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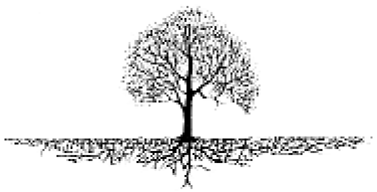
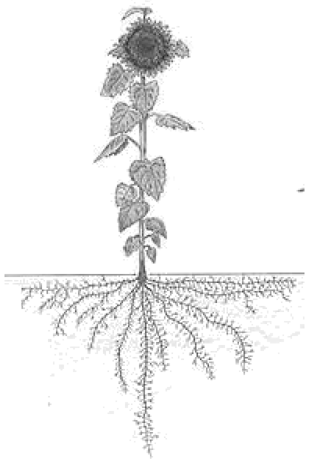


Phytotechnologies useful plants

Database on the botany and the potentialities of some plant species used for

phytoremediation, phytostabilization, hydraulic barriers and

constructed wetlands



Search for the useful species

Help us improve this database by sending your comments/suggestions to laupassa@yahoo.it. Any criticism for improving the information availability will be welcome.

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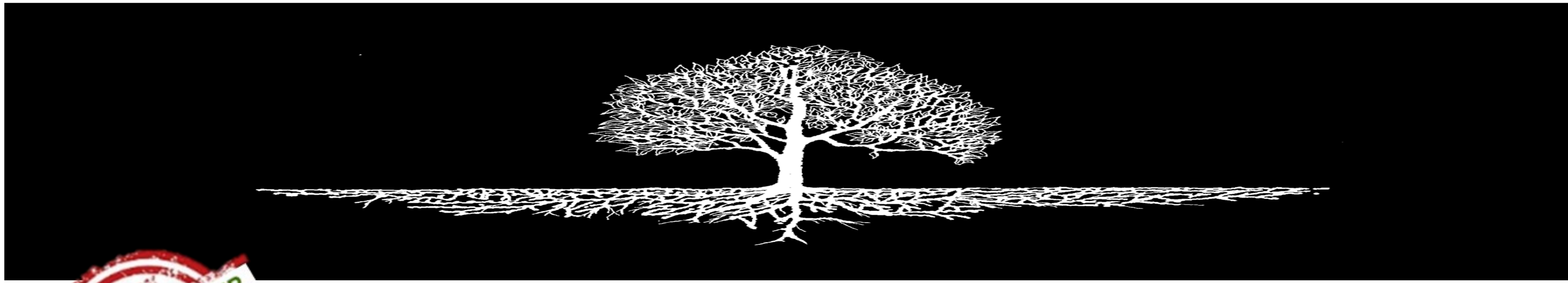

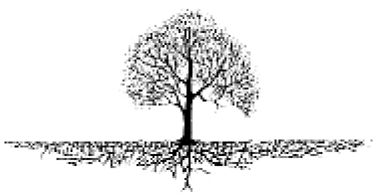

Phytotechnologies

Phytotechnologies are clean-up techniques which use grasses or higher plants for treating environmental contaminants such as heavy metals, trace elements, organic or radioactive compounds in soils, groundwater, municipal, industrial and agricultural wastewater (Baker et al., 1991; Raskin et al., 1997; Wenzel et al., 1999).

Some of these technologies have become attractive alternatives to conventional cleanup technologies due to relatively low costs and the inherently aesthetic nature of planted sites.

Phytotechnologies mechanisms include the overall biological, chemical, and physical processes that enable the uptake, sequestration, degradation, and metabolisation of contaminants, either by plants or by organisms that constitute the plant's rhizosphere.

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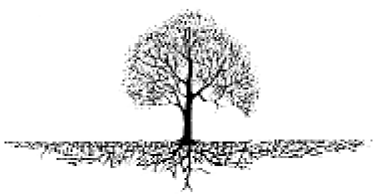

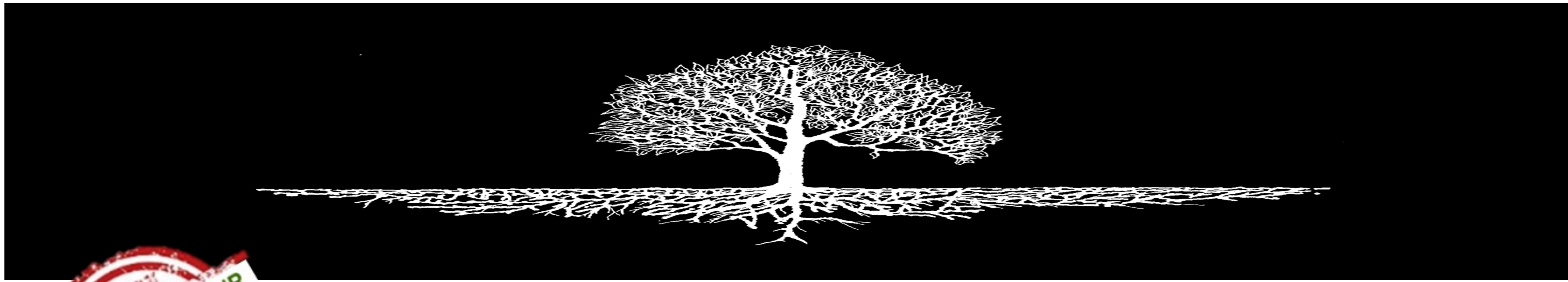

Phytotechnologies

The specific phytoremediation technique used to address a contaminant is dependent not only on the type of constituent and the media that is affected, but also on the remediation goals. Typical goals include containment, stabilization, sequestration and degradation; when the objective is the break-down of the contaminant, we talk about phytoremediation. To achieve these goals, the proper phytotechnology must be designed using detailed knowledge of the site layout, soil characteristics, hydrology, climate conditions, analytical needs, operations and maintenance requirements, economics, public perception, and regulatory environment (ITRC, 2001).

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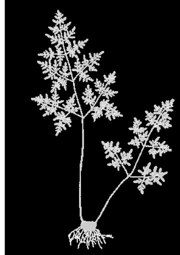
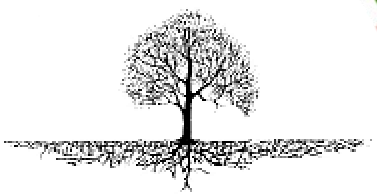


RHIZODEGRADATION



Process description: breakdown of contaminants in the soil through the bioactivity of rhizosphere organisms (bacteria, yeast and fungi). Microbial comunities are enhanced by roots activity.

Contaminants: Organic compounds (TPH, PAHs, pesticides, chlorinated solvents, PCBs)

Plant type: herbaceous species, shrubs, trees, wetland species

Substrate: soil, sediments, sludges, water

Process goals: degradation of the contaminant into other compounds.

