# Developing a practical decision support tool (DST) for the application of gentle remediation options

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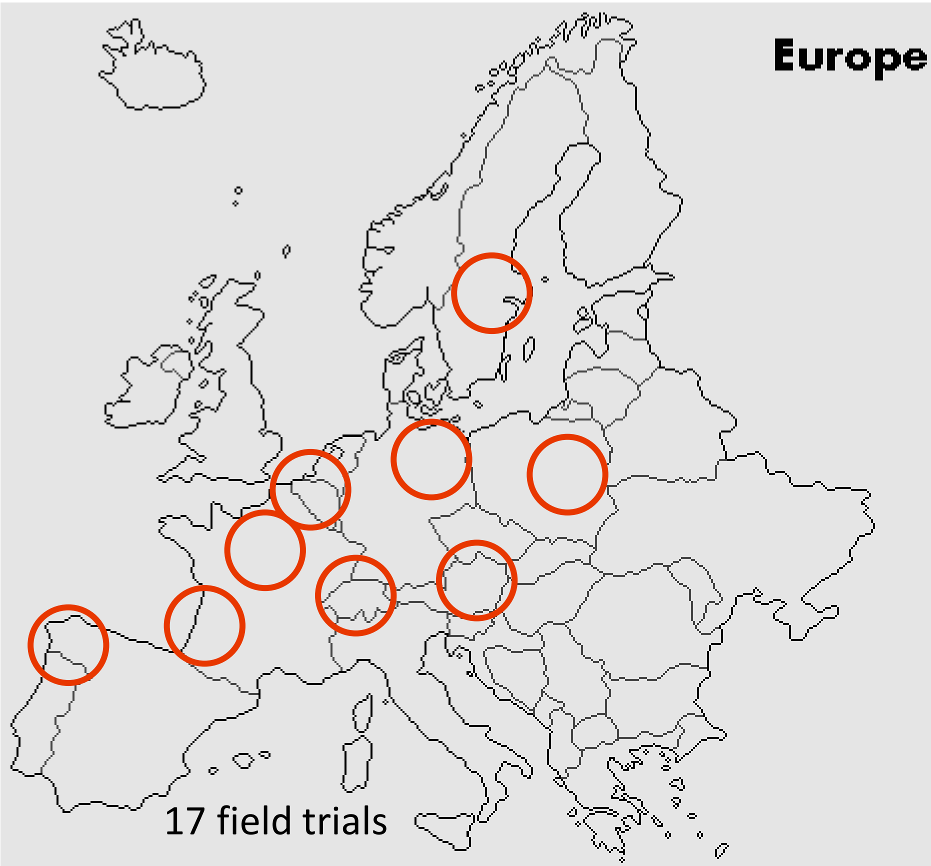
# GREENLAND – Gentle remediation of trace element contaminated land*: Project Objectives




- Assess the efficiency tested in long-term (> 5 year duration) field trials
- Test the possibilities for biomass valorisation
- Evaluation of a set of soil tests to assess GRO performance
- Enhance the efficiency of GRO (e.g. by selection of most effective plants, microbes, and soil amendments)
- **Development of a decision support system, stakeholder engagement guidance, and publication of a guide for practical application**

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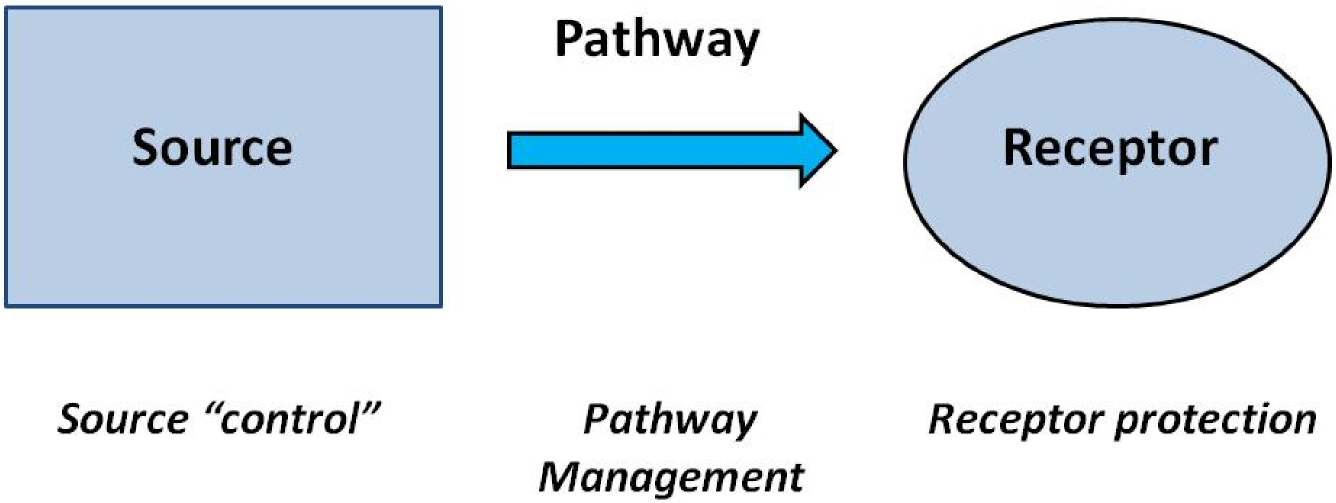
* FP7-KBBE-266124; 2011-2014

