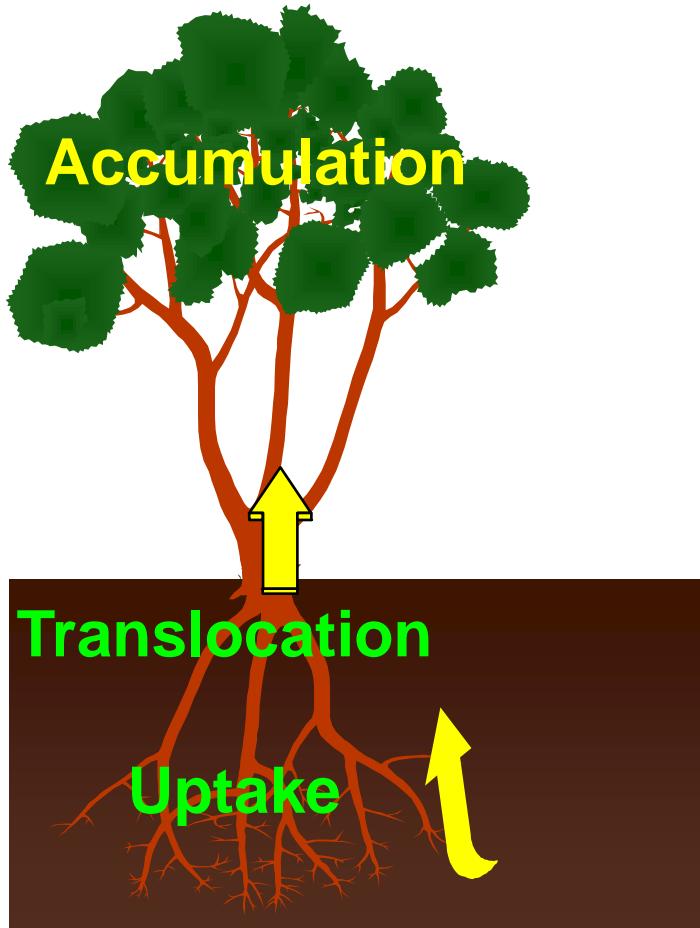
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Gentle remediation options - GRO

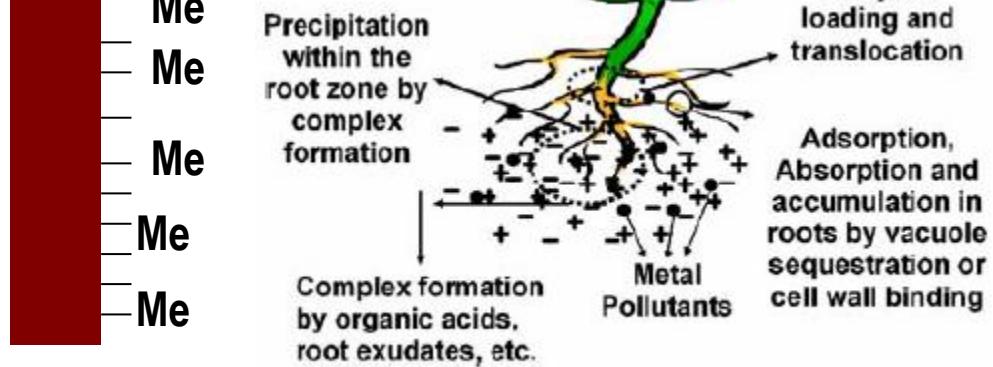
Phytoextraction



In situ immobilisation Aided phytostabilisation

Soil amendments

Me
Me
Me
Me
Me



Why are GRO not applied yet as practical site solution?

- Performance on **large field scale (up-scaling)** remains to be demonstrated
 - **Treatment / Valorisation of TE-contaminated plant biomass** needs to be tested
 - **Stakeholders and decision makers** are little informed about GRO
 - **Decision support tools** do not sufficiently consider GRO (Onwubuya et al, 2009)
 - The success of GRO is mostly reflected by **changes of TE bioavailability**, which is currently not sufficiently considered by legal frameworks; changes in other pollutant linkages should be also assessed.
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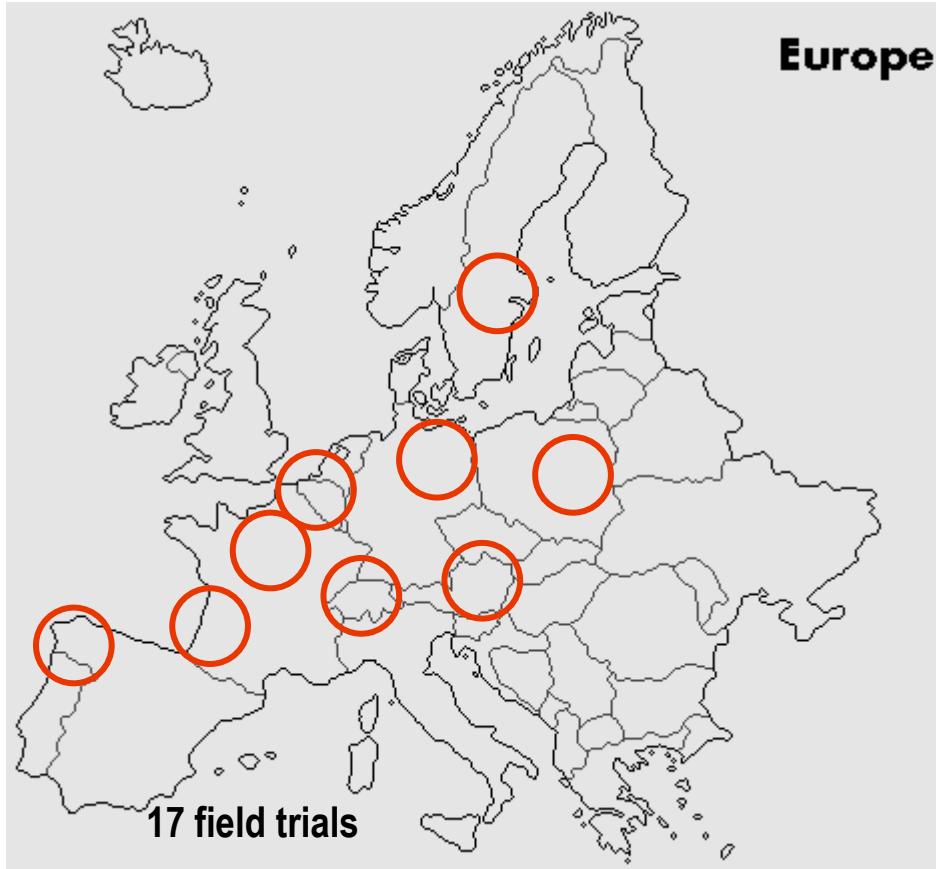
GREENLAND – Gentle remediation of trace element contaminated land*

