PRACTICAL APPLICATIONS OF PHYTOTECHNOLOGIES AT CONTAMINATED SITES

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INTRODUCTION TO PHYTOTECHNOLOGIES

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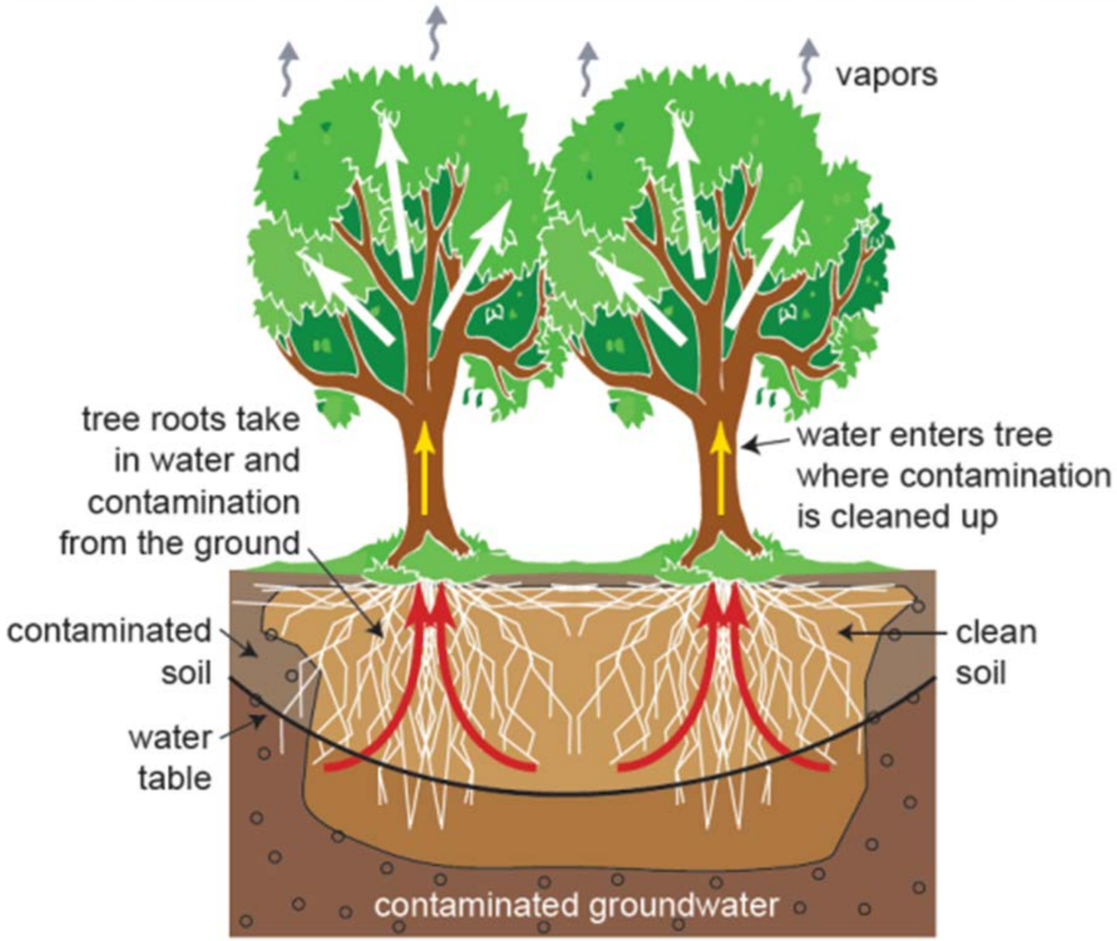
PHYTOTECHNOLOGIES