# Gentle remediation options - GRO

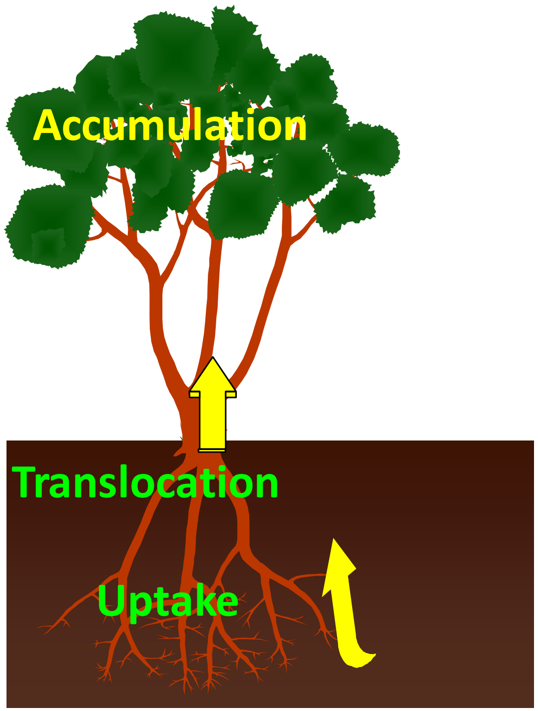
Risk management strategies/techniques that result in no gross reduction (or a net gain) in soil functionality as well as risk management.

Encompass a number of technologies which include the use of plant (phyto-), fungal (myco-) or microbiologically-based methods, with or without chemical additives, for reducing contaminant transfer to local receptors by *in situ* stabilisation or extraction of contaminants

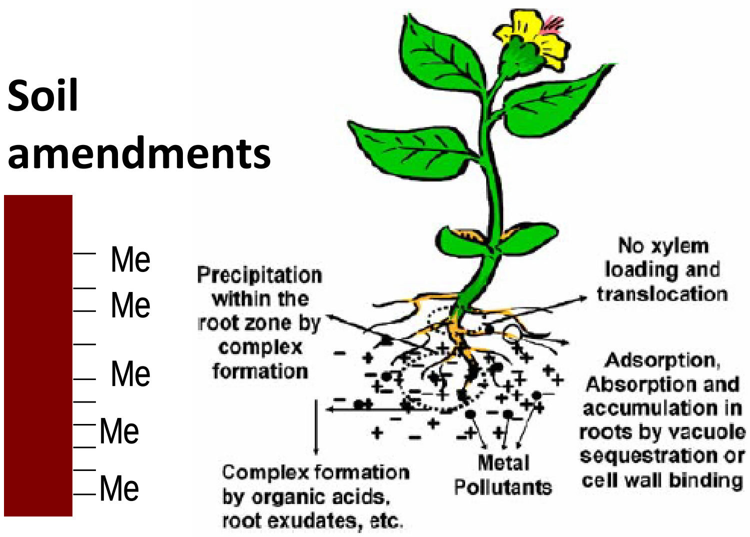



# Gentle remediation options - GRO

## Phytoextraction




## In situ immobilisation
## Aided phytostabilisation

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## Contents and context

- "Gentle" remediation options (GROs) offer strong benefits in terms of deployment costs and sustainability for a range of problems, however, awareness and take up is low, at least in a European context.

- Decision support tools could help, but the take up and acceptance of bespoke systems by stakeholders, such as specialist softwares, is low.

- GREENLAND is therefore adopting a transparent and simple framework for promoting the appropriate use of gentle remediation options and encouraging participation of stakeholders, supplemented by a set of specific design aids for use when GROs appear to be a viable option

# Gentle remediation options - GRO

Number of barriers to the wider adoption of GRO relate to stakeholder awareness and confidence, such as:

(1) stakeholder uncertainty relating to their time-scale and effectiveness as risk management methods;
(2) (within Europe at least) the issue that GRO services are offered by relatively few consultants and contractors, which has limited their availability, and
(3) there is limited awareness of their role as practical site solutions.

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# Gentle remediation options - GRO

Hence, GROs are often simply excluded from decision making.

Effective stakeholder engagement, coupled with efficient and simple decision support, is therefore a key principle in the successful adoption and application of GROs (and in ensuring that the full wider economic and other benefits of GRO methods are realised).