project objectives

- Assess the efficiency tested in long-term field trials
- Test the possibilities for biomass valorisation
- Evaluation of a set of soil tests to assess the pollution level, the progress and success of GRO and the monitoring of sustainability
- Enhance the efficiency of GRO (e.g. by selection of most effective plants, microbes, and soil amendments)
- Development of a decision support system and publication of a guide for practical application

* FP7-KBBE-266124; 2011-2014

GREENLAND



Ecosystem services

Biomass production

Avoid diversion of cropland

Soil biodiversity, promote animal communities, Habitat, connexion

Storing, filtering and transforming nutrients, substances and water

C sequestration minimal use or substitution of nonrenewable inputs

European network of field experiments for:

- climatic conditions
- soil types
- contaminants
- re-use for non-food crops
- recycling of organic waste products

Main objectives

To obtain sustainable ecosystems, without or minimized pollutant linkages/risks, producing (non-food) crops for plant-based feedstock (local market), and promoting ecosystem services
(positive Life cycle analysis)

Main outcome

to promote Bio-Economy and gain environmental, health and societal benefits

No.	Experimental coordinator	Strategy and gentle remediation technology	Plant species	Contaminants	Site type	Duration
1	UHASSELT	phytoextraction using SRC and crops	poplars, willows, maize, rapeseed	Cd, Zn	agricultural soils	7 yrs
2	SLU	phytoextraction using SRC	willows	Cd, Zn (Cu, Ni, Cr, Pb)	Commercial sludge-amended fields	18 yrs / 7 yrs
3	INERIS	phytoextraction using HA and high biomass crop	<i>Arabidopsis halleri</i> rapeseed	Cd, Zn, Pb	Marginal lands in surrounding industrial facility	5 yrs
4	CSIC	phytoextraction using HA and SRC	<i>Thlaspi caerulescens</i> , willows	Cd, Zn	tailings	2 yr
5	INRA	aided phytoextraction using high biomass crops from fast-track breeding	sunflower, tobacco sorghum	Cu and Cu/PAHs	industrial soils	5 yrs
6	LfULG	phytoextraction using SRC	poplars, willows	Cd, As, Pb	agricultural soils	7 yrs
7	PT-F	phytoextraction using high biomass crop from fast-track breeding	sunflower, tobacco	Cd, Zn (Cu, Ni, Cr, Pb)	sludged and agricultural soils on landfill	7 yrs
8	INRA	phytostabilisation and rhizodegradation (SRC and grassy cover)	Poplars, willows, grasses, vetiver	Cu and Cu/PAHs	industrial soils	7 yrs
9	CSIC	phytostabilisation	Tobacco, willows	Cu	tailings	2 yr
10	INERIS	aided phytostabilisation	Miscanthus, spontaneous grasses, shrubs, trees	Cd, Zn, Pb, As, Cu	dredged sediments	1 yr
11	AIT	in situ stabilization/phytoexclusion	barley, maize	Cd, Pb, Zn, (As, Cu)	agricultural soils	10 yrs
12	IUNG	in situ stabilization (lime, sludges)/phytoexclusion	grassland	Cd, Zn, Pb	Post-industrial soils	17 yrs
13	LfULG	in situ stabilization/phytoexclusion	crops, grassland	Cd, As, Pb	agricultural soils	7 yrs

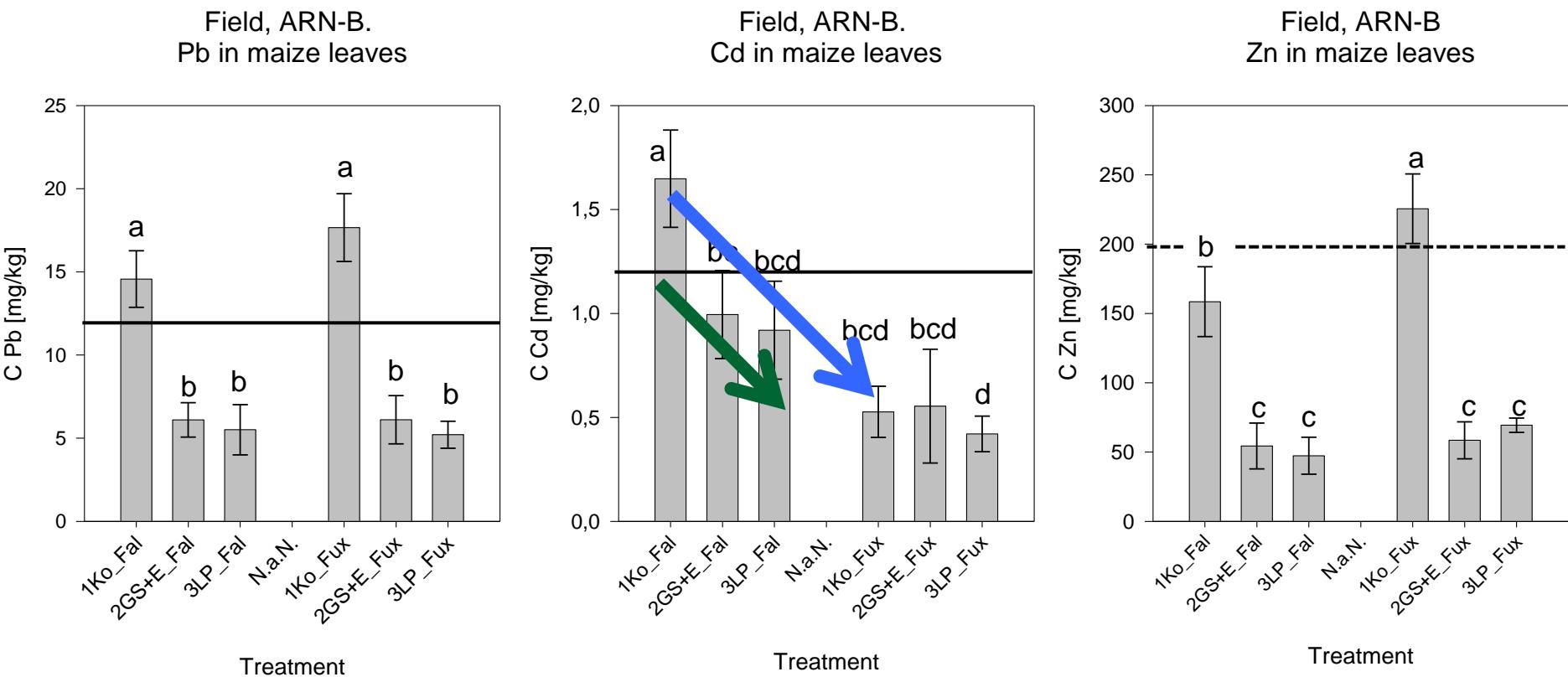
Field experiments – GRO efficiency: Arnoldstein, AT