TYPES OF PHYTOREMEDIATION

Mechanism	Description	Cleanup Goal
Phytodegradation	Ability of plants to take up and break down contaminants within plant tissues through internal enzymatic activity	Remediation by destruction
Phytoextraction	Ability of plants to take up contaminants into the plant and sequester the contaminant within the plant tissue	Remediation by removal of plants containing the contaminant
Phytohydraulics	Ability of plants to take up and transpire water	Containment by control- ling hydrology
Phytosequestration	Ability of plants to sequester certain contaminants into the rhizosphere through release of phytochemicals, and sequester contaminants on/ into the plant roots and stems through transport proteins and cellular processes	Containment
Phytostablization	Ability of plant to reduce the mobility of typically a contaminated media, soil or wetland sediment.	Remediation by decreasing receptor exposure
Phytovolatilization	Ability of plants to take up, translocate, and subsequently volatilize contaminants in the transpiration stream	Remediation by removal through plants
Rhizodegradation	Ability of released phytochemicals to enhance microbial biodegrada- tion of contaminants in the rhizosphere	Remediation by destruction

SOIL AMENDMENTS

- Soil amendments are materials added to soils in order to improve soil quality and establish plant growth.
- Commonly used soil amendments include:
  - municipal biosolids, such as water treatment residuals
  - animal manures and litters
  - sugar beet lime
  - wood ash

RESOURCES

CLU-IN Phytotechnologies Focus Area

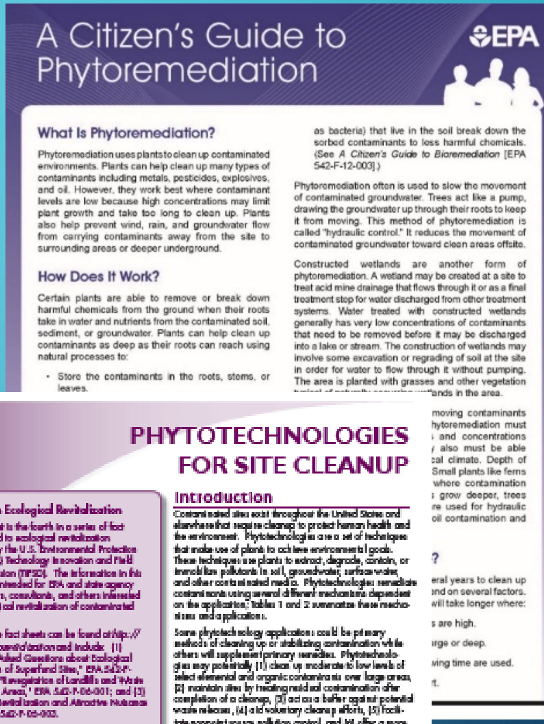
https://clu-in.org/techfocus/default.focus/sec/Phytotechnologies/cat/Overview/

CLU-IN Ecotools Focus Area

https://clu-in.org/ecotools/

Guidance on Soil Bioavailability at Superfund Sites

https://www.epa.gov/superfund/soil-bioavailability-superfund-sites-guidance



A Citizen's Guide to Phytoremediation

EPA

What Is Phytoremediation?

Phytoremediation uses plants to clean up contaminated environments. Plants can help clean up many types of contaminants including metals, pesticides, explosives, and oil. However, they work best where contaminant levels are low because high concentrations may limit plant growth and take too long to clean up. Plants also help prevent wind, rain, and groundwater flow from carrying contaminants away from the site to surrounding areas or deeper underground.

How Does It Work?

Certain plants are able to remove or break down harmful chemicals from the ground when their roots take in water and nutrients from the contaminated soil, sediment, or groundwater. Plants can help clean up contaminants as deep as their roots can reach using natural processes to:

- Store the contaminants in the roots, stems, or leaves.

as bacteria) that live in the soil break down the sorbed contaminants to less harmful chemicals. (See *A Citizen's Guide to Bioremediation* [EPA 542-F-12-003].)

Phytoremediation often is used to slow the movement of contaminated groundwater. Trees act like a pump, drawing the groundwater up through their roots to keep it from moving. This method of phytoremediation is called "hydraulic control." It reduces the movement of contaminated groundwater toward clean areas offsite.

Constructed wetlands are another form of phytoremediation. A wetland may be created at a site to treat acid mine drainage that flows through it or as a final treatment step for water discharged from other treatment systems. Water treated with constructed wetlands generally has very low concentrations of contaminants that need to be removed before it may be discharged into a lake or stream. The construction of wetlands may involve some excavation or regrading of soil at the site in order for water to flow through it without pumping. The area is planted with grasses and other vegetation ...ands in the area.