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Key output of the GREENLAND project is to develop and trial / evaluate practical decision support tools (based on Greenland and other case studies), focussed on GRO, which

(a) can be integrated into existing, well-established and utilised (national) DSTs / decision-frameworks, to ensure ease of operation and wide usage;
(b) can be used to inform and support remediation option selection by wider stakeholders (consultants, planners etc)

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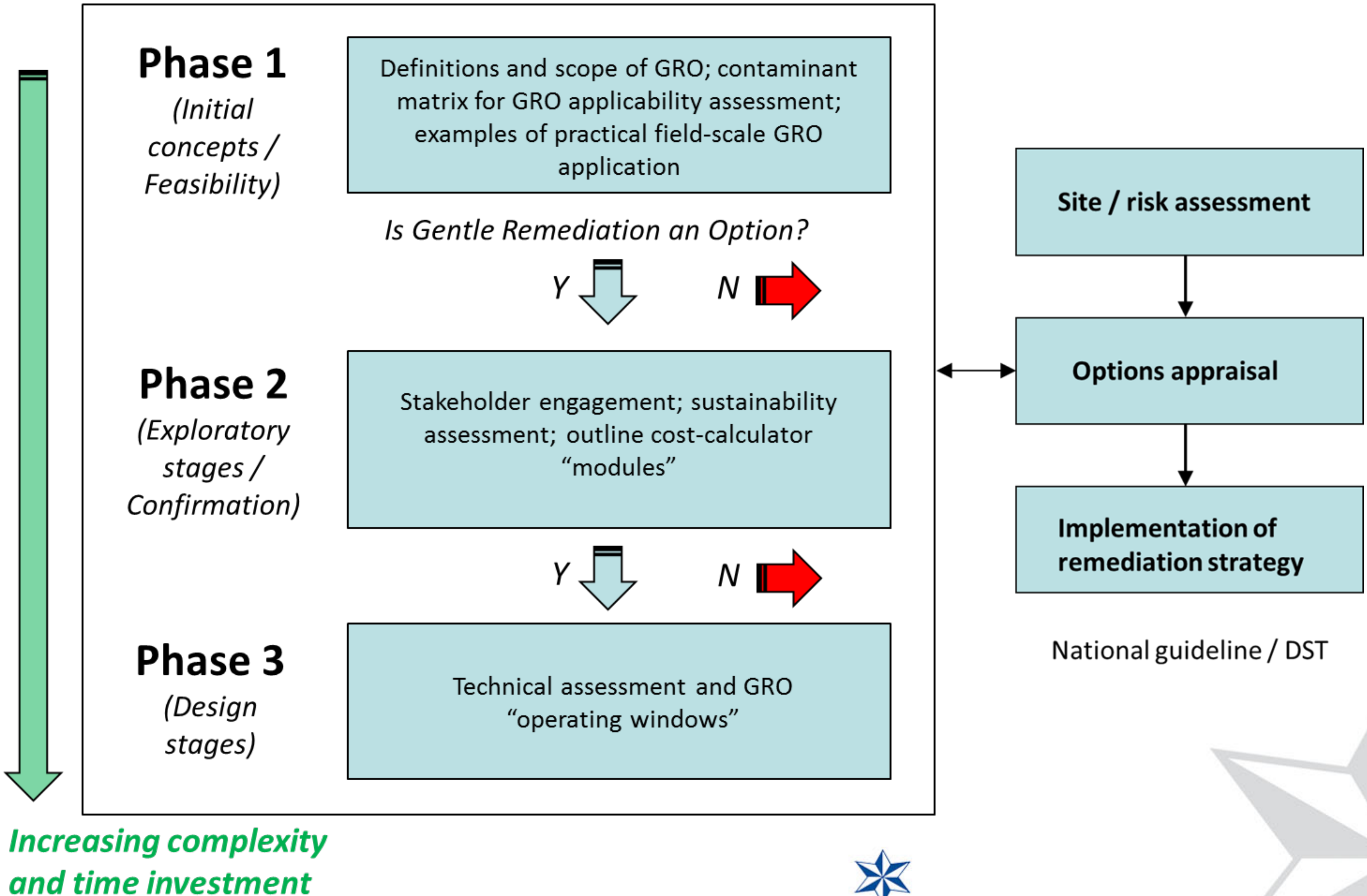
# GREENLAND decision support framework

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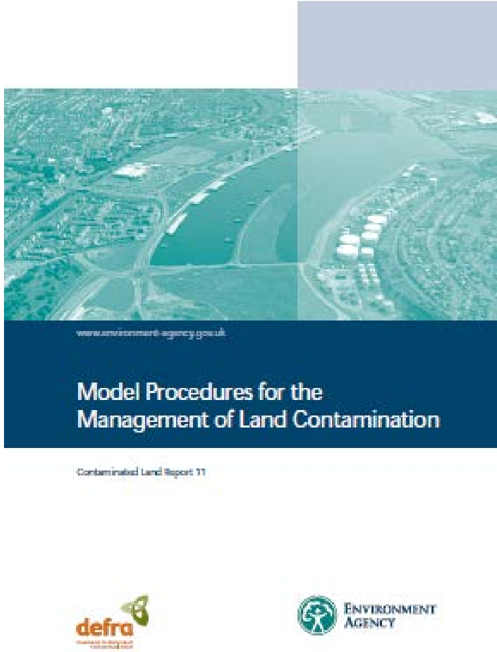
# Documenting the decision support framework