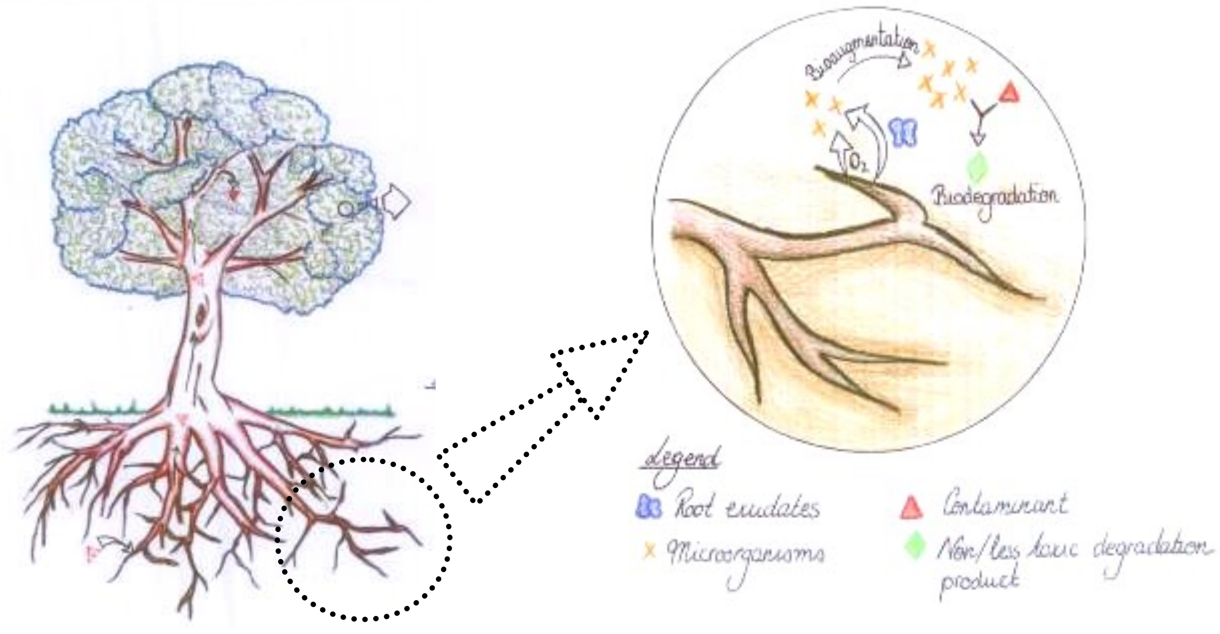
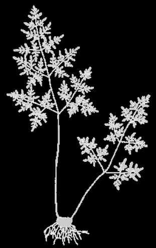
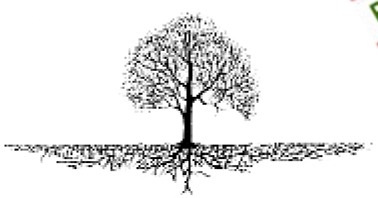


Illustration by Ladina Donatsch



PHYTODEGRADATION



Process description: uptake of contaminants and subsequent transformation by plants

Contaminants: some organic compound (chlorinated solvents, BTEX chemicals, pesticides, phenols)

Plant type: herbaceous species, trees, wetland species

Substrate: soil, sediments, sludges, water

Process goals: mineralization of the contaminant

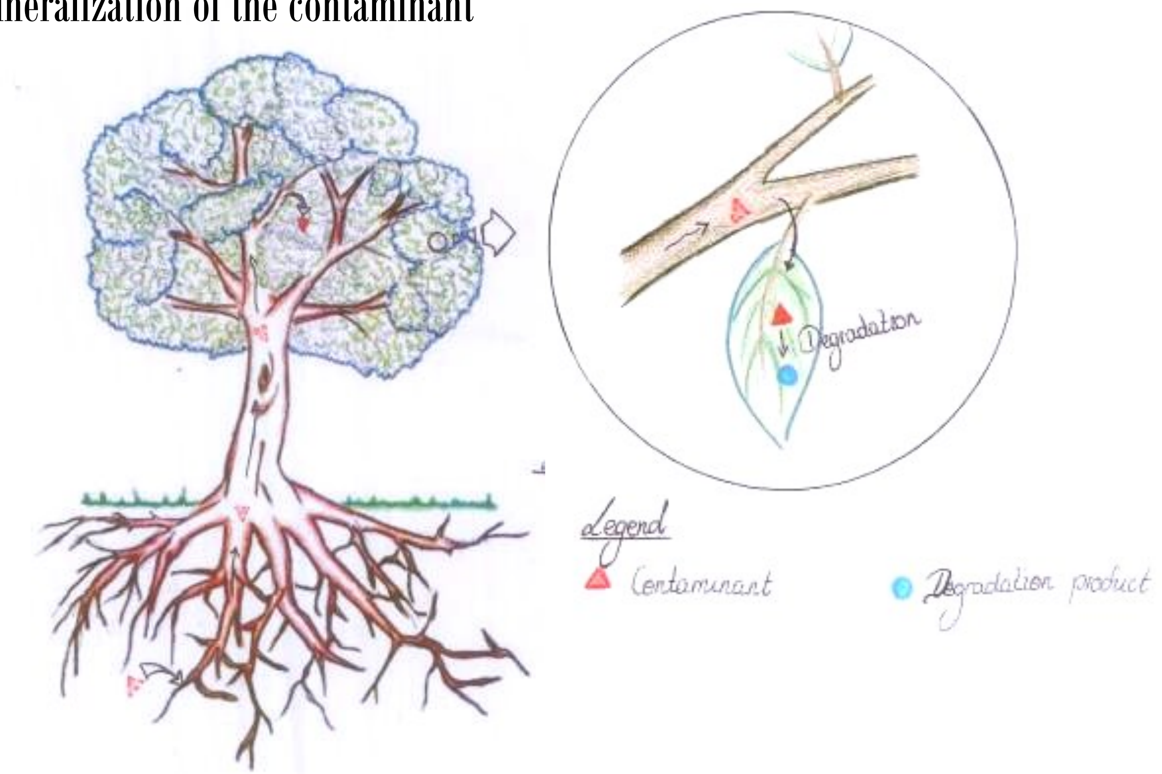


Illustration by Ladna Donatsch

PHYTOEXTRACTION

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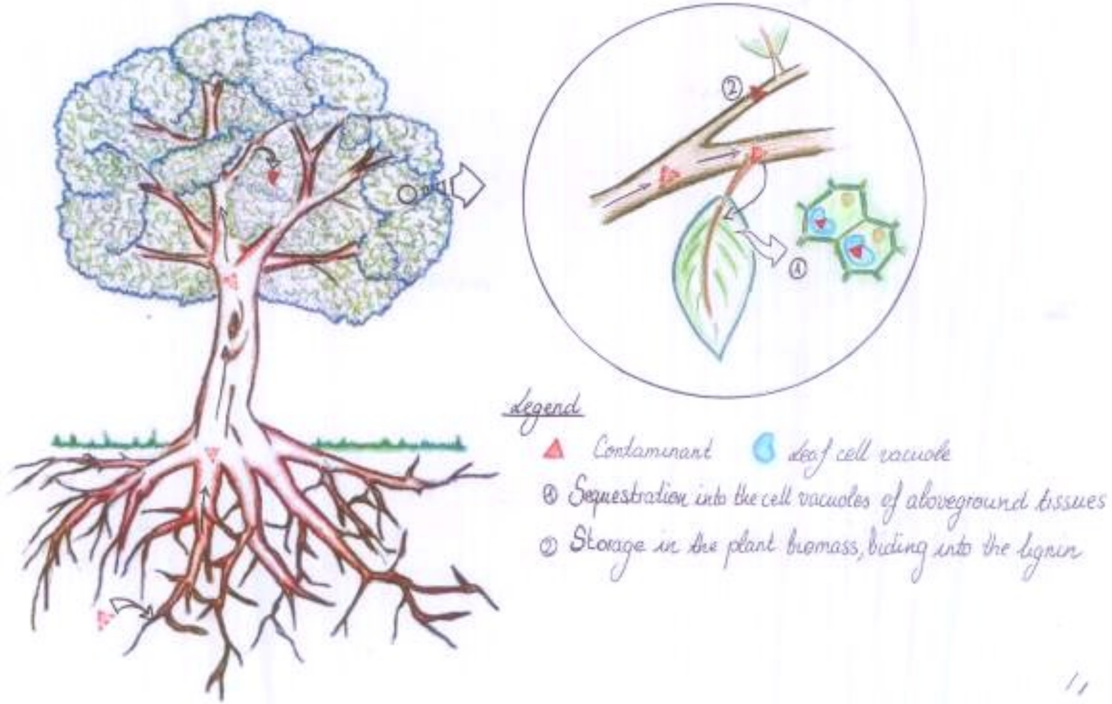
Process description: : some species of plant can extract and accumulate contaminants into the roots and translocate to aboveground shoots or leaves

Contaminants: heavy metals and radionuclides

Plant type: herbaceous species, grasses, trees, wetland species.