...moving contaminants ...hytoremediation must ... and concentrations ... also must be able ...cal climate. Depth of ... Small plants like ferns ... where contamination ... grow deeper, trees ...re used for hydraulic ... oil contamination and

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...eral years to clean up ...end on several factors. ...will take longer where:

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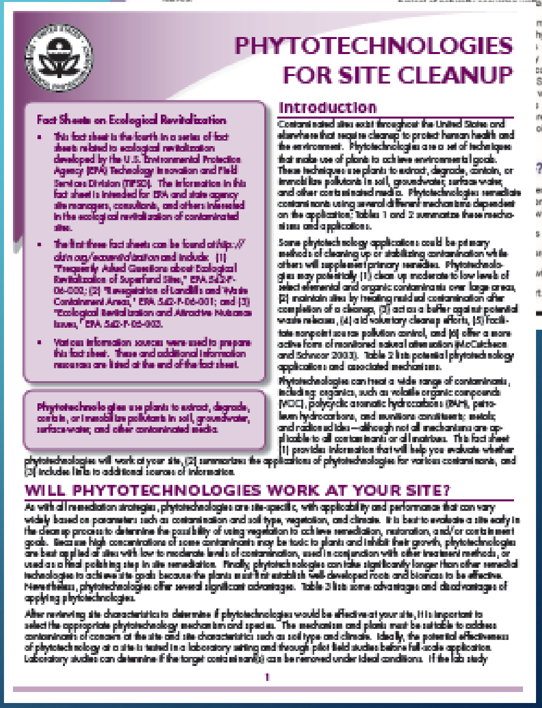


PHYTOTECHNOLOGIES FOR SITE CLEANUP

Fact Sheets on Ecological Revitalization

Introduction

Phytotechnologies use plants to extract, degrade, contain, or immobilize pollutants in soil, groundwater, surface water, and other contaminated media.

WILL PHYTOTECHNOLOGIES WORK AT YOUR SITE?

1

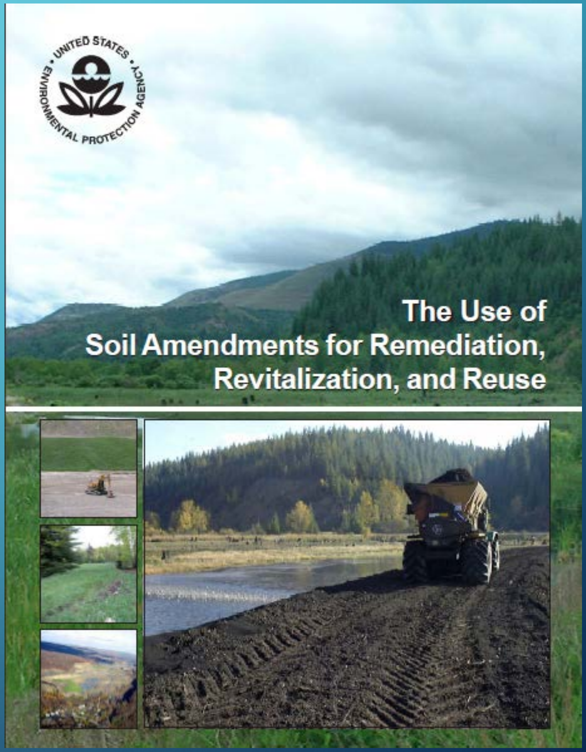
SOIL AMENDMENT RESOURCES

CLU-IN Ecotools Focus Area - Soil

clu-in.org/products/ecorestoration/soil.cfm

The Use of Soil Amendments for Remediation, Revitalization, and Reuse

www.clu-in.org/download/remed/epa-542-r-07-013.pdf



PRACTICAL APPLICATIONS OF PHYTOTECHNOLOGIES AT CONTAMINATED SITES

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PRESENTATION OVERVIEW

- Overview of Phytotechnologies
- Phytotechnology Case Studies
- Application Considerations

OVERVIEW OF PHYTOTECHNOLOGIES

- Phytodegradation
- Phytoextraction
- Phytohydraulics
- Phytosequestration
- Phytostabilization
- Phytovolatilization
- Rhizodegradation

Explicit use of terms is important to make sure what people are saying…hearing…and thinking are in fact the same.