This simple tiered framework has been provided in an *MS Excel* format, and tested using Lommel (BE) and Biogeco (FR) GREENLAND sites, plus Olympics redevelopment (London). Based on model developed in Onwubuya et al (2009)

Format is compatible with CLR11, but portability to other countries also assessed (Germany and Sweden initially).

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Developing decision support tools for the selection of “gentle” remediation approaches

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# Additional tools supporting Phase 1 (Feasibility)

**Definitions**

Scope and risk management capability (High Level Operating Windows)

Practical examples

Contaminant matrix

| GRO | Definition |
|---|---|
| Phytoextraction | The removal of metals or organics from soils by accumulating them in the biomass of plants. When aided by use of soil amendments, this is termed aided phytoextraction. |
| Phytodegradation / phytotransformation | The use of plants (and associated microorganisms such as root-zone bacteria) to uptake, store and degrade organic pollutants. |
| Rhizodegradation | The use of plant roots and associated root-zone microorganisms to degrade organic pollutants. |
| Rhizofiltration | The removal of pollutants from aqueous sources by plant roots and associated microorganisms. |
| Phytostabilisation | Reduction in the bioavailability of pollutants by immobilizing or binding them to the soil matrix and / or living or dead biomass in the soil. When aided by use of soil amendments, this is termed aided phytostabilisation. |
| Phytovolatilisation | Use of plants to take pollutants from the growth matrix, transform them and release them into the atmosphere. |
| *In situ* immobilisation / phytoexclusion | Reduction in the bioavailability of pollutants by immobilizing or binding them to the soil matrix through the incorporation into the soil of organic or inorganic compounds, singly or in combination. Phytoexclusion, the implementation of a stable vegetation cover using plants which do not extract contaminants can be combined with *in situ* immobilisation. |

# Additional tools supporting Phase 1 (Feasibility)

Definitions

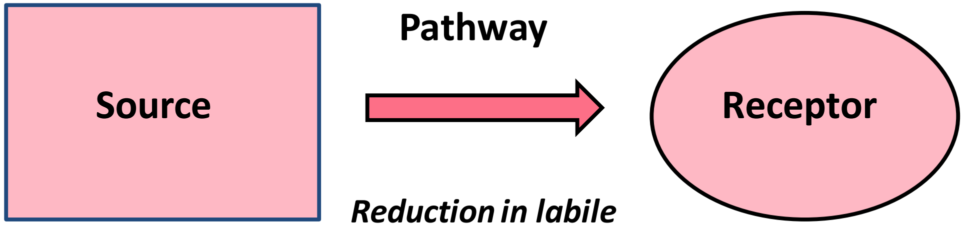
**Scope and risk management capability (High Level Operating Windows)**

Practical examples

Contaminant matrix

| Key questions: |
|---|
| |
| Does the site require immediate redevelopment (< 1 year) |
| Are your local regulatory guidelines based on total soil concentration values? |
| Is the site under hard-standing, or has buildings under active use? |
| Do you require biological functionality of the soil after site treatment? |
| Is the treatment area large, and contaminants are present but not at strongly elevated level |
| Is the economic case for intervention and use of "hard" remediation strategies marginal? |
| Are you redeveloping the site for soft end-use (biomass generation, urban parkland etc)? |

**Considers wider GRO-based <u>risk management</u> strategy, tailored along contaminant linkage model.**




***Gradual removal or immobilisation of source term***

***Reduction in labile pool, rapid reduction in flux of contaminants to receptors at significant risk***

***Using vegetation to manage receptor access to the subsurface***

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# Additional tools supporting Phase 1 (Feasibility)

Definitions

Scope and risk management capability (High Level Operating Windows)

**Practical examples**

Contaminant matrix

| Site name | Biogeco | GRO type | (Aided)phytostabilization |
|---|---|---|---|
| Location | Saint-Médard d'Eyrans, France | Origin of soil contamination | wood washings (start: 1846 – partly closed:) |
| Site type | wood preservation site | Implementation of field trial | start: 2006 – end: |
| Current land use | brownfield, storage of building materials | Duration (actual or expected) | actual:9 years |
| End land use | phytomanaged area | Surface area | 10 ha (2 fenced plots,150 m² for each) |