- ARN-B soil (moderate contamination)
- Cd (5), Pb (950), Zn (500), (As)

- ARN-D soil (high contamination)
- Cd (15), Pb (1600), Zn (1800), (As)

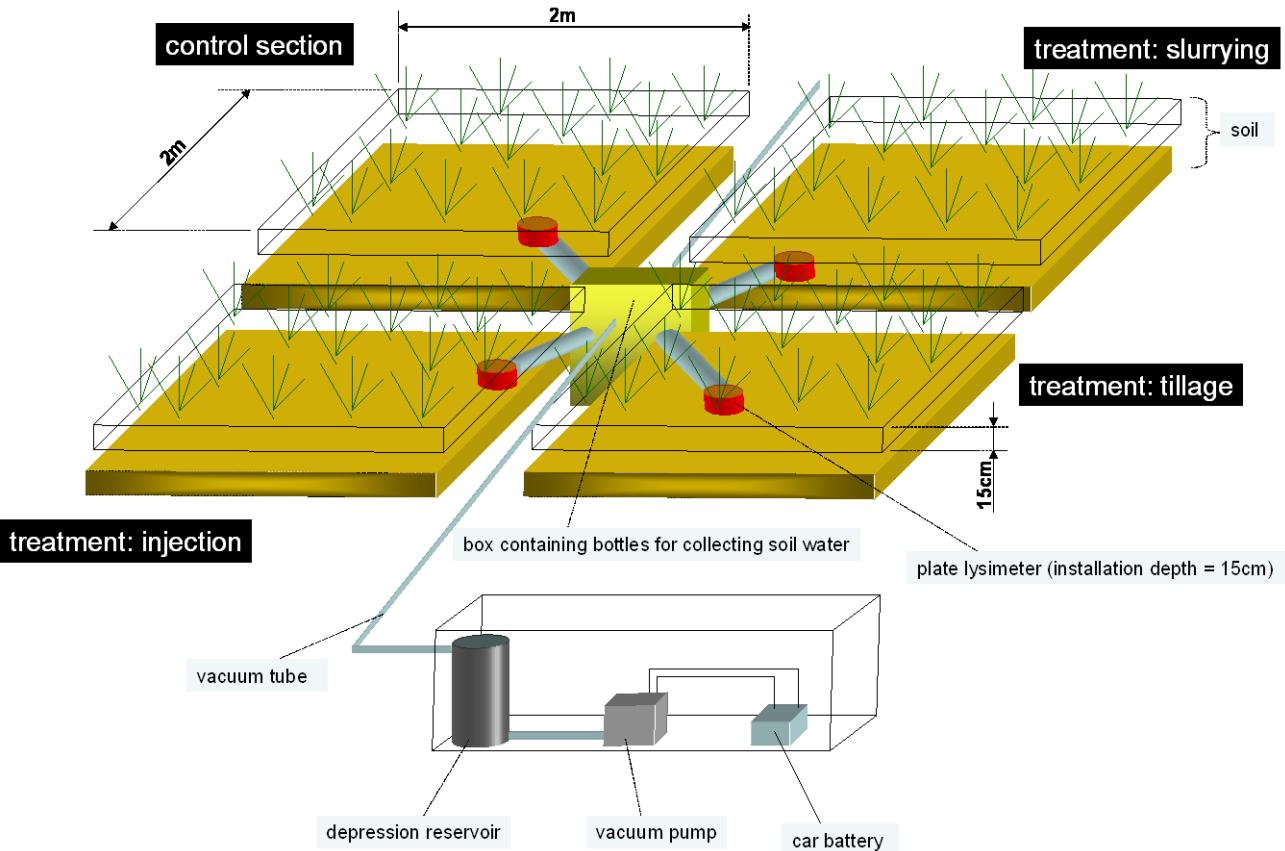


Results 2011: Soil ARN-B (moderately contaminated)

