PHYTOREMEDIATION – TYPES AND APPLICATIONS

What is Phytoremediation?

- **Phytoremediation** : The process of removing contamination from soil or water using plants.
- **phyto = plant**
- **remedium = restoring balance.**

Phytoremediation

Phytoremediation consists of mitigating pollutant concentrations in contaminated soils, water, or air, with plants able to contain, degrade, or eliminate metals, pesticides, solvents,explosives, crude oil and its derivatives, and various other contaminants from the media that contain them.

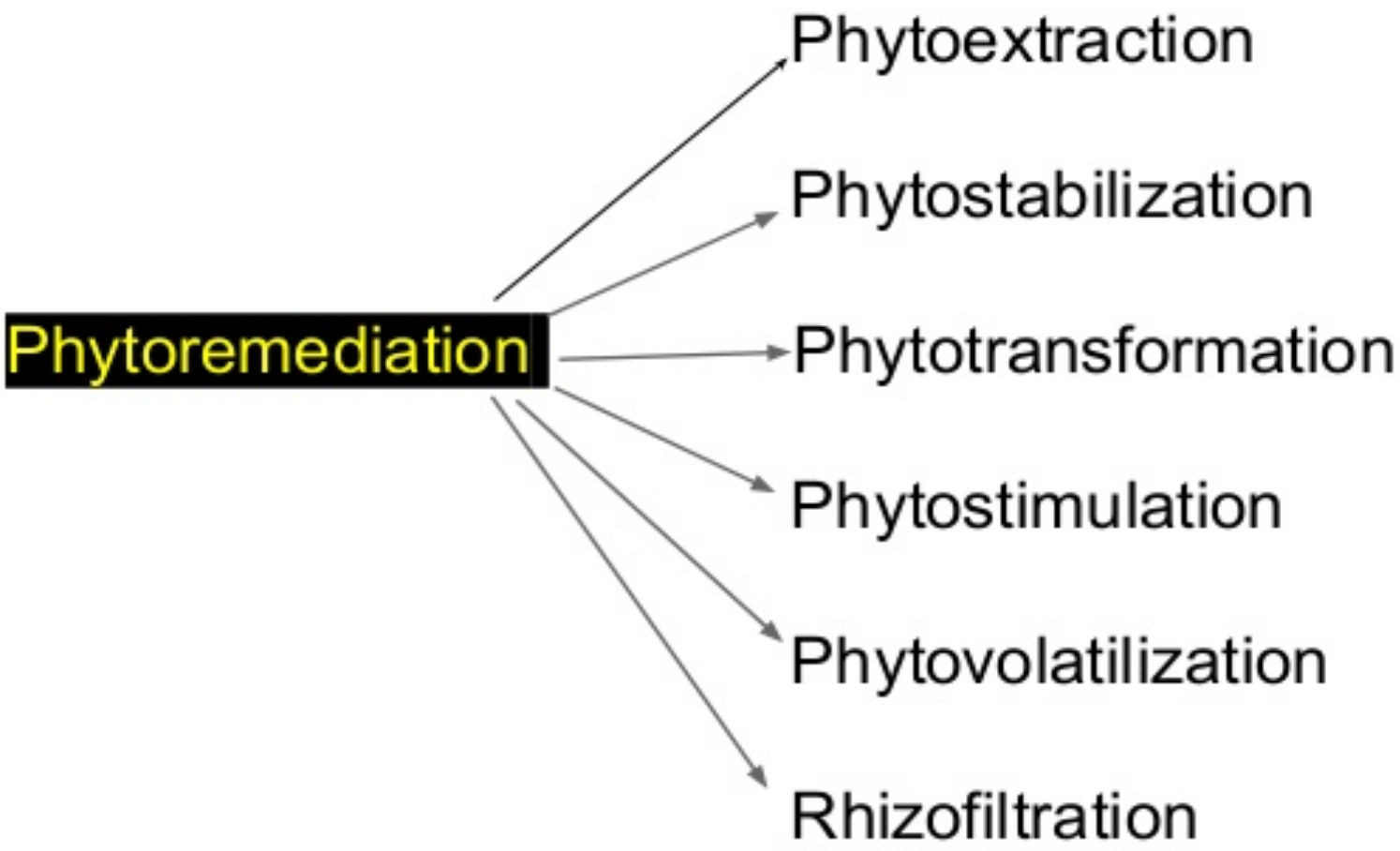
Advantages	Disadvantages
In situ and *ex situ*	Take several years to remediate a contaminated site
Amenable to a variety of organic and inorganic compounds	Limited to shallow groundwater, soils and sediments
Suited to remediation of large areas of soil	Not as effective for sites with high contaminant concentrations
Costs effective compared to conventional methods	Slower than conventional methods
Easy to implement and maintain & accepted by public	Toxicity and bioavailability of biodegradation products are not known
Fewer spread of contaminant via air and water	Contaminants may be mobilized into the ground water.
Conserves natural resources	Influenced by soil and climate conditions of the site. It does not work in the winter.
Environmentally friendly and aesthetically pleasing to the public	Disposal of contaminants accumulated in plants after harvesting - pollution again!