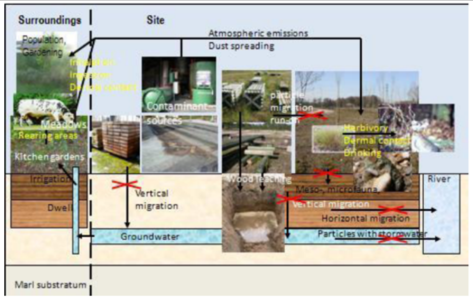
| Soil characteristics | Initial values | Labile pool* untreated | best treatment | Soil pore water$ untreated | Soil pore water Best treatment |
|---|---|---|---|---|---|
| pH | 7.1 | | | 7.16±0.12 | 7.32±0.11 |
| Sand, silt, clay (%) | 85.8 - 8.3 - 5.9 | | | mg C $L^{-1}$ | mg C $L^{-1}$ |
| Organic C (%) | 0.93 | | | 29.4±8.8 a | 40.9±4.7 a |
| CEC | 3.5 | µg $L^{-1}$ (R) | µg $L^{-1}$ (R) | µg $L^{-1}$ | µg $L^{-1}$ |
| As (mg/kg) | 9.8 | nd | nd | 1.8 ± 0.5a | 2.6 ± 0.3b |
| Cd (mg/kg) | 0.12 | nd | nd | nd | nd |
| Cr (mg/kg | 23 | nd | nd | 0.4 ± 0.1a | 0.25 ± 0.15a |
| Cu (mg/kg) | **674** | 285±10 (0.54)a | 141±10 (0.22)b | 519 ± 6a | 665 ± 10b |
| Pb (mg/kg) | 27 | nd | nd | nd | nd |
| Zn (mg/kg) | 46 | 5 ± 1 (0.10)a | 4 ± 1 (0.15)a | 29 ± 3 a | 22 ± 4 ab |

Biogeco

*diffusion in gel thin $ after 6 years; $: Rhizon moister sampler, after 6 years

| Core stakeholder | Function | Remark | Main site operators |
|---|---|---|---|
| Lyonnet SA | Site owner and tenant | | |
| UMR BIOGECO INRA 1202 | Site operator | | |
| Dr M Mench et al | Scientists | Scientific driven | |
| ADEME, Aquitaine Regional Council, EU FP7 Greenland | Funding organization | | |
| Greenland partners | Scientific collaborations | | |
| University of Orléans and Bordeaux | Scientific collaborations | M. Motelica; Ph. Le Coustumer | |

**Conceptual model and relevant contaminant linkages**




*Representing long-term in situ stabilization /phytoexclusion trials (Arnoldstein, AT); phytoextraction (Bettwiesen, SW); aided phytostabilisation (Bordeaux, FR)*

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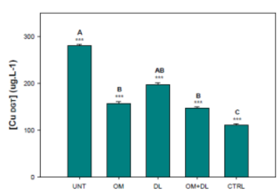
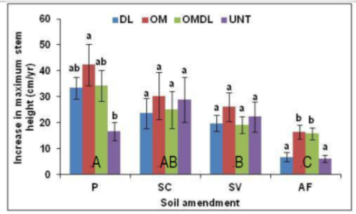
# Additional tools supporting Phase 1 (Feasibility)

Definitions
Scope and risk management capability (High Level Operating Windows)
**Practical examples**
Contaminant matrix

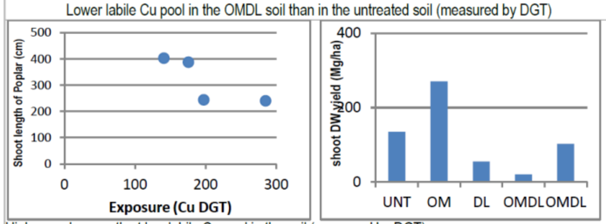
| Remediation success | Description |
|---|---|
| Reduction of labile metal (Cu) pools in the soil | Potential resupply of the soil pore water (DGT) reduced by 49 % |
| Plant and animal communities | Common Cu concentration in poplar and willow leaves; grass shoot Cu decreased from 35 to 18 mg/kg DW; colonization by insects and earthworms |
| Microbe activities | Biotox: inhibition alleviated; increased in soil enzyme activities |
| Reduced Cu migration to groundwater | More Cu bound to soil organic matter |



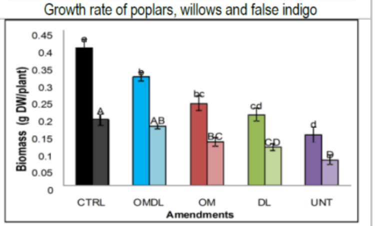
Lower labile Cu pool in the OMDL soil than in the untreated soil (measured by DGT)



Growth rate of poplars, willows and false indigo



Higher poplar growth at low labile Cu pool in the soil (measured by DGT)

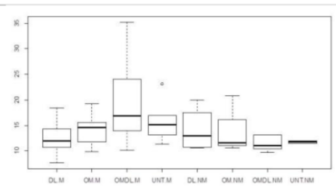


Shoot (dark) and leaf (clear) DW yields of 15-day-old bean grown on the soils after 7 years