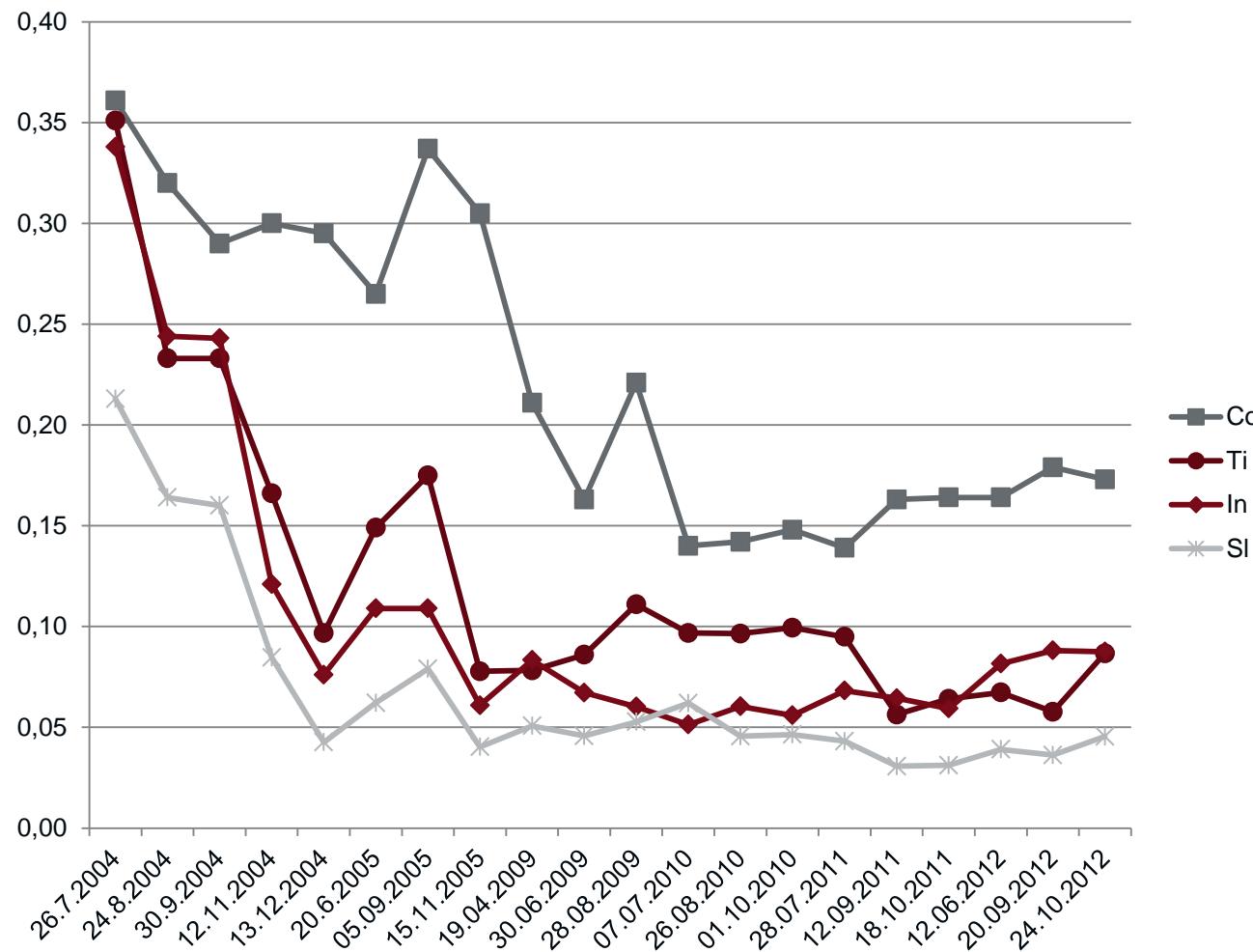


Metal immobilisation on grassland (ARN-D)

Seepage water sampling system (plate lysimeters)