Mechanisms of Phytoremediation

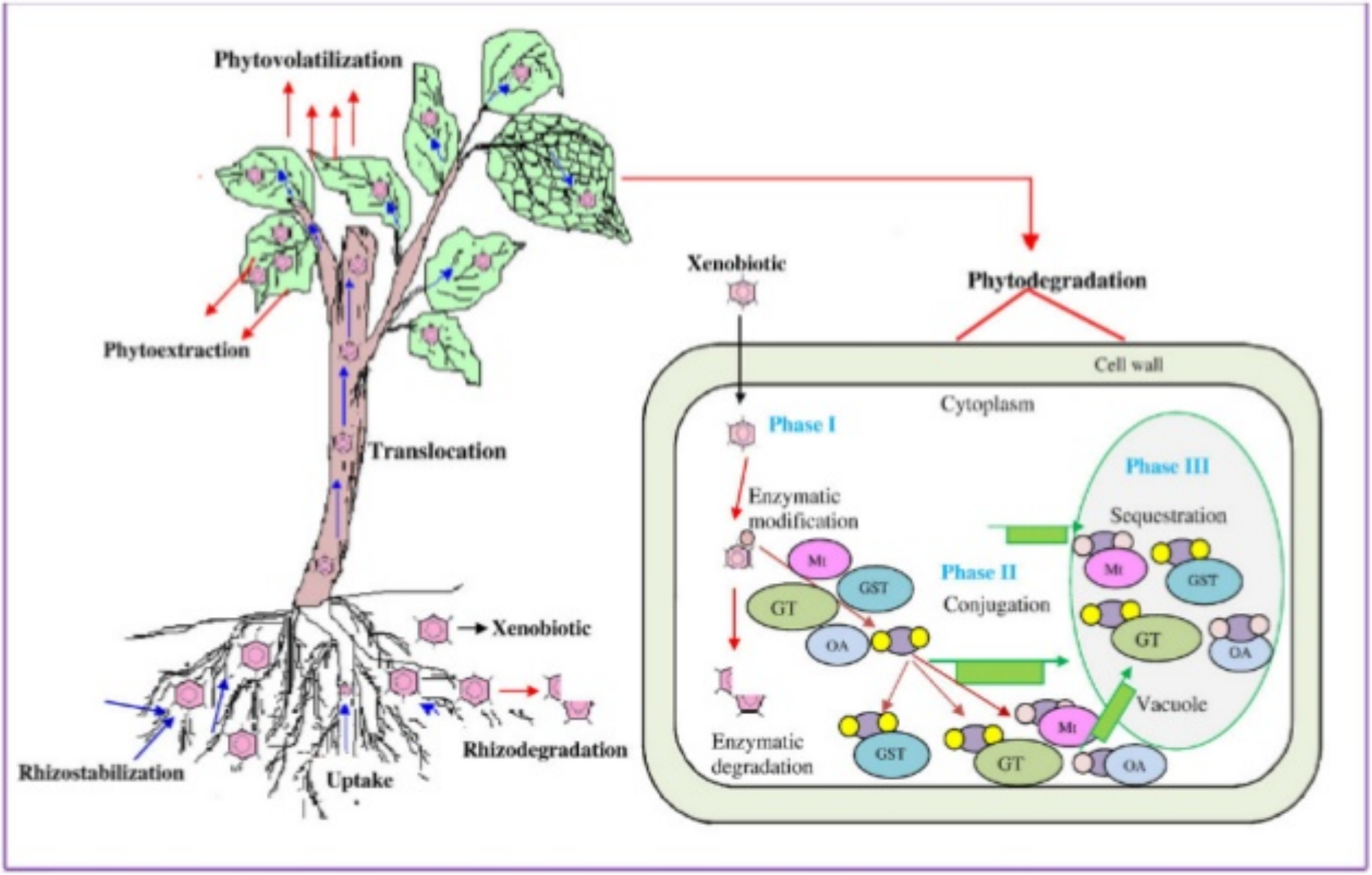
- Depend on the types of contaminant, bioavailability and soil properties.
- There are several ways by which plants clean up contaminated sites.
- Uptake of contaminants occurs primarily in root system