Substrate: soil, sediments, sludges, water

Process goals: mobilization of the contaminant from soil to the plant and contaminant concentration into vegetal tissues.



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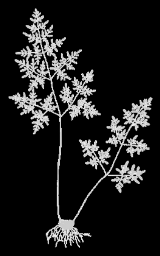

PHYTOVOLATILIZATION

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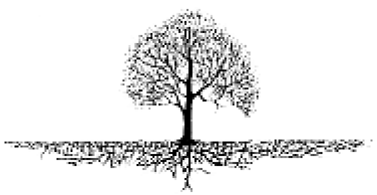


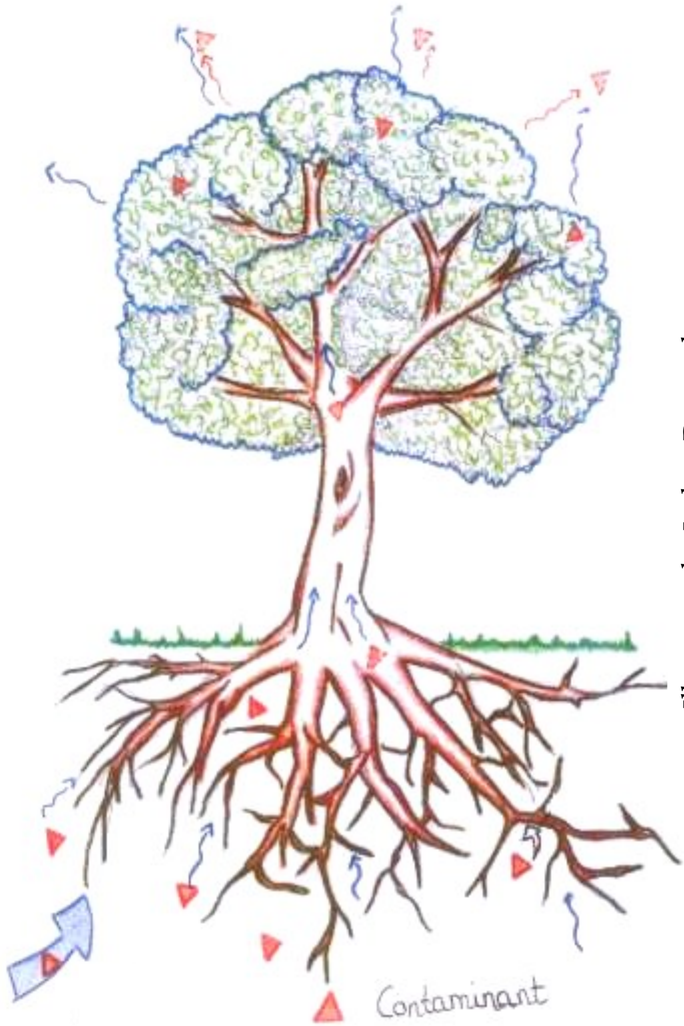
Process description: : the contaminant is uptaken by the plant, eventually modified, and released by the leaves into the atmosphere through the transpiration pathway.

Contaminants: selenium, silver, arsenic, chlorinated solvents , MTBE.

Plant type: herbaceous species, trees, shrubs, wetland species

Substrate: soil, sediments, sludges, water

Process goals: extraction from the substrate and release into the atmosphere.



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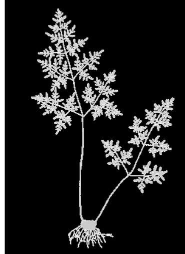
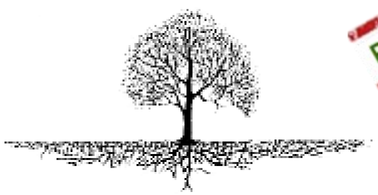


EVAPOTRANSPIRATION



Process description: the rain interception by the leaves, the water uptake and the water transpiration by the plant provide hydraulic control on the contaminated area .

Contaminants: water soluble contaminants

Plant type: herbaceous species, shrubs, trees (especially phreatophytes), wetland species

Substrate: groundwater, surface water and wet soil.

Process goals: hydraulic containment and erosion control.