Zn (mg L⁻¹) in seepage water 2004-2012



field experiments – GRO efficiency: Hasselt/Belgium

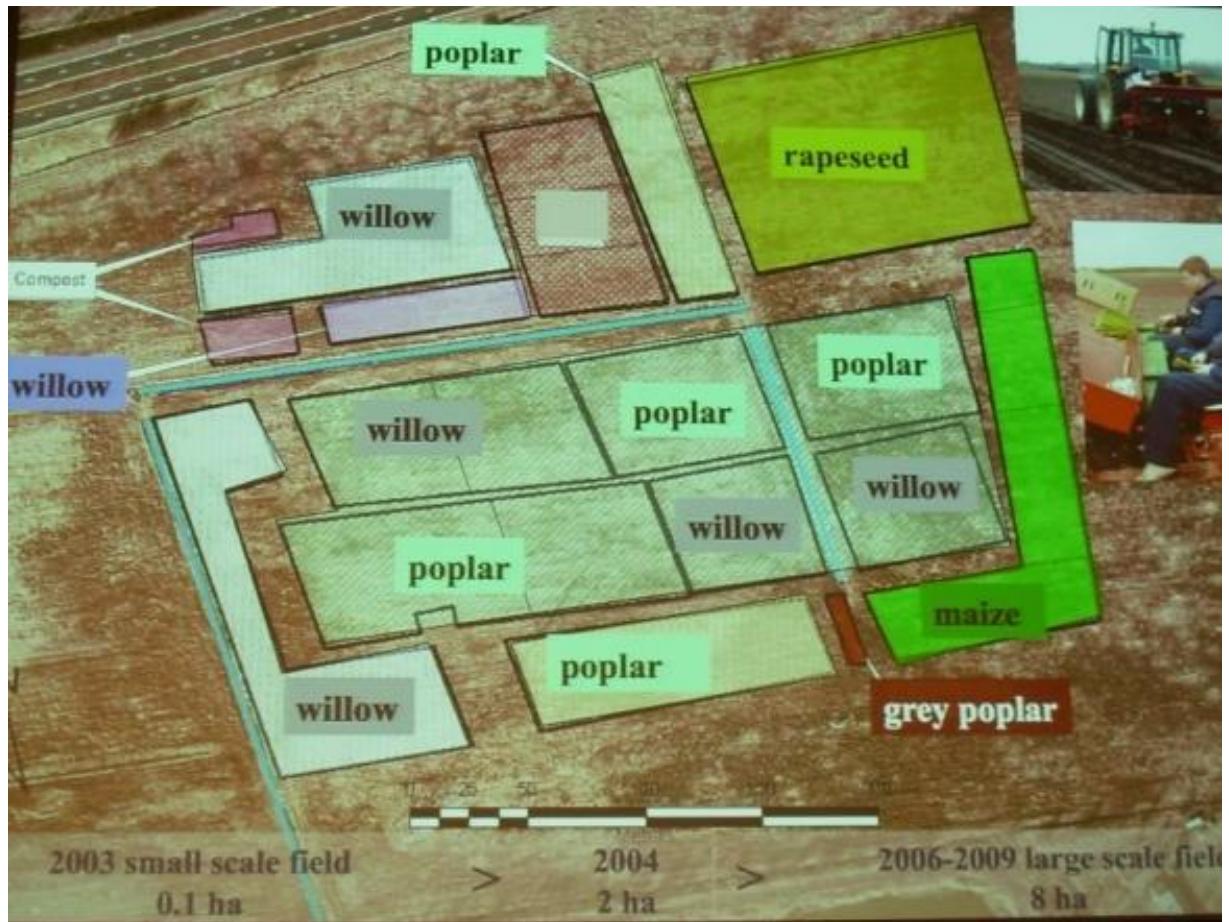
Lommel 2006-2013



Accumulator (Zn, Cd): poplar



Excluder – phytostabilisation – Maize



field experiments – GRO efficiency: Hasselt/Belgium

Lommel/Maatheide 1990-2003



- Application of a beringite+compost mix on 3 ha
- Metal-tolerant *Festuca rubra* and *Agrostis capillaris*

field experiments – GRO efficiency: Hasselt/Belgium

Lommel/Maatheide 1990-2003



1990, 2 weeks after sowing



1995



2002

field experiments – GRO efficiency: Hasselt/Belgium

Lommel/Maatheide 1990-2003

Total zinc concentration (mg/kg dry soil), water-extractable zinc (mg/kg dry soil) and ratio water-extractable zinc on total zinc concentration measured 5 years after the treatment

	Zn-aqua regia extr. (mg/kg)	Zn-water extr. (mg/kg)	ratio (%)
unpolluted garden soil	106±7	0.7±0.06	0.660
M without treatment	11425±506	141.0±11.2	1.234
M with natural vegetation	960±51	10.4±0.81	1.085
treated 1	12075±701	2.1±0.23	0.017

field experiments: IUNG (Poland)

Site 1 – smelter slag 400m from gardens and houses; 2 slag types – Doerschel more acidic, high salinity; both Zn 1-12%, Pb 0.3-4.0%, Cd up to 0.35%; revegetated 1994-1995; 300t/ha biosolids + lime 30t/ha; grass mixture

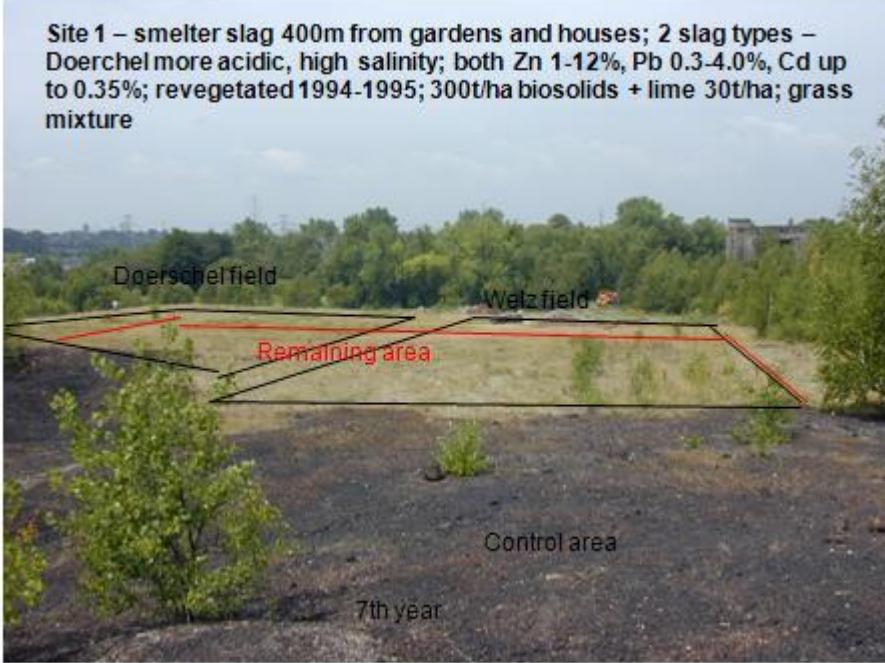
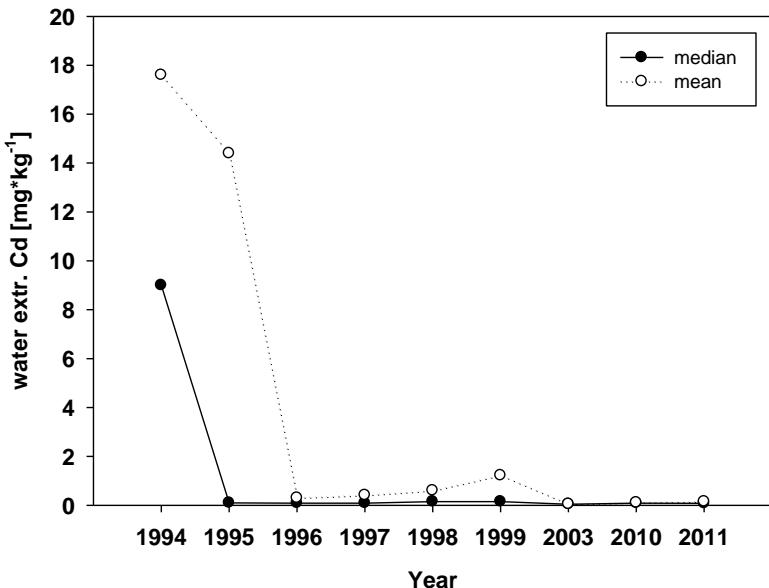


Table 3. Chemical properties of waste materials sampled before (1994) and after remediation amendment with biosolids and lime.