large SA that absorbs and accumulates water and nutrients essential for growth

Phytoremediation mechanisms



Overview


Phytovolatilization
Phytoextraction
Translocation
Xenobiotic
Rhizodegradation
Rhizostabilization
Uptake
Xenobiotic
Phytodegradation
Cell wall
Cytoplasm
Phase I
Enzymatic modification
Enzymatic degradation
Phase II
Conjugation
Phase III
Sequestration
Vacuole
Mt
GST
GT
OA

1. Phytoextraction

Advantages:

- Cost is fairly inexpensive compared to conventional methods.
- Contaminant permanently removed from soil.
- Amount of waste material that must be disposed of is decreased up to 95%
- In some cases, contaminant can be recycled.

Limitations:

• Metal bioavailability within the rhizosphere.

• Rate of metal uptake by roots.

• Proportion of metal “fixed” within the roots.

• Cellular tolerance to toxic metals.

2. Phytostabilization

Advantages:

- No disposal of hazardous material / biomass is required
- Very effective when rapid immobilization is needed to preserve ground and surface waters

Disadvantages:

- Contaminant remain in soil
- Application of extensive fertilisation / soil amendments
- Mandatory monitoring required

3. Phytotransformation

Advantage:

- Both economically and environmentally friendly

Disadvantages:

- Requires more than one growing season to be efficient
- Soil must be less than 3 ft in depth and groundwater within 10 ft of the surface
- Contaminants may still re-enter the food chain through animals or insects that eat plant material

4. Phytostimulation

Advantages:

- *in situ* practice resulting in no disturbance
- No removal of contaminated materials
- Complete mineralisation of the contaminant can occur
- Low installation and maintenance cost

Disadvantages:

- Development of extensive root zone required- takes time
- Root depth limited due to physical structure of soil
- Organic matter from plant may be used as a C source instead of contaminant -> decrease amount of contaminant biodegradation

5. Phytovolatilization

Advantage:

- The contaminant, mercuric ion, may be transformed into a less toxic substance (i.e., elemental Hg).

Disadvantage:

- The mercury released into the atmosphere is likely to be recycled by precipitation and then re-deposited back into lakes and oceans, repeating the production of methyl-mercury by anaerobic bacteria.

6. Rhizofiltration

Advantages:

- Ability to use both terrestrial and aquatic plants for either *in situ* and *ex situ* applications.
- Contaminants do not have to be translocated into shoots.

Disadvantages:

- Constant need to adjust pH.
- Plants may first need to be grown in greenhouse / nursery.
- There is periodic harvesting and plant disposal.
- Tank design should be well engineered.