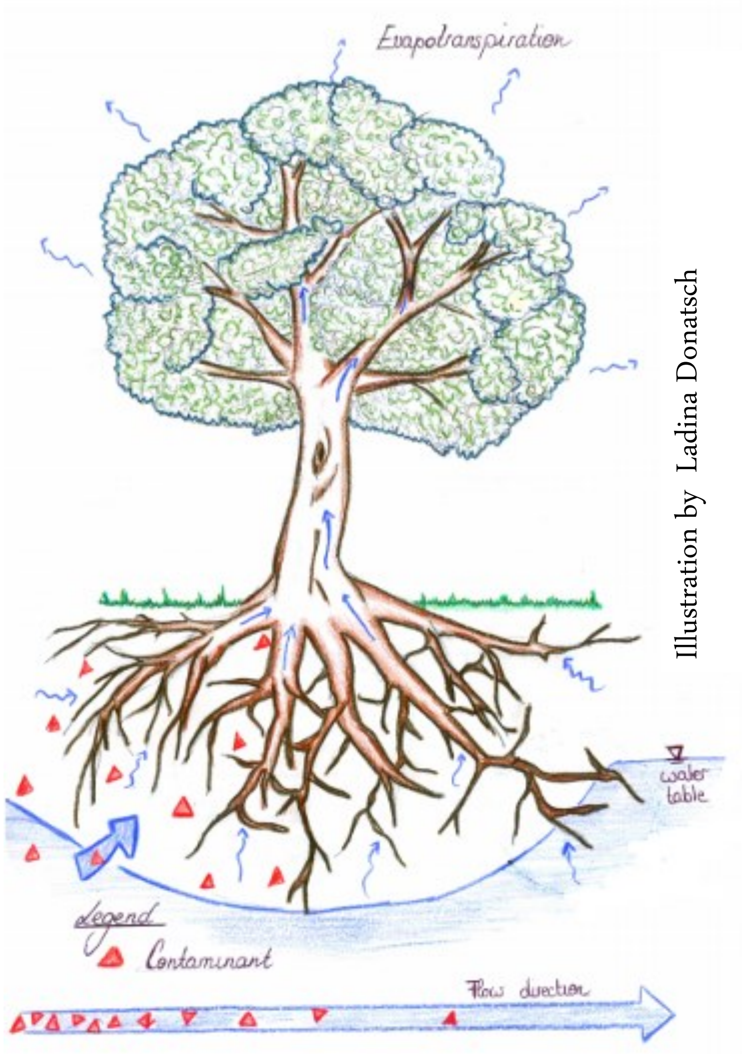


Illustration by Ladina Donatsch

PHYTOSTABILIZATION

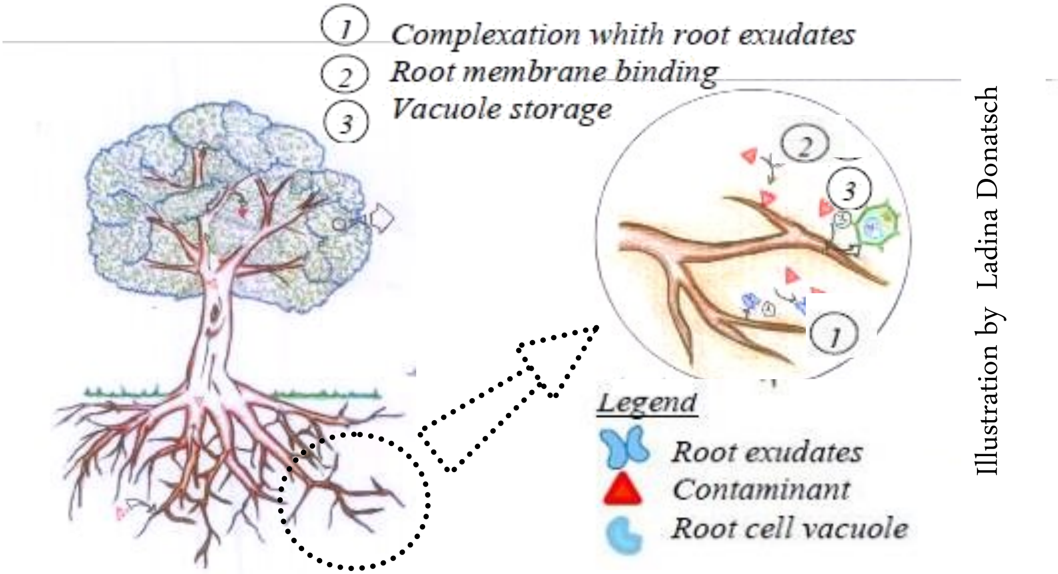
Process description: : absorption and accumulation into the roots, precipitation or immobilization within the root zone.

Contaminants: heavy metals

Plant type: herbaceous species, grass, trees, wetland species

Substrate: soil, sediments, sludges.

Process goals: contaminant mobility reduction and prevention of its migration into the soil, groundwater or air.



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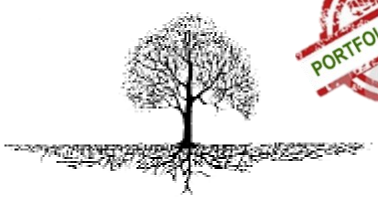

PHYTOTECHNOLOGIES ADVANTAGES

Cost competitive – Phytotechnologies are estimated to be cheaper than other remedial approaches (ITRC, 2001).

Applicability – Phytotechnologies are advantageously applicable to moderately (multi-) contaminated sites of large extension.

Favourable public perception – Increased aesthetics, reduced noise and bad smell.

Greenhouse effect reduction – Carbon dioxide sequestration into biomass .

Removable energy production – Energy can be recovered from the controlled combustion of the harvested biomass.

PHYTOTECHNOLOGIES LIMITATIONS

Root depth – Some efficient phytoextractors root little deep .

Applicability– Generally, the use of phytoremediation is limited to : sites with low to medium contaminant concentrations, top soil contaminant localization, bioavailability of contaminants

Treatment duration – Phytotechnologies can be relatively slow in comparison to current remediation technologies.

Seasonal dependence – For deciduous plants the efficiency is strongly reduced during the winter dormancy .

Potential contamination of food chain - Possibility of contaminant entrance into the food chain through animal consumption of plant biomass.

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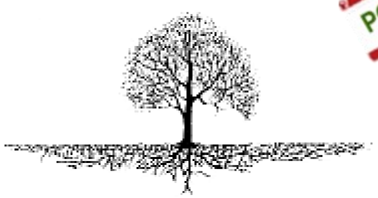

→ Search by botanical name

→ Search by pollutant

- Heavy metals
- Organic contaminants
- Radionuclides
- Nutrients

→ Search by substrate to treat

- Water
- Soil

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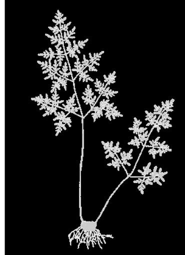

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Click on the links below to view the corresponding data sheets; the name of each species is followed by the name of the contaminants on which it has effect.

Acer-pseudoplatanus-Zn-Cd-Pb

Agrostis-castellana-As-Pb-Mn-Zn-Cu-Hydrocarbons

Agrostis-stolonifera-heavy-metals-arsenic-hydrocarbons

Agrostis-tenuis-Cu-Zn-Pb-Arsenic

Alnus-glutinosa-Zn-Cd-Pb-Cu

Amaranthus-tricolor-Radionuclides-Hydrocarbons-Cadmium

Arundo-donax-Cd-Ni-As-Pb-Zn-Nutrients

Brassica-napus-Heavy-Metals-Organics

Cannabis-sativa-Cd-Cr-Ni-Pb-Zn-Organics-Radionuclides

Cynodon-dactylon-Organics-Cr-Pb-Zn-Cu

Eucalyptus-globulus-Cd-Zn-Cu-Pb-As-Organics

Festuca-arundinacea-Heavy-Metals-Organics

Festuca-rubra-Cd-Cu-Pb-Zn-Organics

Fraxinus-excelsior-Cd-Pb-Zn-Cu-Organics

Helianthus-annuus-Pb-Cd-Cr-Ni-Radionuclides

Holcus-lanatus-As-Pb-Zn-Cd

Linum-usitatissimums-Cu-Cd-Pb

Medicago-lupulina-Cu-Pb-Ni-Zn

Medicago-sativa-Cd-Cr-Cu-Ni-Zn-Organics

Phalaris-arundinacea-heavy-metals-organics-nutrients

Phragmites-australis-heavy-metals-organics-nutrients

POPULUS spp.

Pteris vittata-As

Robinia-pseudoacacia-heavy-metals-organics

SALIX spp.

Tamarix spp.

Zea-mays-heavy-metals-organic-contaminants

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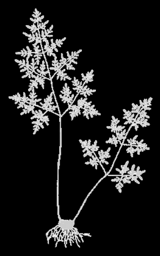

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QUALITY PORTFOLIO IRET-CNR CONTROL

Click on the links below to view the corresponding data sheets for each POPLAR hybrid.