OVERVIEW OF PHYTOTECHNOLOGIES

- **Phytodegradation**

This is the use of plants to actual degrade (maybe transform) the contaminant… so not applicable to elements.

OVERVIEW OF PHYTOTECHNOLOGIES

- **Phytoextraction**

This is extraction from the soil or groundwater…may be accumulated by the plant or releases from the plant unchanged. Applicable to metals/elements as well as organic contaminants; hyperaccumulators, but not necessarily.

OVERVIEW OF PHYTOTECHNOLOGIES

- **Phytohydraulics**

This is the use of plants to influence groundwater. It does not refer to any treatment, only the alteration of a contaminant plume or decrease the water contact with waste – evapotranspiration cap.

OVERVIEW OF PHYTOTECHNOLOGIES

- **Phytosequestration**

This refers to the use of plants to reduce the mobility of contaminants. This could involve chemical reactions or binding.

OVERVIEW OF PHYTOTECHNOLOGIES

- **Phytostabilization**

This refers to the use of plants to reduce the mobility of typically a contaminated media, soil or wetland sediment. This is typically a physical process which results in decreases in receptor exposure to contaminants, which is a specific goal.

OVERVIEW OF PHYTOTECHNOLOGIES

- **Phytovolatilization**

This is the use of plants to be effectively a biological air stripper, move the contaminants from subsurface contaminated media.

OVERVIEW OF PHYTOTECHNOLOGIES

- **Rhizodegradation**

This is the use of plants to create a zone of contaminant degradation around the plant root system. The plant root ecosystem is referred to as the "rhizosphere"; there is a relationship between the plant and the microbial community within the rhizosphere, the degradation may occur by the plant, the microbes, or both.

OVERVIEW OF PHYTOTECHNOLOGIES

- Phytodegradation
- Phytoextraction
- Phytohydraulics
- Phytosequestration
- Phytostabilization
- Phytovolatilization
- Rhizodegradation

Obviously some of the have overlap and multiple processes may be occurring and desired to occur at the same time. This is a reason why the terminology needs to be correct and explicit to avoid confusion with stakeholders.

