Metals in European soils & Phytomanagement – a sustainable remediation approach

Eleni G. Papazoglou[1], Berien Elbersen[2]

[1]Agricultural University of Athens, Greece

[2]Wageningen University, The Netherlands

Midas

MARGINAL LANDS, INDUSTRIAL CROPS
AND INNOVATIVE BIO-BASED VALUE CHAINS

Funded by the European Union

This project has received funding from the European Union's Horizon Europe Research and Innovation Programme under Grant Agreement No. 101082070.

SOIL POLLUTION

Soil pollution is defined as the presence of a chemical or substance in the soil that is either misplaced or present in concentrations exceeding natural levels, causing adverse effects on non-target organisms. More than 10 million major sites worldwide are polluted.

EC-JRC & EIONET (EEA) performed a survey with National Reference Centres in 39 European countries:

- Approx. 2.5 million potentially contaminated sites.
- 37.3 % of those sites are contaminated by metals and metalloids (metal(loid)s).

Still **there is no EU wide spatially specific data on polluted sites and their status of pollution & cleaning.**

GOLD project*: Made an approach to map polluted sites and to estimate the area potentially suitable for biomass production with phytoremediation.

Payá Pérez & Rodriguez Eugenio (2018) and LSI003 indicator EEA 'Progress in management of contaminated sites'

*https://www.gold-h2020.eu/

POINT SOUCE POLLUTION – area estimates GOLD

Midas

Area (ha)	Type of potentially polluted sites				
Country	**Military**	**Industrial & brownfields**	**Quarries**	**Landfills**	**Total area**
Austria	17.551	4.157	8.423	927	31.058
Belgium	13.777	11.208	4.948	739	30.672
Bulgaria	9.973	17.400	30.418	2.462	60.253
Croatia	10.217	3.679	2.352	708	16.956
Czech Republic	42.335	14.581	21.100	2.504	80.520
Denmark	21.218	9.711	4.306	181	35.416
Estonia	8.538	3.733	7.523	3.163	22.957
Finland	48.932	13.971	14.586	3.844	81.333
France	126.163	78.260	55.948	10.164	270.535
Germany	118.826	65.857	84.051	18.652	287.386
Greece	15.373	5.904	25.319	2.325	48.921
Hungary	14.785	31.178	9.151	2.311	57.425
Ireland	2.253	4.924	8.605	821	16.603
Italia	36.462	43.963	37.393	5.967	123.785
Latvia	5.720	4.973	3.287	180	14.160
Lithuania	5.207	12.962	5.281	146	23.596
Luxembourg	21	355	197	201	774
Malta	10	55	280		345
Netherlands	11.026	19.076	810	783	31.695
Poland	56.571	44.248	36.234	11.003	148.056
Portugal	9.299	9.873	9.976	1.094	30.242
Romania	16.755	80.607	22.453	5.401	125.216
Slovakia	14.641	12.640	3.543	1.302	32.126
Slovenia	1.177	737	863	61	2.838
Spain	90.160	43.326	49.973	4.588	188.047
Sweden	39.404	17.848	10.261	2.051	69.564
United Kingdom	97.519	36.874	42.057	6.793	183.243
Total area	**833.913**	**592.100**	**499.338**	**88.371**	**2.013.722**

Point source pollution comes from any single identifiable source.

In Europe, Largest areas (OSM) as potential polluted sites are military (41%), industrial and brownfields (29%), quarries (25%) and landfills (4%).

The total area of potentially polluted sites with land cover types suitable for phytoremediation, and with less than 40% of the area sealed (impervious), is 2,013,722 ha in the EU27 and UK (0.5% of the total surface area of these countries).

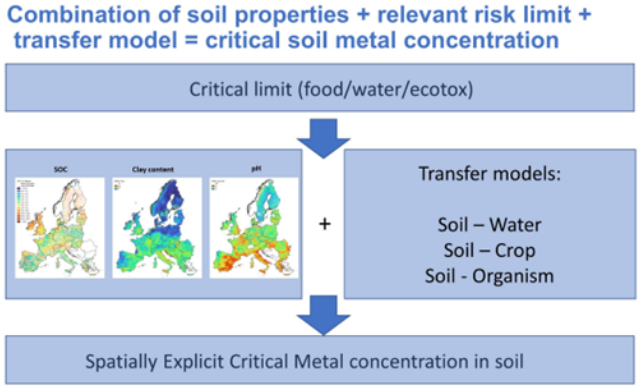
France, Germany, Spain and UK have the largest total areas of all types of potentially polluted sites (> 150,000 ha each).