Soil treatments: Unt untreated; OM compost; DL: dolomitic limestone; OMDL: compost + DL; CTRL: uncontaminated soil, AF: Amorpha fruticosa, P: Populus nigra, SC: Salix caprea, SV: Salix viminalis

**Key progresses with time**




Foliar Cu concentration in mycorrhizal (M) and non-mycorrhizal (NM) poplars are similar to common values

*Representing long-term in situ stabilization /phytoexclusion trials (Arnoldstein, AT); phytoextraction (Bettwiesen, SW); aided phytostabilisation (Bordeaux, FR)*

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# Additional tools supporting Phase 1 (Feasibility)

Definitions
Scope and risk management capability (High Level Operating Windows)
Practical examples
**Contaminant matrix**

Highlights when research / trials have shown effectiveness at (a) pot/greenhouse and (b) field scale

| Contaminant \ GRO | Phytoextraction | Phytostabilisation (including aided phytostabilisation) | In situ immobilisation / phytoexclusion |
|---|---|---|---|
| Arsenic | ✓ | ✓ | ✓ |
| Barium | ✗ | ✗ | ✗ |
| Cadmium | ✓ | ✓ | ✓ |
| Chromium | ✓ | ✓ | ✗ |
| Copper | ✓ | ✓ | ✓ |
| Lead | ✓ | ✓ | ✓ |
| Mercury | ✓ | ✓ | ✗ |
| Nickel | ✓ | ✓ | ✗ |
| Selenium | ✓ | ✓ | ✗ |
| Zinc | ✓ | ✓ | ✗ |

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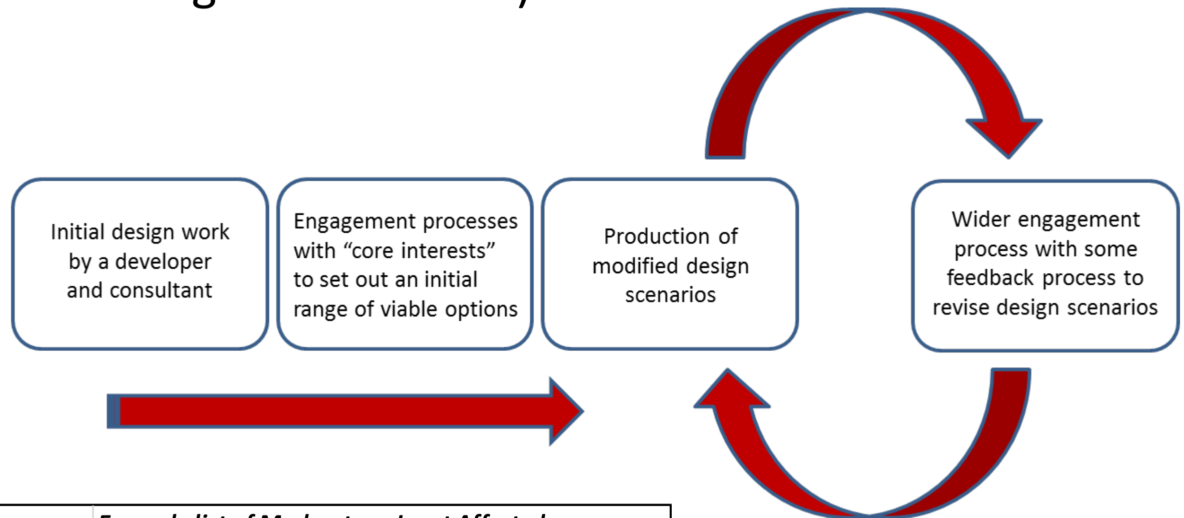
# Additional tools supporting Phase 2 (Exploratory stages / Confirmation)

Includes modules on:
Stakeholder engagement (models for engagement, principles of stakeholder engagement and GRO, criteria for the identification of different stakeholders categories / profiles, and list of e.g. stakeholders)




| *Example list of Most Affected or Affecting ("Core") stakeholders* | *Example list of Moderate or Least Affected or Affecting ("Non-Core") stakeholders* |
|---|---|
| | Local community |
| Developer (i.e. the individual or organisation seeking to develop the land area for alternative use) | Investors |
| Site Owner (i.e. the legal owner of the site) | Insurers |
| Regulator (i.e. the local, regional or national body responsible for.....) | Campaigning groups |
| Planner (......) | Future site users |
| Service provider (i.e. the contractor or consultant providing the remediation or regeneration service) | Local and regional press |
| Current and future site users (e.g. biomass producers) | Conservation bodies |
| Local authorities as owner, financer, regulator | Biomass / bioproduct users |
| | Recreational users |
| | Scientific community |

From: Cundy A.B., R.P.Bardos, A.Church, M.Puschenreiter, W.Friesl-Hanl, I.Mueller, S.Neu, M.Mench, N.Witters and J.Vangronsveld, 2013. Developing principles of sustainability and stakeholder engagement for "gentle" remediation approaches: the European context. *Journal of Environmental Management*, **129**, 283-291.