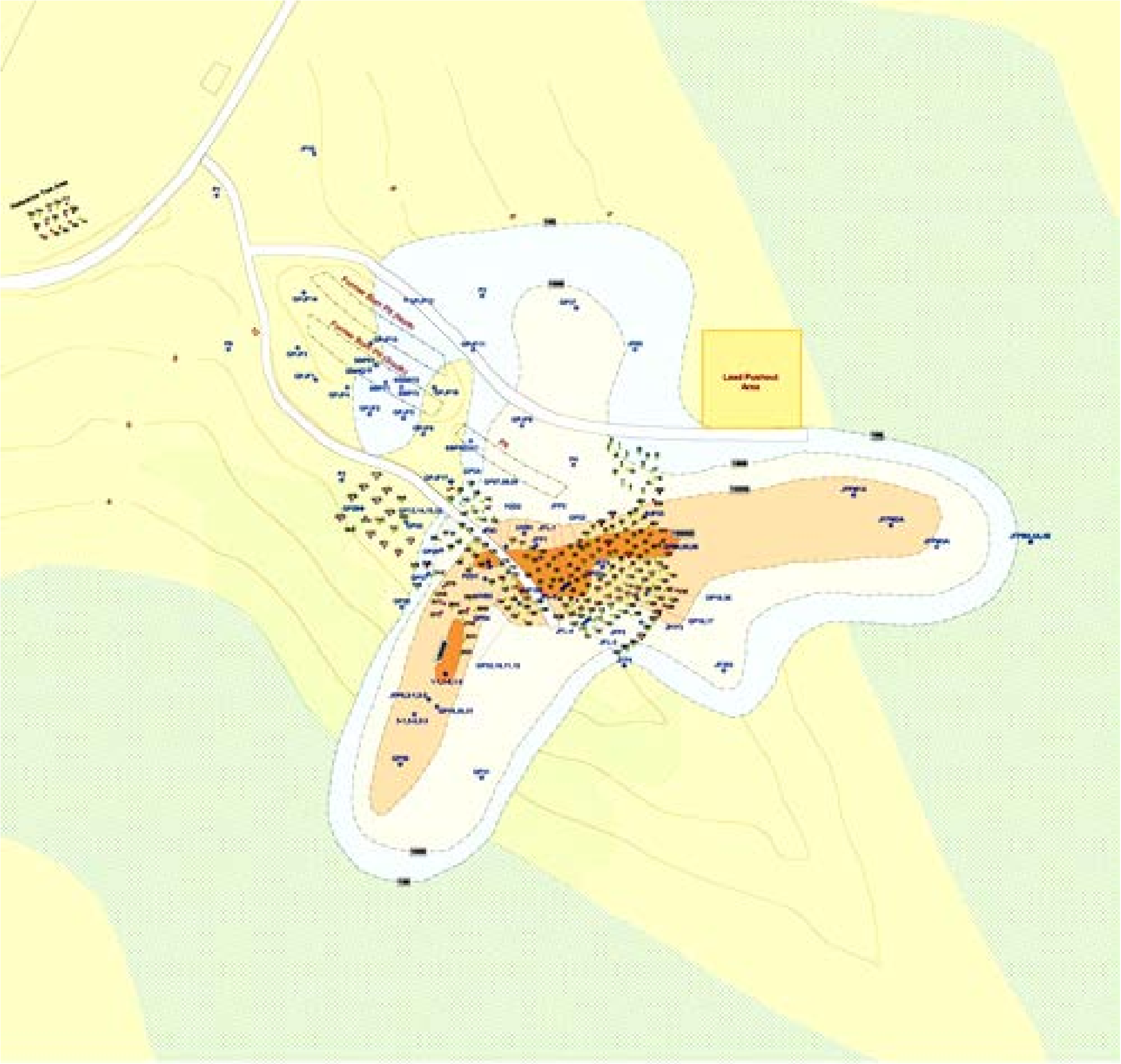
CASE STUDIES

CASE STUDY – J-FIELD, ABERDEEN PROVING GROUND

CONTAMINANTS OF CONCERNS

	Groundwater (µg/L)
1,1,2,2-tetrachloroethane (1122)	390,000
trichloroethene (TCE)	93,000
cis-1,2-dichloroethene (c-DCE)	81,000
tetrachloroethene (PCE)	11,000
trans-1,2-dichloroethene (t-DCE)	29,000
1,1,2-trichloroethane (TCA)	7,100
vinyl chloride	150
ethene	509
ethene	27