P. ALBA

- *Clone 6K3*
- *Clone 14P11*

P. x CANADENSIS (P.xEuroamericana)

- *Clone Argyle*
- *Clone A4A*
- *Clone DN5*
- *Clone I 214*
- *Clone Luisa Avanzo*
- *Clone Gaver*

P. DELTOIDES

- *Clone Lux*

P. DELTOIDES X P. MAXIMOWICZII (Clone Eridano)

P. DELTOIDES X P. YUNNANENSIS (Clone Kawa)

P.GENEROSA (Clone 11-5)

P.GENEROSAxP.NIGRA (clone Monviso)

P. NIGRA

- *Clone Poli*
- *Clone 58-861*
- *Clone Wolterson*

P. NIGRAxP. MAXIMOWICZII (clone NM6)

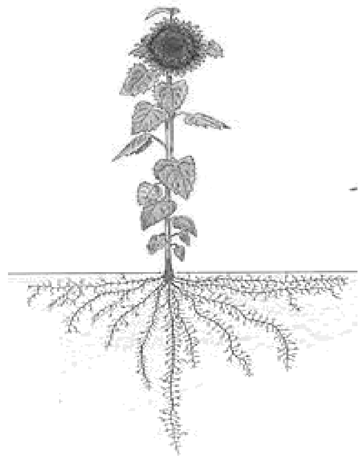
P. TRICHOCARPA

- *Clone Nisqually*
- *Clone Fritzi Pauley*
- *Clone Trichobel*

P. TRICHOCARPAxP . KOREANA

P. TRICHOCARPAxP. BALSAMIFERA (Balsam spire)

P. TRICHOCARPAxP. DELTOIDES (clone Beauprè)



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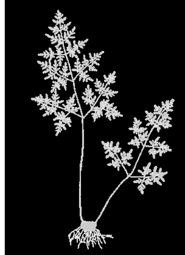

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S. ALBA
- *Clone SS 5*
- *Clone SP 3*
- *Clone 6-03*
- *Clone 2-03*
- *Clone QUIRANI*
- *Clone CRETONE*

S. ALBA X S. MATSUDANA (clone Tangoio)

S. BABILONICA

S. BURJATICA

S. CAPREA

S. CINEREA

S. DASYCLADOS

S. TRIANDRA X S. VIMINALIS (clone Q83)

S. VIMINALIS

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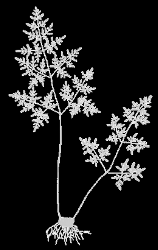

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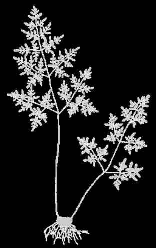
- Cadmium
- Cobalt
- Chromium
- Copper
- Manganese
- Nickel
- Lead
- Zinc



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ALLUMINIUM

Click on the links below to view the corresponding data sheets; the name of each species is followed by the name of the contaminants on which it has effect.

Agrostis-stolonifera-heavy-metals-Arsenic-hydrocarbons

Brassica-napus-Heavy-Metals-Organics

Festuca-arundinacea-Heavy-Metals-Organics

Phalaris-arundinacea-heavy-metals-organics-nutrients

Phragmites-australis-heavy-metals-organics-nutrients

Robinia-pseudoacacia-heavy-metals-organics

P. nigra Clone Wolterson

P. x canadensis, clone Gaver

P. tricocarpa, clone Fritzi Pauley and clone Trichobel

P. tricocarpa xP. balsamifera(Balsam spire)

P. tricocarpa xP. deltoides (clone Beauprè)

Tamarix spp.

Zea-mays-heavy-metals-organic-contaminants

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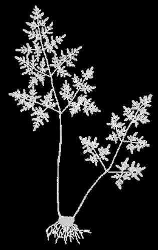

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PORTFOLIO IRET-CNR

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ARSENIC

Click on the links below to view the corresponding data sheets; the name of each species is followed by the name of the contaminants on which it has effect.

- *Agrostis-castellana*-As-Pb-Mn-Zn-Cu-Hydrocarbons
- *Agrostis-stolonifera-heavy-metals-Arsenic-hydrocarbons*
- *Agrostis-tenuis*-Cu-Zn-Pb-Arsenic
- *Arundo-donax*-Cd-Ni-As-Pb-Zn-Nutrients
- *Eucalyptus-globulus*-Cd-Zn-Cu-Pb-As-Organics
- *Holcus-lanatus*-As-Pb-Zn-Cd
- *Phragmites-australis*-heavy-metals-organics-nutrients
- *Pteris vittata-As*
- *P. nigra xP. maximowiczii (clone NM6)*
- *P. trichocarpa xP. koreana*
- *S. alba*
- *Salix caprea - Zn, As, Cd, Pb*
- *Salix dasyclados – Zn, As, Cd, Pb*
- *Tamarix* spp.
- *Robinia-pseudoacacia*-heavy-metals-organics
- *Zea-mays*-heavy-metals-organic-contaminants

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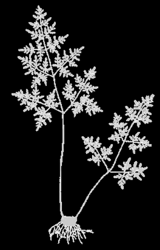

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CADMIUM

Click on the links below to view the corresponding data sheets; the name of each species is followed by the name of the contaminants on which it has effect.

- *Acer-pseudoplatanus*-Zn-Cd-Pb
- *Agrostis-stolonifera-heavy-metals-Arsenic-hydrocarbons*
- *Alnus-glutinosa*-Zn-Cd-Pb-Cu
- *Amaranthus-tricolor*-Radionuclides-Hydrocarbons-Cadmium
- *Arundo-donax*-Cd-Ni-As-Pb-Zn-Nutrients
- *Brassica-napus*-Heavy-Metals-Organics
- *Cannabis-sativa*-Cd-Cr-Ni-Pb-Zn-Organics-Radionuclides
- *Eucalyptus-globulus*-Cd-Zn-Cu-Pb-As-Organics
- *Festuca-arundinacea*-Heavy-Metals-Organics
- *Festuca-rubra*-Cd-Cu-Pb-Zn-Organics
- *Fraxinus-excelsior*-Cd-Pb-Zn-Cu-Organics
- *Helianthus-annuus*-Pb-Cd-Cr-Ni-Radionuclides
- *Holcus-lanatus*-As-Pb-Zn-Cd
- *Linum-usitatissimums*-Cu-Cd-Pb
- *Medicago-sativa*-Cd-Cr-Cu-Ni-Zn-Organics
- *Phalaris-arundinacea*-heavy-metals-organics-nutrients
- *Phragmites-australis*-heavy-metals-organics-nutrients
- *POPULUS spp.*
- *Robinia-pseudoacacia*-heavy-metals-organics
- *SALIX spp.*
- *Tamarix spp.*
- *Zea-mays*-heavy-metals-organic-contaminants

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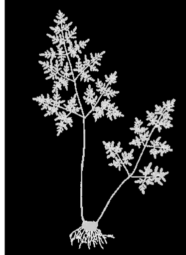

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Click on the links below to view the corresponding data sheets; the name of each species is followed by the name of the contaminants on which it has effect.

COBALT

Agrostis-stolonifera-heavy-metals-Arsenic-hydrocarbons

Brassica-napus-Heavy-Metals-Organics

Festuca-arundinacea-Heavy-Metals-Organics

Phalaris-arundinacea-heavy-metals-organics-nutrients

Phragmites-australis-heavy-metals-organics-nutrients

Salix viminalis Mineral oil, PHAs, Cr, Co, Ni, Cu, Zn, Cd, Pb

Robinia-pseudoacacia-heavy-metals-organics

Tamarix spp.

Zea-mays-heavy-metals-organic-contaminants

MANGANESE

Agrostis-stolonifera-heavy-metals-Arsenic-hydrocarbons

Agrostis-castellana-As-Pb-Mn-Zn-Cu-Hydrocarbons

Brassica-napus-Heavy-Metals-Organics

Festuca-arundinacea-Heavy-Metals-Organics

Phalaris-arundinacea-heavy-metals-organics-nutrients

Phragmites-australis-heavy-metals-organics-nutrients

Robinia-pseudoacacia-heavy-metals-organics

Tamarix spp.