Waste material	Sampling time	Soluble	Soluble	Soluble	pH	EC
		Zn	Cd	Pb		
Welz	Before	343	17.6	1.80	7.00	7.30
	1995	279	17.7	1.10	7.20	3.50
	1996	10.4	0.41	0.34	7.47	1.63
	1997	11.4	0.55	0.41	7.70	1.28
	1998	33.3	0.62	0.02	7.22	0.99
	1999	31.7	1.22	0.03	7.39	1.15
Doerschel	Before	1670	108	5.40	5.80	16.0
	1995†	983	57.4	2.90	6.00	9.00
	1996	12.4	0.66	0.42	7.44	2.98
	1997	17.9	0.80	0.40	7.74	2.06
	1998	24.1	0.48	0.01	7.28	1.53
	1999	104	0.99	0.02	7.36	2.08

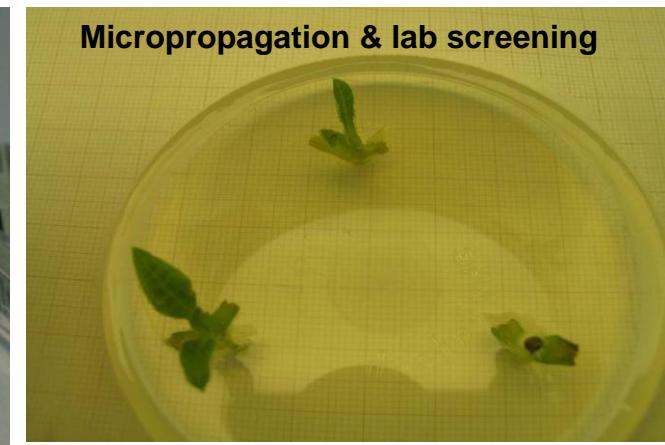
† Sampled before retreatment of Doerschel waste.

field experiments: Phytotech Foundation (CH): Improved metal phytoextraction of tobacco by *in vitro* breeding

1. Tobacco clones with improved metal uptake were obtained from *in vitro* breeding (non-GMOs)



2. *In vitro* bred tobacco were tested since years under real field conditions (PHYTAC, COST 837, 859, GREENLAND...)



Rafz (CH) 23.10.2003

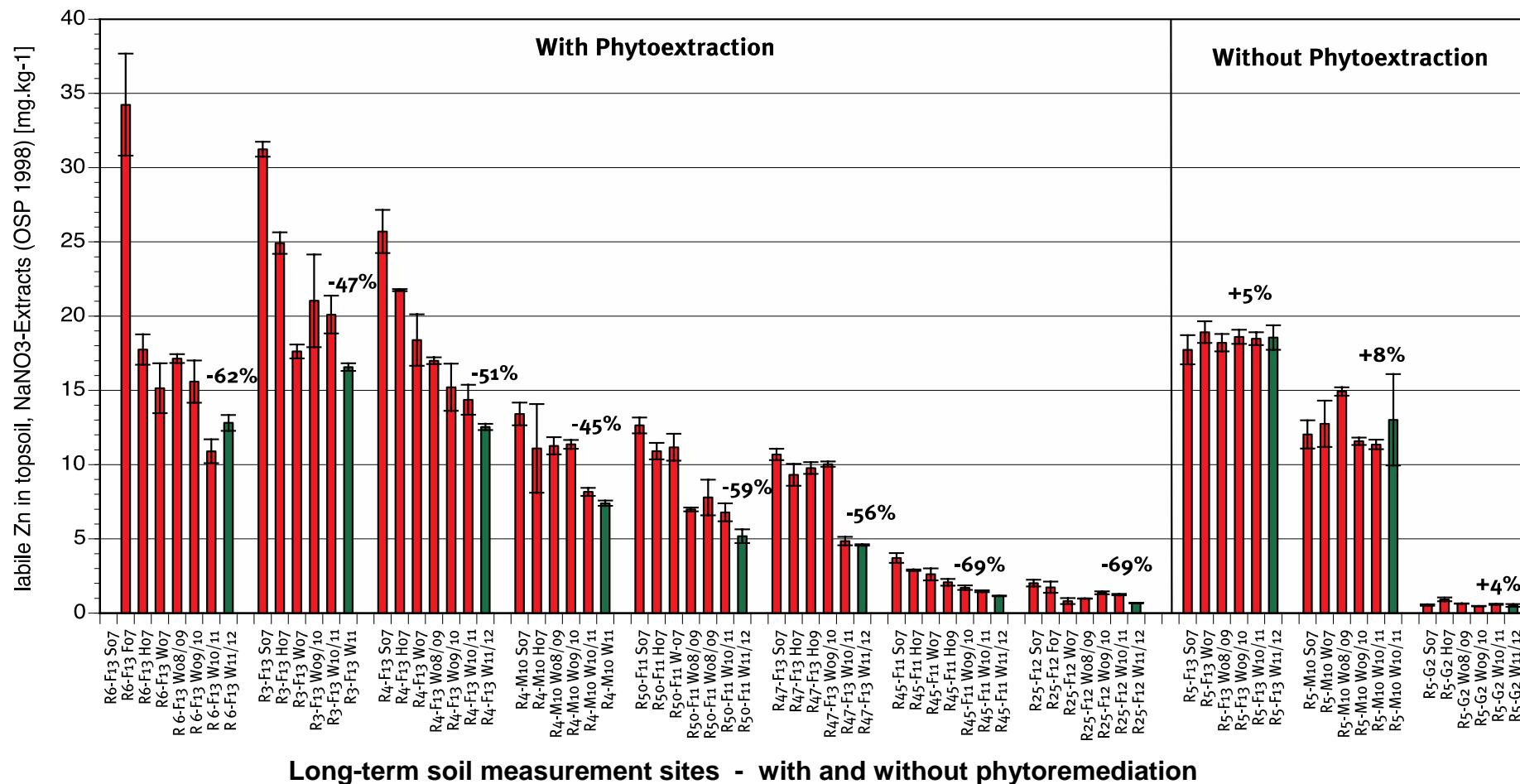


Balen (B) 20.8.2003



➤ A freeland assessment of 4th FWP PHYTAC on the acid sandy soil of Balen (zinc smelter) in Belgium showed a promising enhanced metal extraction up to a factor of 12-15 for Cd, Zn, and Pb.