DIFFUSE POLLUTION – area estimates GOLD

Diffuse pollution refers to pollution that originates from widespread and dispersed activities rather than a single, identifiable source, e.g. acid rain, application of pesticides, urban run-off, etc.

Complexity of diffuse pollution:

1) There is no discrete source.
2) At EU level: no harmonized approach to detect risks. Soil screening values (SSVs) vary widely in EU
3) Diffuse pollution is a slow process leading to steady build-up of pollutants. Typically, pollution levels are moderate and most SSVs used across the EU are not targeting such pollution levels.



Modelled diffuse pollution to assess whether the soil concentration (Cd, Zn, Pb, Cu) exceeds critical limits for food quality, ecosystem health and drinking water quality.

Critical concentrations of metals in soil are **highly variable** and depend on:

1) **soil properties** (pH, soil organic carbon, soil texture, etc), and
2) **the intended end point,** such as ensuring food safety, protecting ecosystem health, or maintaining drinking water quality.

Midas

Waste disposal

Mining & smelting

Industrial activities

SOURCES OF METAL(LOID)s IN SOIL

Agrochemicals

Fossil fuel combustion

Irrigation with contaminated water

IMPACTS OF SOIL POLLUTION

Midas

Metal(loid)s are:

- Non-degradable over time.
- Toxic to humans and animals, often ca
  disease
- Disrupti
  process
  stunted
  yields.
- Disrupti
  commun
  biochem
- Leading
  ecosyst
  resulting in the loss of e
  services.

Polluted land cannot be used for food or feed production but can be utilized for non-food industrial crops, freeing up valuable agricultural land and supporting economic growth

Polluted soil

Polluted water

an diseases

Unsafe food

REMEDIATION TECHNIQUES FOR METAL(LOID)s POLLUTED SOIL

Midas

REMEDIATION TECHNIQUES

PHYSICAL

- Excavation and disposal
- Soil replacement
- Soil isolation
- Thermal treatment
- Electrokinetics

CHEMICAL

- Virtification
- Soil washing
- Solidification/stabilization

BIOLOGICAL

Bioremediation

Critical limitation

Metals cannot be biodegraded by microorganisms and be removed from soil

Phytoremediation

✓ promising phytotechnology

Physicochemical methods of soil remediation are usually **expensive** and often result in a **deterioration** of the soil ecosystem.