How long does phytoremediation takes?

- The time depends on:

- Type and number of plants used
- Type and amount of harmful chemicals present
- Size and depth of polluted area
- Type of soil and conditions present

- Often, it takes many years to clean up a site with phytoremediation.

Types of plant used

- Plant species are selected for use based on factors such as:
  - ability to extract or degrade the contaminants of concern
  - adaptation to local climates
  - high biomass
  - depth root structure
  - compatibility with soils
  - growth rate
  - ease of planting and maintenance
  - ability to take up large quantities of water through the roots.

APPLICATIONS

Process & Mechanism of contaminant removal

Phytotechnology	Mechanism	Pollutants	Plants
Phytoextraction	Hyperaccumulation in harvestable parts of plants	Inorganic: Co, Cr, Ni, Pb, Zn, Au, Hg, Mo, Ag, Cd Radionuclides: Sr, Cs, Pb, U	*Brassica juncea, Thalspi caerulescens, Helianthus annus*
Rhizofilteration	Rhizosphere accumulation though sorption, concentration and precipitation	Organics/Inorganics: Metals like Cd, Cu, Ni, Zn,Cr Radionuclides	*Brassica juncea, Helianthus annus,* Tobacco, Rye, Spinach and Corn
Phytovolatilization	Volatilization by leaves through transpiration	Organics/Inorganics: Chlorinated solvents, inorganics (Se, Hg, As)	*Arabidopsis thaliana*, Poplars, Alfalfa, *Brassica juncea*
Phytodegradation	Pollutant eradication	Organic compounds, Chlorinated solvents, Phenols, Herbicides, Munitions	Hybrid poplars, Stonewort, Black willow, Algae
Phytostabilization	Complexation, sorption and precipitation	Inorganics: As, Cd, Cu, Cr, Pb, Zn, Hs	*Brassica juncea*, Hybrid poplars, Grasses

http://www.geoengineer.org/education/web-based-class-projects/geoenvironmental-remediation-technologies/phytoremediation?showall=1&limitstart=

Aquatic plants in Phytoremediation…

- ✓ Mainly heavy metal – *Eichhornia crassipes, Salvinia minima, Pistia sp. Lemna minor*
- ✓ TNT, RDX – *Elodea michx, Ceratophyllum sp., Sagittaria latifolia*
- ✓ Radionuclides (Cs 137, Co 60) – *Potamogeton sp., Typha*
- ✓ Selenium (phytovolatilisation) – *Sesuvium portulacastrum*
- ✓ Petroleum Hydrocarbon, Pb, Zn, Cd - *Rhizophora mangle, Avicennia etc…*

phytotechnology

phytoremediation has been recently supplanted by the term "phytotechnologies", used to indicate all applications in which plants are used to manage and control pollutants, even without removing or destroying it.

PROS...

- Amendable to a broad range of organic and inorganic contaminants including many metals with limited alternative options.
- Cost effective and ecologically friendly in which plant utilizes its natural abilities to restore environment
- Reduces the amount of waste to be landfilled (up to 95%), can be further
- utilized as bio-ore of heavy metals.
- Does not require expensive equipment or highly specialized personnel
- Alternative or complimentary to mechanical congenital cleaning methodologies which mostly require high capital input, labor and intensive energy.
- Easy to maintain and accepted by public
- Fewer spread of contaminant via air and water

CONS...

- Compared to engineering methods... too slow or only seasonally effective.
- hyper accumulators are shallow root system, slow growth, small biomass production – limited to shallow sediment, soil and waterbody
- Regulatory agencies often require significant progress in remediation to be made in only a few years, making most phytoremediation applications unsuitable.
- For some pollutants such as TCE, the concentration of the pollutant is not reduced sufficiently to meet regulatory requirements.
- the pollutants can be at phytotoxic concentrations or recalcitrant - plants are not effective
- Disposal of contaminants harvested in the plant biomass- again pollution
- wildlife and people may consume the plants - IAS