Zea-mays-heavy-metals-organic-contaminants

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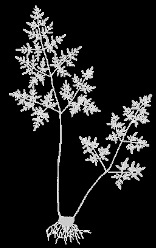

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QUALITY PORTFOLIO IRET-CNR CONTROL

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Click on the links below to view the corresponding data sheets; the name of each species is followed by the name of the contaminants on which it has effect.

CHROMIUM

Agrostis-stolonifera-heavy-metals-Arsenic-hydrocarbons

Brassica-napus-Heavy-Metals-Organics

Cannabis-sativa-Cd-Cr-Ni-Pb-Zn-Organics-Radionuclides

Cynodon-dactylon-Organics-Cr-Pb-Zn-Cu

Festuca-arundinacea-Heavy-Metals-Organics

Helianthus-annuus-Pb-Cd-Cr-Ni-Radionuclides

Medicago-sativa-Cd-Cr-Cu-Ni-Zn-Organics

Phalaris-arundinacea-heavy-metals-organics-nutrients

Phragmites-australis-heavy-metals-organics-nutrients

P. alba

P. nigra

P. x canadensis, clone I 214

P. deltoides X P. maximowiczii (Clone Eridano)

Robinia-pseudoacacia-heavy-metals-organics

S. alba

S. triandra x S. viminalis(clone Q83)

S. viminalis

S. burjatica

Tamarix spp.

Zea-mays-heavy-metals-organic-contaminants

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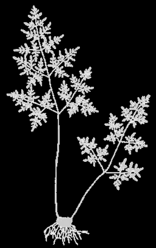

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Click on the links below to view the corresponding data sheets; the name of each species is followed by the name of the contaminants on which it has effect.

COPPER

Agrostis-castellana-As-Pb-Mn-Zn-Cu-Hydrocarbons

Agrostis-stolonifera-heavy-metals-Arsenic-hydrocarbons

Agrostis-tenuis-Cu-Zn-Pb-Arsenic

Alnus-glutinosa-Zn-Cd-Pb-Cu

Brassica-napus-Heavy-Metals-Organics

Cynodon-dactylon-Organics-Cr-Pb-Zn-Cu

Eucalyptus-globulus-Cd-Zn-Cu-Pb-As-Organics

Festuca-arundinacea-Heavy-Metals-Organics

Festuca-rubra-Cd-Cu-Pb-Zn-Organics

Fraxinus-excelsior-Cd-Pb-Zn-Cu-Organics

Linum-usitatissimums-Cu-Cd-Pb

Medicago-lupulina-Cu-Pb-Ni-Zn

Medicago-sativa-Cd-Cr-Cu-Ni-Zn-Organics

Phalaris-arundinacea-heavy-metals-organics-nutrients

Phragmites-australis-heavy-metals-organics-nutrients

P. alba

P. nigra

P. x canadensis, clone I 214

P. deltoides X P. maximowiczii (Clone Eridano)

P. tricocarpa xP. deltoides (clone Beauprè)

Robinia-pseudoacacia-heavy-metals-organics

S. alba

S. viminalis -Mineral oil, PHAs, Cr, Co, Ni, Cu, Zn, Cd, Pb

S. burjatica - Cr, Ni, Cu, Zn, Pb

S. triandra x S. viminalis(clone Q83)

P. trichocarpa xP. koreana

Tamarix spp.

Zea-mays-heavy-metals-organic-contaminants

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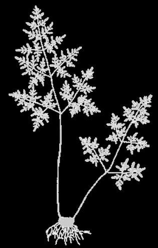

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Click on the links below to view the corresponding data sheets; the name of each species is followed by the name of the contaminants on which it has effect.

NICKEL

Agrostis-stolonifera-heavy-metals-Arsenic-hydrocarbons

Arundo-donax-Cd-Ni-As-Pb-Zn-Nutrients

Brassica-napus-Heavy-Metals-Organics

Cannabis-sativa-Cd-Cr-Ni-Pb-Zn-Organics-Radionuclides

Festuca-arundinacea-Heavy-Metals-Organics

Helianthus-annuus-Pb-Cd-Cr-Ni-Radionuclides

Medicago-lupulina-Cu-Pb-Ni-Zn

Phalaris-arundinacea-heavy-metals-organics-nutrients

Phragmites-australis-heavy-metals-organics-nutrients

P. alba

P. nigra

P. x canadensis, clone DN5

P. nigra x P. maximowiczii- Ni, Zn, As, Cd, Pb

P. tricocarpa x P. deltoides- Al, Ni, Cu, Zn, Cd

Robinia-pseudoacacia-heavy-metals-organics

S. alba

S. triandra x S. viminalis(clone Q83)

S. viminalis

S. burjatica

Tamarix spp.

Zea-mays-heavy-metals-organic-contaminants

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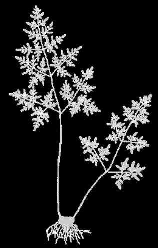

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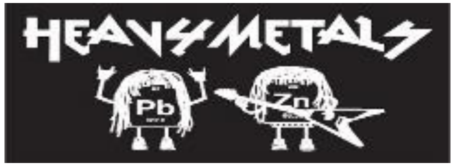
HEAVY METALS

Click on the links below to view the corresponding data sheets; the name of each species is followed by the name of the contaminants on which it has effect.

LEAD

- *Acer-pseudoplatanus*-Zn-Cd-Pb
- *Agrostis-castellana*-As-Pb-Mn-Zn-Cu-Hydrocarbons
- *Agrostis-stolonifera-heavy-metals-Arsenic-hydrocarbons*
- *Agrostis-tenuis*-Cu-Zn-Pb-Arsenic
- *Alnus-glutinosa*-Zn-Cd-Pb-Cu
- *Arundo-donax*-Cd-Ni-As-Pb-Zn-Nutrients
- *Brassica-napus*-Heavy-Metals-Organics
- *Cannabis-sativa*-Cd-Cr-Ni-Pb-Zn-Organics-Radionuclides
- *Cynodon-dactylon*-Organics-Cr-Pb-Zn-Cu
- *Eucalyptus-globulus*-Cd-Zn-Cu-Pb-As-Organics
- *Festuca-arundinacea*-Heavy-Metals-Organics
- *Festuca-rubra*-Cd-Cu-Pb-Zn-Organics
- *Fraxinus-excelsior*-Cd-Pb-Zn-Cu-Organics
- *Helianthus-annuus*-Pb-Cd-Cr-Ni-Radionuclides
- *Holcus-lanatus*-As-Pb-Zn-Cd
- *Linum-usitatissimums*-Cu-Cd-Pb
- *Medicago-lupulina*-Cu-Pb-Ni-Zn
- *Phalaris-arundinacea*-heavy-metals-organics-nutrients
- *Phragmites-australis*-heavy-metals-organics-nutrients
- *POPULUS spp.*
- *Robinia-pseudoacacia*-heavy-metals-organics
- *SALIX spp.*
- *Tamarix* spp.
- *Zea-mays*-heavy-metals-organic-contaminants



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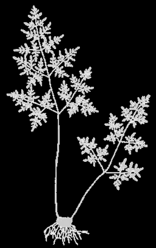

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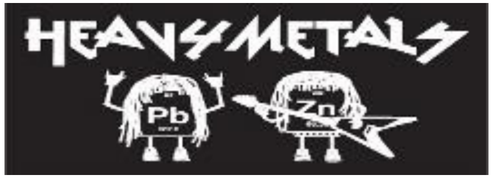
Click on the links below to view the corresponding data sheets; the name of each species is followed by the name of the contaminants on which it has effect.