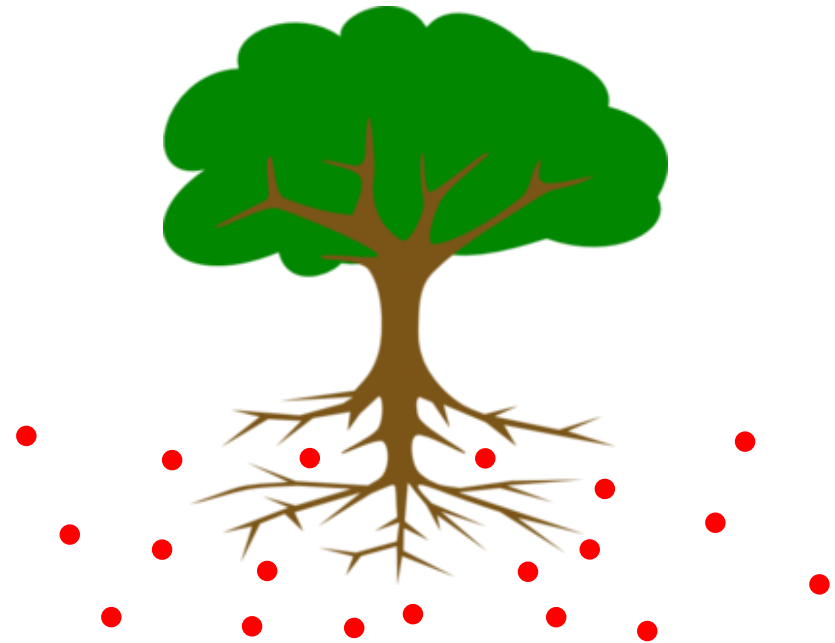
PHYTOREMEDIATION

Midas

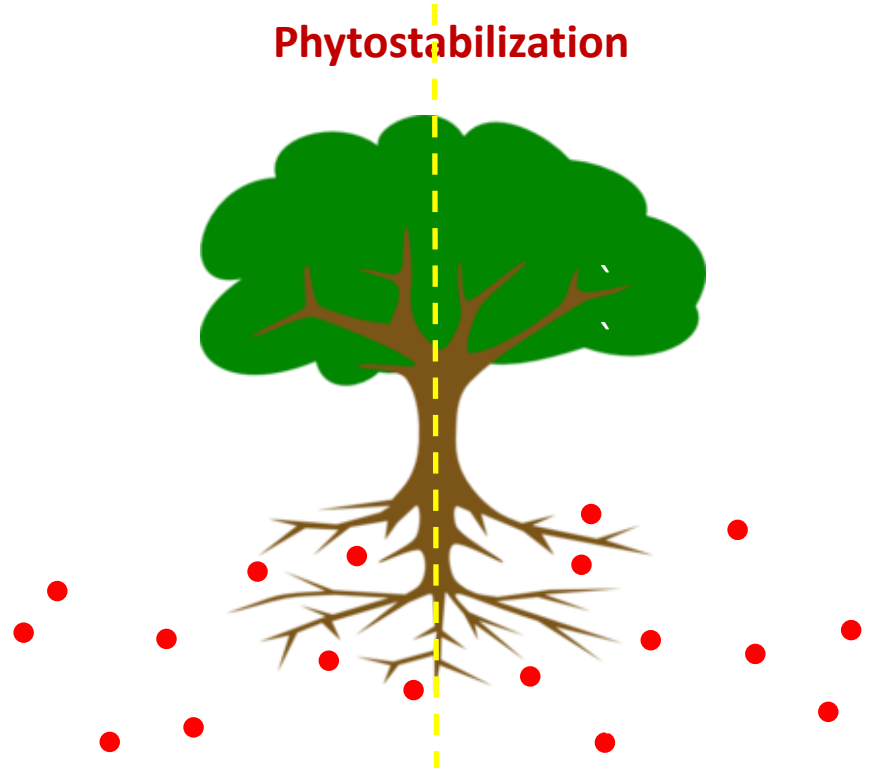
Phytoremediation is a set of phytotechnologies that uses green plants to remove contaminants from the environment or to render them harmless.