TOTAL VOLATILE ORGANIC COMPOUNDS IN GROUNDWATER

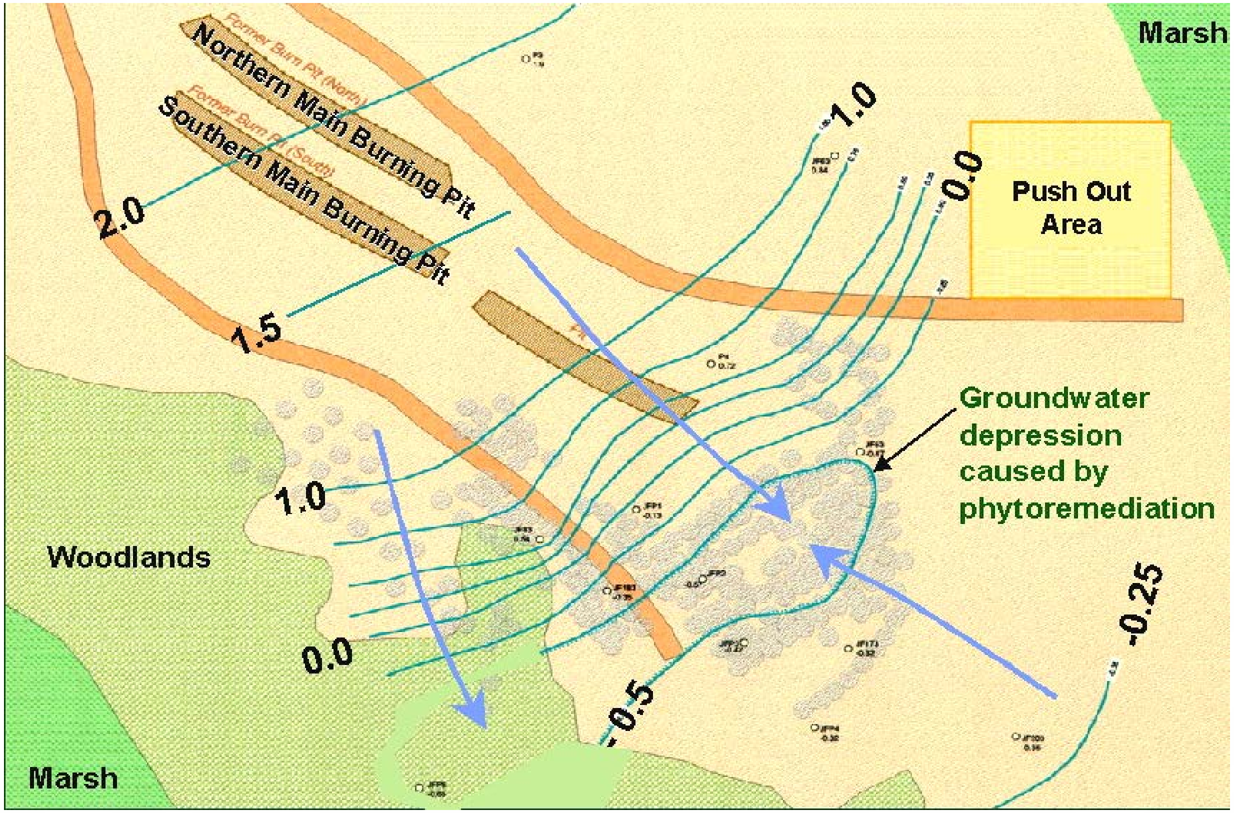


TECHNOLOGIES CONSIDERED

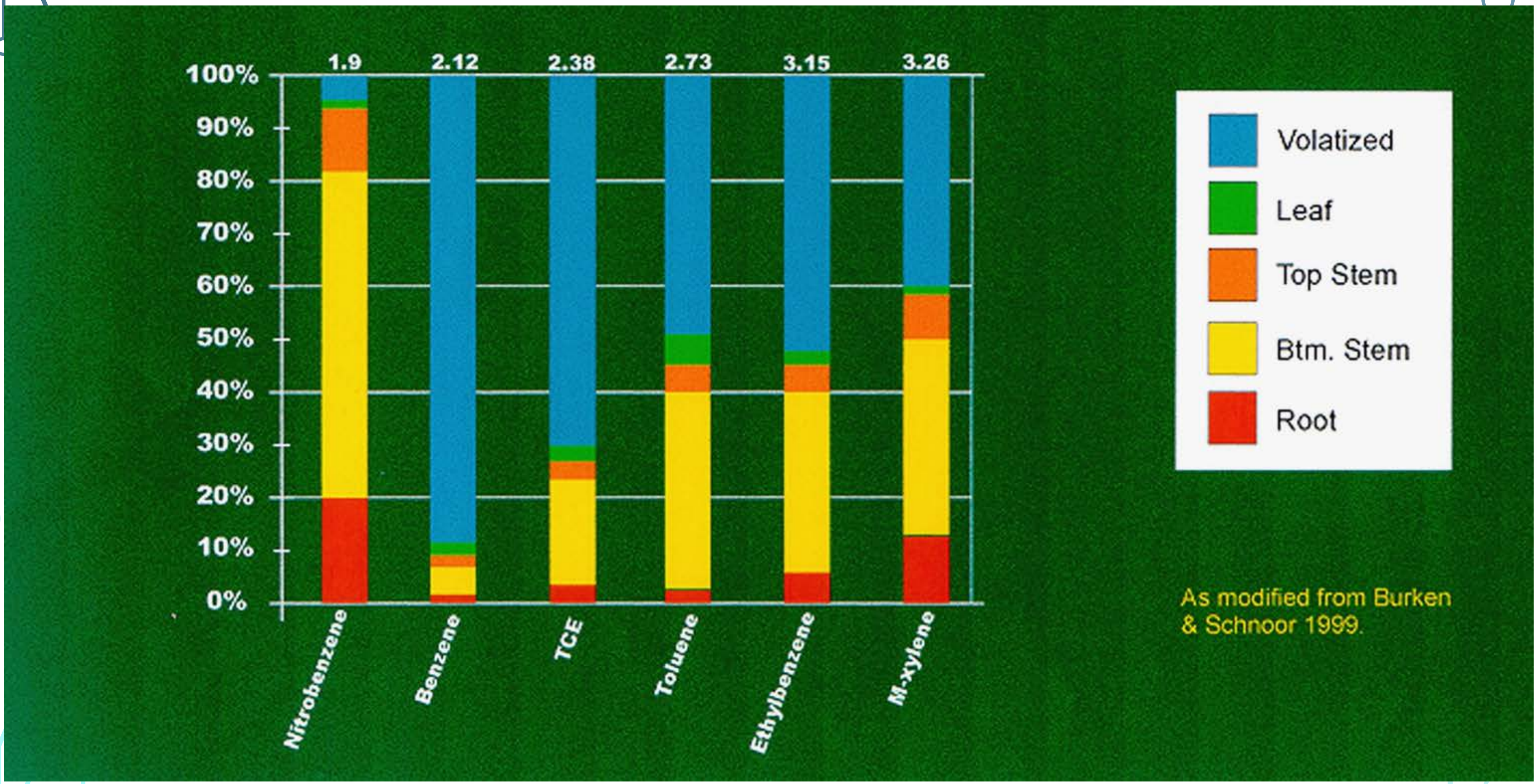
- Pump and treat
- Recirculating wells
- Hydrogen release compounds (HRD)
- Natural attenuation
- Phytoremediation