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# Additional tools supporting Phase 2 (Exploratory stages / Confirmation)

Includes modules on:
Sustainability assessment (economic, environmental and social benefits, linking to the HOMBRE BOM, and links to SURF-UK indicator sets)

HOMBRE

**SERVICE**

Examples……

**INTERVENTION**

Examples

| | |
|---|---|
| | Intervention **strongly contributes** to delivery of this service |
| | Intervention **contributes some and/ or indirect benefits** in delivering this service |
| | Intervention **may contribute or be detrimental** to delivery of service depending on site specific circumstances including management/design |
| | **No influence** - ***potential to apply complimentary intervention with further services and added value as output*** |
| | Intervention **may be detrimental to** delivery of this service if not managed/designed appropriately |
| ! | In the event a brownfield site/part of a brownfield site is classified by a regulator as contaminated - appropriate risk mitigation must form part of the redevelopment strategy for the borwnfield site |
| ^ | Negative influence/s could be negated with appropriate management/design |

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# Additional tools supporting Phase 2 (Exploratory stages / Confirmation)

## Sustainability assessment module (Onwubuya 2013)

| Sustainability Elements | Source Parameters | Information Sources | Key Decisions |
|---|---|---|---|
| Environment | **Procedure 1**<br>Use SURF framework and retrieve headline indicators | Procedure 1.<br>SURF-UK: indicator descriptions | **Procedure 1**<br>In order to establish and consider possible impacts that a remediation option (s) may have on the environment, a semi-quantitative assessment approach can be utilised in form of a Multi Criteria Analysis (MCA). Sustainability indicators (as detailed in the SURF indicator) should be identified using the information source (weblink) provided. The indicators to be considered can then be ranked in form of greater or lesser importance (e.g. 3 - High /2-Medium/1-Low weighting), and then scored (out of 5). A ranking order can then be established accordingly to show most suitable to least suitable technology.<br>**Procedure 2**<br>This step can be considered in tandem with Procedure 1 or afterwards if additional information is deemed necessary. A more complicated LCA quantitative assessment can be carried out. An LCA inventory should be collated using any of the applicable sources outlined in the web address provided and full life cycle analysis carried out. This, however, is a resource hungry process and requires huge time investment .<br><br>**Following the review of the indicators, all applicable indicators should be considered during DST selection.** |
| | **Procedure 2**<br>Outline various parameters that may be considered in a typical LCA procedure. Information will be retrieved from source which will be highlighted in the 'information sources' column.<br>Utilises EPA sponsored website LCAccess which provides abundance information regarding Life cycle inventory data sources. The primary focus of this source is on LCI databases and LCI data providers.<br>Follow link provided in the 'information sources column. | Procedure 2<br>http://www.epa.gov/nrmrl/std/lca/lca.html | |

Similar produced for Economic and Social indicators – utilises SuRF sustainability indicators (semi-quantitative ranking system, Procedure 1) followed by web-links to more resource-hungry quantitative analysis (LCA etc for "Environment" and "Economic" indicators) as needed

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# Additional tools supporting Phase 2 (Exploratory stages / Confirmation)

Includes modules on:

Outline cost calculator (user-entered cost data – allows estimation of economic value proposition of GRO). Module “calibrated” using data from GREENLAND sites  - use to test the cost calculator and give input examples

| General Site Information | | |
|---|---|---|
| **Name of site** | | |
| **Country** | | |
| **Site type** | | |
| **Site coordinates** | | |
| **Distance to crop supplier** | | km |
| **Distance to biomass processor** | | km |
| **Size of site** | | m² |
| | 0 | ha |
| **Depth of contamination** | | m |
| **Density soil** | | ton/m³ |
| **Total weight per ha** | 0 | ton |
| | | |
| **Discount rate** | 4 | % |

| General contamination information | | |
|---|---|---|
| Extraction (0) or stabilisation (1)? | 1 | |
| **Define metal(s):** | | |
| **Concentration in soil** | 1 | |
| **Concentration in solution** | | |
| **Start:** | | |
| Start concentration | | mg/kg soil |
| Contamination in soil | 0 | kg/ha |
| | | |
| stabilisation for how long? | 15 | years |

| General Plant Information | | |
|---|---|---|
| **Plant used** | | |
| | | |
| **Rotation speed of crop** | 1 | year |
| | | |
| **Remediated surface/plant** | | m²/plant |
| | 0 | ha/plant |
| | | |
| **Kg of dry mass per harvest per ha** | | Kg DM/ha |
| **Of which ...% is in** | | |
| Plant part 1 | plant part 1 | |
| *% of total biomass plant part 1* | 100 | |
| Plant part 2 | plant part 2 | |
| *% of total biomass plant part 2* | | |
| Plant part 3 | plant part 3 | |
| *% of total biomass plant part 3* | | |
| Plant part 4 | plant part 4 | |
| *% of total biomass plant part 4* | | |
| Plant part 5 | plant part 5 | |
| *% of total biomass plant part 5* | | |
| | | |
| **Extraction in mg/kg DM per harvest per part, only for extraction** | | |
| plant part 1 | | mg/kg DM |
| plant part 2 | | mg/kg DM |
| plant part 3 | | mg/kg DM |
| plant part 4 | | mg/kg DM |
| plant part 5 | | mg/kg DM |