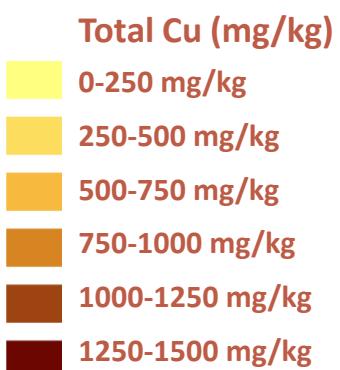
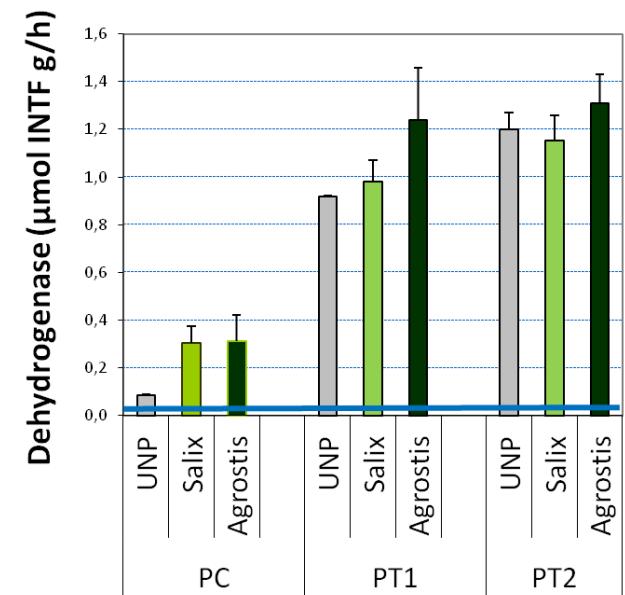
Field experiments: Phytotech Foundation (CH): Treatment effect over 5 Years - Reduction of labile Zinc in topsoil, site Bettwiesen on landfill Grüenau-Buech-Alpenblick 2007 – 2011/12



Site Bettwiesen on Landfill Grüenau-Buech-Alpenblick after 248 Weeks of Phytoextraction with improved sunflower and tobacco in crop rotation scheme - Soil Series June 2007 – Winter 2011/12 (A07-W11/12)

field experiments – GRO efficiency:

Touro, Spain; 2011-2013



Harmonisation of methods to assess the bioavailability of TE and development of tool set to monitor the sustainability of GRO

- To achieve a convincing argument towards the decision makers, we need a harmonisation of methods to assess the initial and residual risks and the success of GRO on a comparable (and pan-European) basis.
- To select/harmonise methods describing the bioavailable/bioaccessible TE fractions among European case studies
- To select methods which can be used as indicators for GRO success and as sustainability monitoring tools.

Standard risk assessment and long term monitoring

Plant-microbial-soil system

Time (4 years)
(bi)annual (bio)monitoring

Characterisation of soils

General physicochemical properties

pH, CEC, C, N, available P (olsens), total [metal], etc.

Intensity of contaminant exposures

H_2O - NO_3^- , NH_4NO_3^- , EDTA-extractable [metal], soil pore water, DGT Ecotoxicity tests: plants, bioaccessibility (DIN 19738), earthworms, nematodes, etc.

Biochemical properties

Oxidoreductase & hydrolase (C, N, P, S cycles) enzyme activities

Plant growth and establishment

Survival, growth & coverage

Bacterial community structure

Plant ionome; contaminant accumulation

Ecosystem services:
water filtration, C sequestration, biodiversity, etc.

Case site	AIT Arnoldstein	IUNG Piekarz	INRA Biogeo	HAU Lommel	PT-F Bettryiesen	LfULG Freiberg-Halsbrucke	SLU Högbyt orp
Contamination level**	H	VH	VH	H	VH	H	L
Treatment	Aided phytostabilisation				Phytoextraction		
	Tr 1*	Tr 2*	Tr 1*	Tr 2*			
Extractions							
AqReg		Cd, Pb					
EDTA	Cd, Zn	Zn	Cd	Cu	Cd, Zn, Pb	Cd, Pb	
NH ₄ NO ₃	Cd, Pb, Zn		Pb	Cu	Cu	Zn, Pb	Cd
NaNO ₃	Cd, Pb, Zn		Zn, Cd			Zn, Cd, Pb	
H ₂ O	Cd, Zn	Pb	Pb	Cu		Zn, Cd	
C _{DGT}	-		-				-
C _{rh}	-		-	Cu			-
R _{DGT}	-		-	Cu	Zn		-
Plantox							
<i>Lettuce</i>							
shoot mass DW			X				-
shoot mass FW			X	X	X		-
<i>Turnip</i>							
seed germination			-	X	-		-
shoot mass DW	X		-	X	-	-	X
<i>Dwarfbeans</i>							
shoot mass DW	X		X			X	
primary leave mass	X			X	X	X	
root mass	X		X	X		X	
shoot length	X	X				X	
Soil Ecotoxicity							
Number of worms			-	-		-	
Nematode growth			-	-		-	X
Nematode reproduction			-	-		-	X
Plant Enzymes							
<i>Leaves</i>							
ME	X				X	X	X
ICDH	X	X			X		
GPOD	X				X		X
<i>Roots</i>							
ME		X					
GIDH	X		X				
GPOD	X						

Assessment of biomass valorisation options

- to review existing processes and types of biomass; to compile information on current and under development processes
- to test various types of plant biomass collected on case study sites (WP1)
- to assess advantages and limitations regarding technical aspects, regulations, acceptance and costs
- Treatment options:
 - Incineration
 - Gasification
 - Anaerobic digestion
 - Solvolysis
 - Microwave thermal treatment
 - Oil production

Improvement of GRO efficiency

- Selection and testing of more efficient plant species, varieties, clones
- Selection and testing of more efficient microbial strains (rhizobacteria, endophytes)
- Application of agronomic practices for improving GRO efficiency

Development of a decision support tool and a best-practice guidance document

- best-practice guidance document for the application of GRO at field-scale
- Guidelines for stakeholder participation, engagement and empowerment when implementing GRO
- To develop a decision support tool, focused on GRO, which can be integrated into existing, well-established and utilised (national) DSTs / decision-frameworks.