ZINC

- *Acer-pseudoplatanus*-Zn-Cd-Pb
- *Agrostis-castellana*-As-Pb-Mn-Zn-Cu-Hydrocarbons
- *Agrostis-stolonifera-heavy-metals-Arsenic-hydrocarbons*
- *Agrostis-tenuis*-Cu-Zn-Pb-Arsenic
- *Alnus-glutinosa*-Zn-Cd-Pb-Cu
- *Arundo-donax*-Cd-Ni-As-Pb-Zn-Nutrients
- *Brassica-napus*-Heavy-Metals-Organics
- *Cannabis-sativa*-Cd-Cr-Ni-Pb-Zn-Organics-Radionuclides
- *Cynodon-dactylon*-Organics-Cr-Pb-Zn-Cu
- *Eucalyptus-globulus*-Cd-Zn-Cu-Pb-As-Organics
- *Festuca-arundinacea*-Heavy-Metals-Organics
- *Festuca-rubra*-Cd-Cu-Pb-Zn-Organics
- *Fraxinus-excelsior*-Cd-Pb-Zn-Cu-Organics
- *Holcus-lanatus*-As-Pb-Zn-Cd
- *Medicago-lupulina*-Cu-Pb-Ni-Zn
- *Medicago-sativa*-Cd-Cr-Cu-Ni-Zn-Organics
- *Phalaris-arundinacea*-heavy-metals-organics-nutrients
- *Phragmites-australis*-heavy-metals-organics-nutrients
- *POPULUS spp.*
- *Robinia-pseudoacacia*-heavy-metals-organics
- *SALIX spp.*
- *Tamarix* spp.
- *Zea-mays*-heavy-metals-organic-contaminants



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ORGANIC POLLUTANTS

Click on the links below to view the corresponding data sheets; the name of each species is followed by the name of the contaminants on which it has effect.

- *Agrostis-castellana*-As-Pb-Mn-Zn-Cu-Hydrocarbons
- *Agrostis-stolonifera-heavy-metals-Arsenic-hydrocarbons*
- *Amaranthus-tricolor*-Radionuclides-Hydrocarbons-Cadmium
- *Brassica-napus*-Heavy-Metals-Organics
- *Cannabis-sativa*-Cd-Cr-Ni-Pb-Zn-Organics-Radionuclides
- *Cynodon-dactylon*-Organics-Cr-Pb-Zn-Cu
- *Eucalyptus-globulus*-Cd-Zn-Cu-Pb-As-Organics
- *Festuca-arundinacea*-Heavy-Metals-Organics
- *Festuca-rubra*-Cd-Cu-Pb-Zn-Organics
- *Fraxinus-excelsior*-Cd-Pb-Zn-Cu-Organics
- *Medicago-sativa*-Cd-Cr-Cu-Ni-Zn-Organics
- *Phalaris-arundinacea*-heavy-metals-organics-nutrients
- *Phragmites-australis*-heavy-metals-organics-nutrients
- *POPULUS spp.*
- *Robinia-pseudoacacia*-heavy-metals-organics
- **SALIX spp.**
- *Tamarix* spp.
- *Zea-mays*-heavy-metals-organic-contaminants

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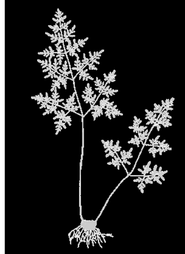

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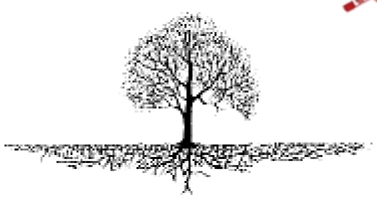

RADIONUCLIDES

Click on the links below to view the corresponding data sheets; the name of each species is followed by the name of the contaminants on which it has effect.

Amaranthus-tricolor-Radionuclides-Hydrocarbons-Cadmium

Cannabis-sativa-Cd-Cr-Ni-Pb-Zn-Organics-Radionuclides

Helianthus-annuus-Pb-Cd-Cr-Ni-Radionuclides

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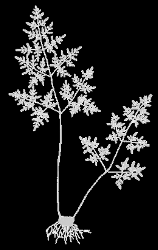

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PORTFOLIO IRET-CNR

NUTRIENTS (nitrogen and phosphorus)

Click on the links below to view the corresponding data sheets; the name of each species is followed by the name of the contaminants on which it has effect.

Arundo-donax-Cd-Ni-As-Pb-Zn-Nutrients

Phalaris-arundinacea-heavy-metals-organics-nutrients

Phragmites-australis-heavy-metals-organics-nutrients

POPULUS spp.

SALIX spp.

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Rhizoremediation

Rhizoremediation is a type of phytoremediation in which contaminants are treated in the root area through the symbiotic association of plants with microorganisms and other biota. Complementary metabolic activities of roots and bacteria result in the degradation of contaminants to non toxic or less toxic compounds. Microorganisms able to degrade pollutants (bacteria, algae and fungi) proliferate in the rhizosphere niche where they find key nutrients supporting their growth. For this reason, the breakdown of contaminants in the soil through microbial activity is also known as plant assisted bioremediation.

Although rhizoremediation is a natural process (natural attenuation), it can also be optimized by adding substances to stimulate growth and biodegradation (enhanced natural attenuation) and by deliberately manipulating the rhizosphere with the introduction of specific acclimated microbes (bioaugmentation) (Kuiper et al, 2004).

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Rhizoremediation

Bioavailability is one of the main factors affecting the biodegradation rate of a contaminant in soil. This bioavailability can be increased by using surfactants, amphipathic molecules with both a hydrophobic and a hydrophilic part. By accumulating on the interfaces, they are can form micelles where substances that are generally insoluble in water, such as hydrocarbons, may be solubilized in water, and in turn, are made more available for microorganisms metabolism. However, chemical surfactants are themselves a source of pollution. By contrast, many microorganisms (*Pseudomonas aeruginosa, Bacillus subtilis, Pichia pastoris*, etc.) can produce structurally diversified surface-active agents, known as biosurfactants. Biosurfactants are much less harmful for the natural ecosystems due to their low toxicity and biodegradable nature. Their use is considered a valuable means to promote bioremediation (Kuiper et al, 2004; ARPA Lombardia, 2003).

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Rhizosphere

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Most of the phytoremediation processes take place in the rhizosphere, the area around a plant root that is inhabited by a unique population of microorganisms influenced by the chemicals released from plant roots, as described for the first time by Lorenz Hiltner in 1904. As might be expected because of the inherent complexity and diversity of plant root systems, the rhizosphere is not a region of definable size or shape, but instead, consists of a gradient in chemical, biological and physical properties which change both radially and longitudinally along the root. Rhizodeposits make the rhizosphere a desirable niche for microbial communities to proliferate.

One teaspoon of bare or tilled soil contains more microorganisms than there are people on Earth, however, the rhizosphere can have 1000-2000 times that number (1010-1012 cells per gram rhizosphere soil) making it a pretty crowded place (McNear Jr 2013). The plant root-soil interface is therefore a dynamic region in which numerous biogeochemical processes take place driven by the physical activity, and the diversity of chemicals released by the plant root.