# Additional tools supporting Phase 2 (Exploratory stages / Confirmation)

Includes modules on:

Outline cost calculator (user-entered cost data – allows estimation of economic value proposition of GRO). Module “calibrated” using data from GREENLAND sites - use to test the cost calculator and give input examples

**Inc:**

**Preparation costs;**

**Plant and planting costs;**

**Site costs;**

**Biomass costs and revenues;**

**Monitoring costs**

**etc.**

| General Site Information | | |
|---|---|---|
| Name of site | | |
| Country | | |
| Site type | | |
| Site coordinates | | |
| Distance to crop supplier | | km |
| Distance to biomass processor | | km |
| Size of site | | |
| | 0 | ha |
| Depth of contamination | | m |
| Density soil | | ton/m³ |
| Total weight per ha | 0 | ton |
| | | |
| Discount rate | 4 | % |

| General contamination information | | |
|---|---|---|
| Extraction (0) or stabilisation (1)? | 1 | |
| Define metal(s): | | |
| Concentration in soil | 1 | |
| Concentration in solution | | |
| Start: | | |
| Start concentration | | mg/kg soil |
| Contamination in soil | 0 | kg/ha |
| | | |
| stabilisation for how long? | 15 | years |

| General Plant Information | | |
|---|---|---|
| Plant used | | |
| | | |
| Rotation speed of crop | 1 | year |
| | | |
| Remediated surface/plant | | m²/plant |
| | 0 | ha/plant |
| | | |
| Kg of dry mass per harvest per ha | | Kg DM/ha |
| Of which x% is in | | |
| Plant part 1 | plant part 1 | |
| *% of total biomass plant part 1* | 100 | |
| Plant part 2 | plant part 2 | |
| *% of total biomass plant part 2* | | |
| Plant part 3 | plant part 3 | |
| *% of total biomass plant part 3* | | |
| Plant part 4 | plant part 4 | |
| *% of total biomass plant part 4* | | |
| Plant part 5 | plant part 5 | |
| *% of total biomass plant part 5* | | |
| | | |
| Extraction in mg/kg DM per harvest per part, only for extraction | | |
| plant part 1 | | mg/kg DM |
| plant part 2 | | mg/kg DM |
| plant part 3 | | mg/kg DM |
| plant part 4 | | mg/kg DM |
| plant part 5 | | mg/kg DM |

# Additional tools supporting Phase 3 (Design Stages)

Detailed operating windows *(optimal temperature, precipitation, pH, depth of contamination etc)*

Technical datasets *(cultivars and amendments, safe biomass use, indicators of success and methods, stakeholder engagement guidance)* and design / implementation guidance

**Appendix 6: Stakeholder engagement guidelines for application of "gentle" remediation approaches (GROs).**

**Introduction**

***Definitions and key concepts***

**Stakeholder engagement is a broad inclusive and continuous process between a project and those potentially affected by it.** The World Bank (2012) describes the aims of stakeholder engagement as building up and maintaining an open and constructive relationship with stakeholders and thereby facilitating a project's management of its operations, including its environmental and social effects and risks. Effective stakeholder engagement is also seen as reducing key remediation project risks, for example failure to gain acceptance and delays due to antagonistic relationships; and also as means of reducing project management costs and timescale (RESCUE 2005; REVIT 2007).

***Need for stakeholder engagement when applying GRO.***

Stakeholder involvement has been identified as a key requirement for the optimal application of sustainable remediation strategies (CL:AIRE, 2011), and in site regeneration more widely (REVIT, 2007; RESCUE, 2005). Effective and sustained stakeholder engagement is critical to the acceptance of GROs, particularly for larger

## Aim is to produce practical, usable tool to interface with existing DSTs (e.g. HOMBRE) and national guidance.......

Aims to communicate the potential wider benefits and risk management capabilities of GRO, supported by information on large-scale examples of successful GRO application, presented in a robust and non-technical way

This is an area where demonstrator sites (e.g. the Greenland case studies and others) can make a significant contribution to decision support via providing evidence on the effectiveness of GRO under varying site contexts and conditions – “windows of opportunity”

DST will be validated by the GREENLAND project advisory board (representing key regulators) and contaminated land consultants in workshop events, finalisation date December 2014

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