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Developing principles of sustainability and stakeholder engagement for “gentle” remediation approaches: The European context



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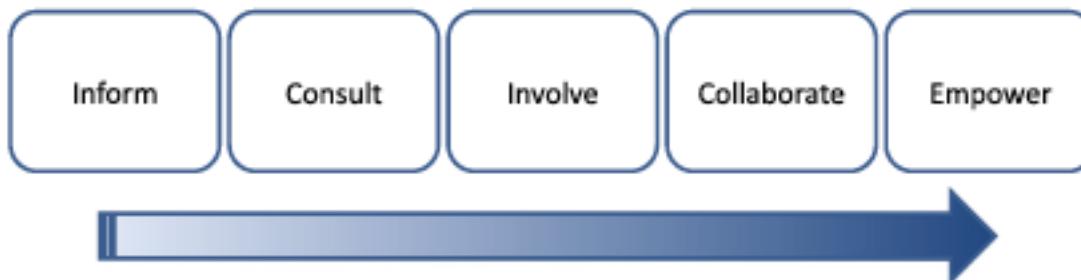
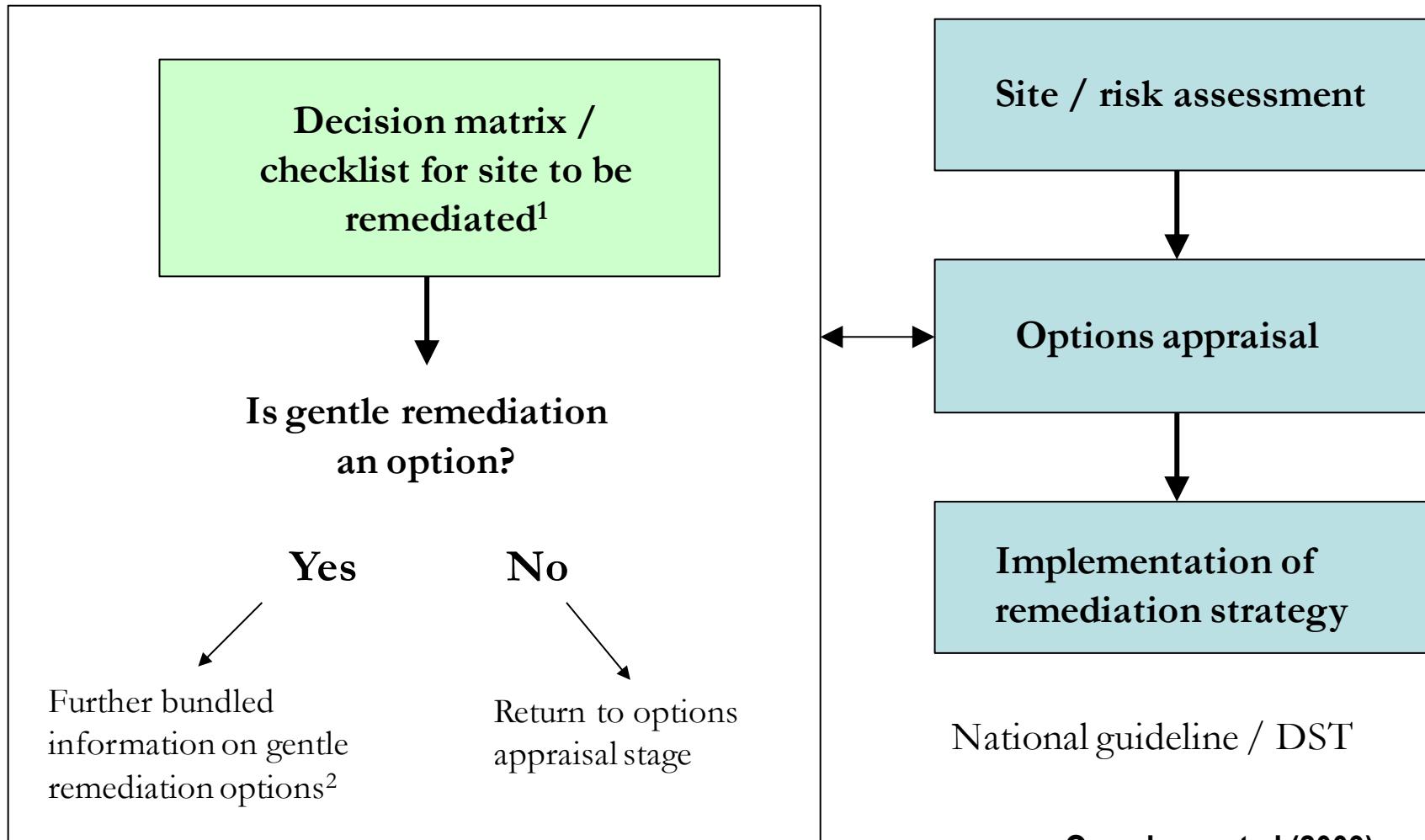


Fig. 3. Spectrum of stakeholder engagement and empowerment activities (after REVIT Project, 2007). Note that the lower arrow shows direction of increasing depth of stakeholder interaction and engagement and is not intended to show a “flow” of activities, as stakeholder engagement activities are frequently iterative and non-linear in nature and may involve the full range of these involvement measures (see text for discussion).



Onwubuya et al (2009)

GREENLAND: consortium

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 - 2 Jaco Vangronsveld, Universiteit Hasselt
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