Main strategies for metal phytoremediation

Phytoextraction



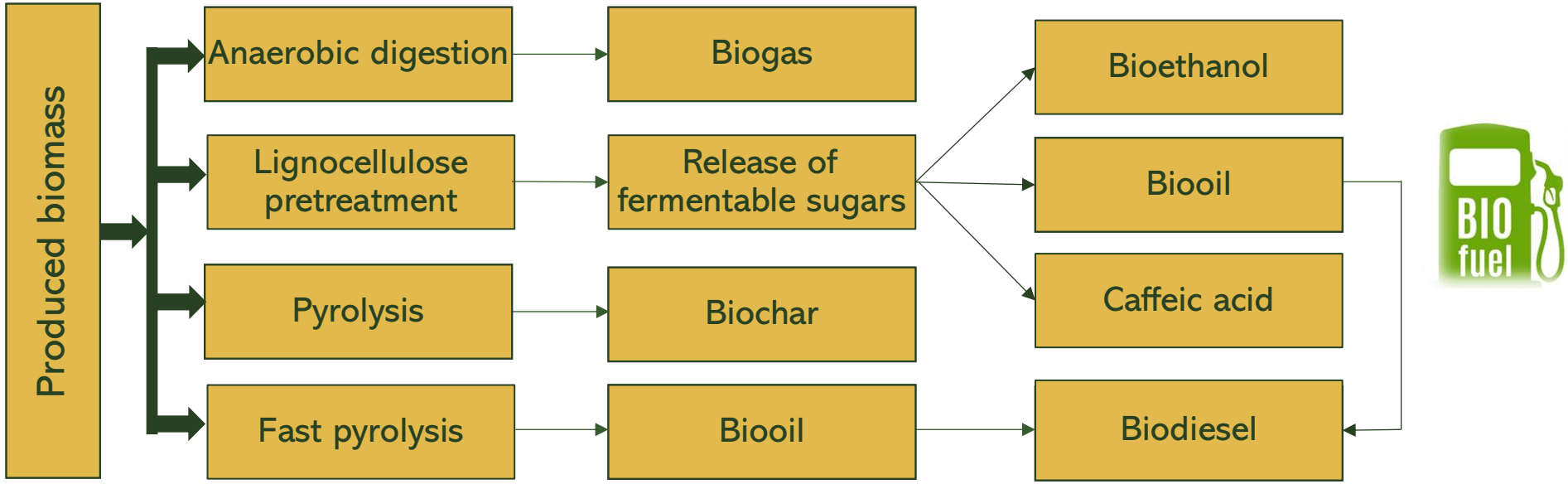
Phytostabilization



PHYTOMANAGEMENT

Phytomanagement is to pair phytoremediation with sustainable and profitable site management options, using plant species that will produce marketable biomass and thus the landowners /land managers / stakeholders will have an economic revenue.

PHYTOMANAGEMENT WITH ENERGY CROPS

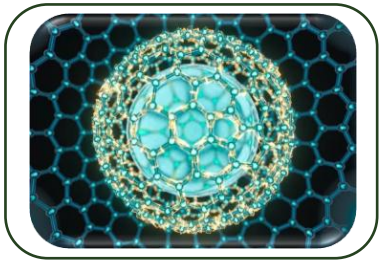


OTHER POTENTIAL INDUSTRIAL USES OF BIOMASS PRODUCED ON POLLUTED SITES

Midas

Thin films

Biochemicals



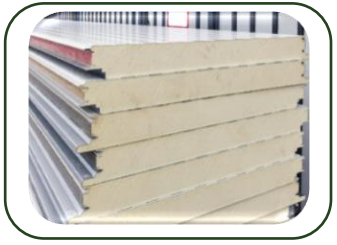
Biopolymers

Pulp & paper

Construction materials

Bioplastics

Biofabrics



Insulation panels

DESIRED CHARACTERISTICS OF CROPS SUITABLE FOR PHYTOMANAGEMENT

Midas

- Tolerant to soil pollutants
- Accumulate pollutants in the aerial biomass (phytoextraction)
- Stabilize the pollutants in soil fractions (phytostabilisation)
- High yielding, fast growing, with widespread and large root system
- Low production cost (low inputs for water, fertilizers, etc.) and easy harvest ability
- Non consumable by humans and animals
- Able to be cultivated in polluted land with satisfactory yields, giving satisfactory net profit

BIOMASS CROPS WITH POTENTIAL IN PHYTOMANAGEMENT

Midas

Annual herbaceous crops

Industrial hemp (*Cannabis sativa* L.)

Cd
Cu
Pb
Zn
Cr
Ni
Hg

Kenaf *(Hibiscus cannabinus* L.)

Cd
Cu
Cr
Hg

Flax *(Linum usitatissimatum* L.)

Cd
Ni
Pb
Sb

Sorghum *(Sorghum bicolor* L.)

Cd
Zn
Pb
Ni
As
Sb

Perennial herbaceous crops

Midas

Miscanthus (*Miscanthus x giganteus*)

Zn
Pb
Cd
As
Cr
Ni
Cu

Giant reed (*Arundo donax* L.)

Cd
Ni
Pb
As
Cr
Zn

Switchgrass (*Panicum virgatum* L.)

Cd
Zn
Pb
Cr

Cardoon (*Cynara cardunculus* L.)

Cd
As
Ni

Woody species

Midas

Willow (*Salix spp.*)

Cd
Zn
Pb
Ni
Cu

Poplar (*Populous spp.*)

Cd
Zn

Black locust (*Robinia pseudoacacia* L.)