CASE STUDY – J-FIELD, ABERDEEN PROVING GROUND

CASE STUDY – J-FIELD, ABERDEEN PROVING GROUND



DISTRIBUTION AND VOLATILIZATION OF ORGANIC COMPOUNDS IN THE PLANT



CASE STUDY – J-FIELD, ABERDEEN PROVING GROUND

Phytotechnologies applied:

- Hydrolics
- Extraction
- Degradation
- Rhizoshere
- volitilization

CASE STUDY – J-FIELD, ABERDEEN PROVING GROUND

What made it work?

- Shallow aquifer contamination – but recognized they needed to force the trees to send the roots deep
- Contaminant levels were not so high as to adversely affect the trees
- Organic soluble degradable compounds and translocated through the tree (Koc)
- Plants selected have high water uptake/transpiration rate
- Made sure the hybrid poplars used had the "degradation system" turned on – the correct phenotype

CASE STUDY – CHINESE BRAKE FERN

CASE STUDY – CHINESE BRAKE FERN

Crozet, VA

- Area is wooded hillside, surface soil contamination of As from historical farming.
- Soil concentrations between 50.4 and 111 ppm goal of reducing soils to below 58 ppm.
- Limited acreage that was targeted for phytoremediation.

CASE STUDY – CHINESE BRAKE FERN

Crozet, VA phytoremediation notes

- Fern can extract 40-50 mg/kg from a 1 foot area.
- The Goal was to:
  - reduce soil As levels without major disruption of landscape
  - decrease truck traffic for disposal
- (estimates were 60 -70 trucks for soil removal 1 -2 trucks per year for plant disposal)
- you tube video available Crozet, VA phytoremediation project

CASE STUDY – CHINESE BRAKE FERN

Phytotechnologies applied:

- Extraction

CASE STUDY – CHINESE BRAKE FERN

Worked because:

- climate was conducive to the ferns growth;
- irrigation was readily available;
- contamination was surface soils;
- contamination levels were above acceptable risk range but not source level contamination; and
- landscape was not conducive to excavation

CASE STUDY – SHARON STEEL

- Sharon Steel Corporation Farrell Works Disposal Area Site is located in the Cities of Hermitage and Farrell, Mercer County, Pennsylvania. Wastes at this site included byproducts from steel manufacturing including basic oxygen furnace sludge and slag and pickle liquor.