Cd
Pb
Hg
As
Ni
Cu

Eucalyptus (*Eucalyptus spp.*)

Cd
Hg
Pb

LIMITATIONS OF PHYTOMANAGEMENT

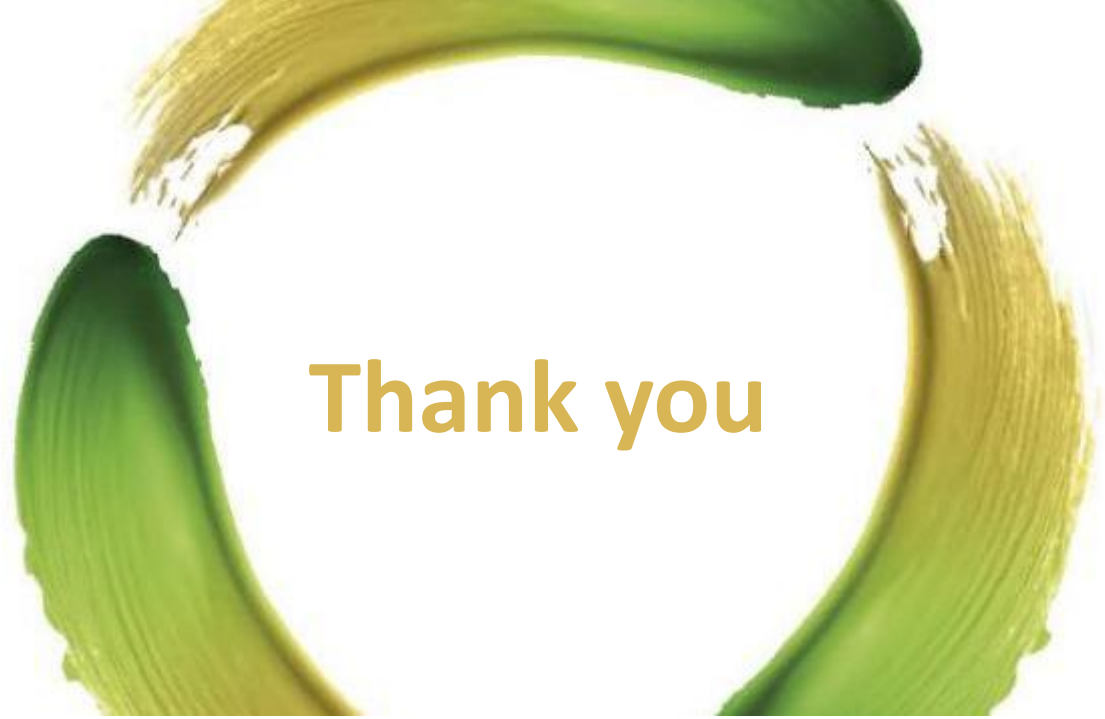
Midas

- Slow growth rate of metal accumulating plant species
- Low bioavailability of heavy metals in soil
- Remediation is limited to the depth of the rhizosphere
- Extremely slow technique
- Large areas of land are often required to produce sufficient plant biomass for effective remediation
- High concentrations of pollutants can be toxic to plants, causing stunted growth, reduced biomass, or plant death
- While phytomanagement can reduce pollutant concentrations, it does not always completely eliminate pollutants, leaving residual pollution behind.

Nevertheless, even if the crops used do not bioaccumulate heavy metals and metalloids in their biomass for soil pollution mitigation, phytomanagement can still serve to stabilize pollution by preventing the spread of pollutants to the air and reducing leaching into water sources.

Midas

MARGINAL LANDS, INDUSTRIAL CROPS
AND INNOVATIVE BIO-BASED VALUE CHAINS



Thank you

midas-bioeconomy.eu

midas-project

@MIDAS_EUProject

MIDAS Project

info@midas-bioeconomy.eu

Funded by the European Union

*This project has received funding from the European Union's Horizon Europe Research and Innovation Programme under Grant Agreement No. **101082070**. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or REA. Neither the European Union nor the granting authority can be held responsible for them.*