CASE STUDY – SHARON STEEL

- The site covers about 330 acres, including 100 acres of wetlands

CASE STUDY - SHARON STEEL

- The Remedial Action selected in the ROD for OU1 includes: grading, consolidating, and capping steel slag and sludge with a biosolids-enhanced cap. In addition, the Shenango River bank will be stabilized, wetlands constructed, erosion controls installed, …

CASE STUDY - SHARON STEEL

Phytotechnologies applied:

- Stabilization
- (maybe sequestration)

CASE STUDY - SHARON STEEL

Why did it work?

- Alternative to approach is capping with soil and planting, land use remains the same;
- Physical movement of contaminated "soil" (wind and water erosion) largest exposure pathway.

APPLICATION CONSIDERATIONS

Phytodegradation

- Ability to tolerate concentrations of contaminants
- Ability to take up the contaminant
- Ability to "extract" the contaminant from soil matrix
- Ability to degrade the contaminant
- Plants are non-invasive species
- Plants are appropriate to local climate
- Plants are tolerant of adverse environmental conditions

APPLICATION CONSIDERATIONS

Phytoextraction

- Ability to tolerate concentrations of contaminants
- Ability to take up the contaminant (prefer that they can concentrate – hyperaccumulators)
- Ability to "extract" the contaminant from soil matrix (you need to understand what controls the contaminant availability to the plant – Pb example)
- Plants are non-invasive species
- Plants are appropriate to local climate
- Plants are tolerant of adverse environmental conditions

APPLICATION CONSIDERATIONS

Phytohydraulics

- Ability to tolerate concentrations of contaminants
- Plants have a high evapotranspiration rate
- Plants are non-invasive species
- Plants are appropriate to local climate
- Plants are tolerant of adverse environmental conditions
- Extensive root system and higher growth rate.
- Tolerance of adverse environmental conditions.

APPLICATION CONSIDERATIONS

Phytosequestration

- Ability to tolerate concentrations of contaminants
- Ability to take up the contaminant or capacity to release exudates to stimulate microorganism growth and/or required for contaminant transformation
- Plants are non-invasive species
- Plants are appropriate to local climate
- Plants are tolerant of adverse environmental conditions
- Extensive root system

APPLICATION CONSIDERATIONS

Phytostabilization

- Ability to tolerate concentrations of contaminants
- Plants are non-invasive species
- Plants are appropriate to local climate
- Plants are tolerant of adverse environmental conditions
- Extensive root system and higher growth rate.
- Tolerance of adverse environmental conditions.

APPLICATION CONSIDERATIONS

Phytovolatilization (applicable only to volatile contaminants)

- Ability to tolerate concentrations of contaminants
- Ability to take up the contaminant
- Ability to "extract" the contaminant from soil matrix
- Plants must be able to translocate the contaminant through the plant effectively
- Plants have a high evapotranspiration rate
- Plants are non-invasive species
- Plants are appropriate to local climate
- Plants are tolerant of adverse environmental conditions
- Extensive root system and higher growth rate.
- Tolerance of adverse environmental conditions.

APPLICATION CONSIDERATIONS

Rhizodegradation

- Ability to tolerate concentrations of contaminants
- Ability to release exudates to stimulate microorganism growth (and thereby microbial degradation) and/or which directly degrade the contaminant
- Extensive root system and higher growth rate
- Plants are non-invasive species
- Plants are appropriate to local climate
- Plants are tolerant of adverse environmental conditions
- Tolerance of adverse environmental conditions.

RESOURCES

CLU-IN Phytotechnologies Focus Area

https://clu-in.org/techfocus/default.focus/sec/Phytotechnologies/cat/Overview/

CLU-IN Ecotools Focus Area

https://clu-in.org/ecotools/

Guidance on Soil Bioavailability at Superfund Sites

https://www.epa.gov/superfund/soil-bioavailability-superfund-sites-guidance

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QUESTIONS?