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Rhizosphere

The microbial consortium of the rhizosphere includes bacteria, algae and fungi, among other microorganisms. Rhizosphere bacteria are the most abundant type of microorganism and perform several functions such as the promotion of plant growth, the protection against plant pathogens, the production of chelators for delivering key plants nutrients and the degradation of contaminants. An important plant-fungi association is mycorrhiza. Mycorrhizal fungi associated with plant roots affect the acquisition of nutrients by the root and is a large sink of carbon that can be made available to microrganism. The mycorrhizal infection is usually a mutual relation, with the fungi receiving sugars from the host plant in exchange for improving the plant's mineral nutrient uptake efficiency thanks to an increase of the absorption area, as well as providing protection against pathogens (Barea et al, 2005, Morgan et al, 2005; Bais et al, 2006).

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Phytoremediation websites

Interstate Technology and Regulatory Cooperation Work Group (ITRC): from this site you can download the phytoremediation decision tree document.

"Contaminated Site clean-up information", by EPA, provide a general description on approaches to clean up contaminated sites. You can also download a citizen's guide to phytoremediation

Botanical database

Data sheets edited by Centro Sperimentale per il Vivaismo: synthetic description of ornamental garden plants, it including information about uses and cultivation.

Taxonomic Information System – created by a partnership of U.S., Canadian, and Mexican agencies (ITIS-North America) and taxonomic specialists.

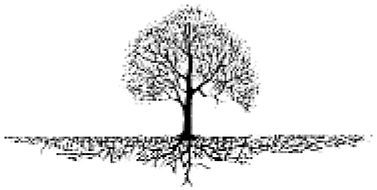
United States Department of Agriculture

www.backyardgardener.com provides gardening information on thousands of plants

Involved organizations

CNR, *Earth and Environment Department*

IRET, *Institute of Agro-environmental and Forest biology (CNR)*



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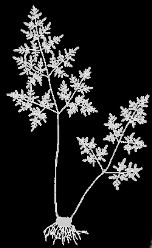

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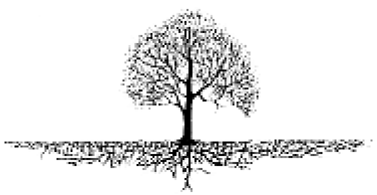

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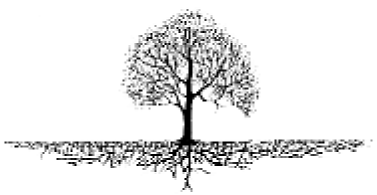

BONIFICA RECUPERO ENERGIA

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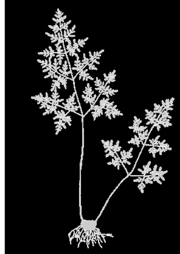
In 2008, the Department of Forest Environment and Resources (Disafri, Tuscia University) and the Institute of Agro-environmental Biology and Forestry (IBAF CNR, currently IRET), together with the coordination of Arpa Umbria (Umbria Regional Agency for the Environment), cooperated in order to create the Remida project (Remediation energy production & soil management), with the aim to provide to the public service with an innovative and sustainable tool for the management of contaminated sites.

The Remida project is based on the implementation of phytortechnologies, according to the Short Rotation Coppice (SRC) practice (i.e. the cultivation of fast-growing species as energy crop).

ARPA umbria

Cnr

UNIVERSITÀ Tuscia DIBAF



REFERENCES

PHYTOTECHNOLOGIES

How does it work

Operating mechanisms
- *Rhizodegradation*
- *Phytodegradation*
- *Phytoextraction*
- *Phytovolatilization*
- *Evapotranspiration*
- *Phytostabilization*

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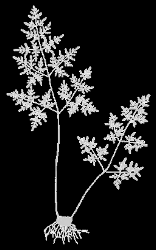

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- Rhizodegradation
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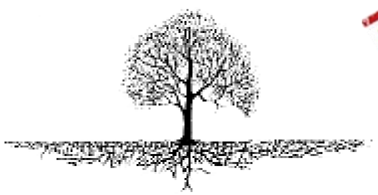

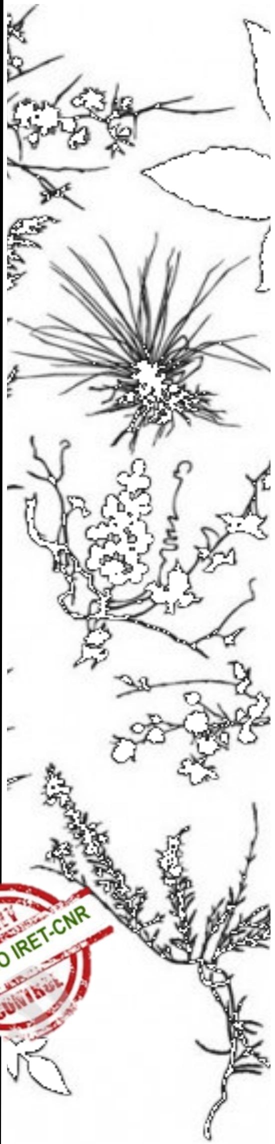

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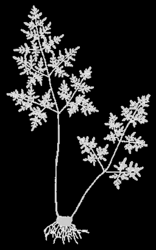

ACRONYMS

PHYTOTECHNOLOGIES

How does it work

Operating mechanisms

- *Rhizodegradation*
- *Phytodegradation*
- *Phytoextraction*
- *Phytovolatilization*
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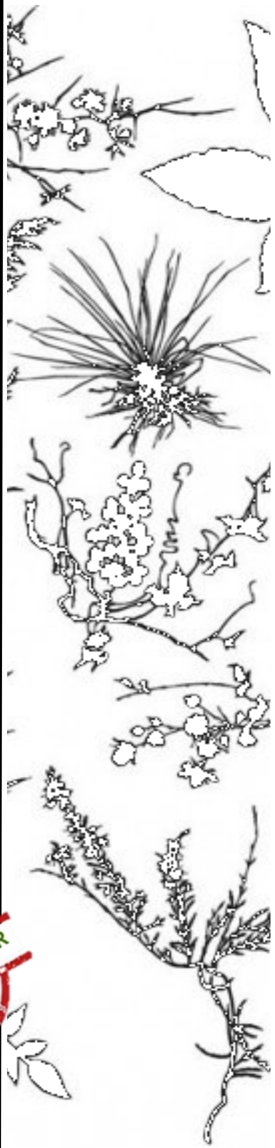
QUALITY PORTFOLIO IRET-CNR CONTROL



TPH – Total Petroleum Hydrocarbons – mixture of hydrocarbons occurring in crude oil

PAH – Polycyclic aromatic hydrocarbons, constitued by fused aromatic rings

PCB - Polychlorinated biphenyls, a class of organic compounds with one to ten chlorine atoms attached to biphenyl (a molecule composed of two benzene rings)

BTEX - Benzene, Toluene, Etilbenzene and Xilene

MTBE – metyl-t-butyl ether

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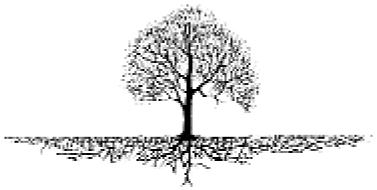

APPLICATIONS

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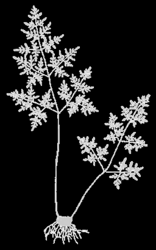
Some applications of phytotechnologies are summarized below:

Phytocapping – technique of landfill cover with the objective to reduce leachate and methane generation. In this technique, trees are established on a layer of soil cap placed over the refuse. Soil cover acts as a ‘storage’ and trees act as ‘bio-pump and filters’.

Riparian buffer strips -vegetated areas next to water resources that protect water resources from nonpoint source pollution and provide bank stabilization and aquatic and wildlife habitat. These are used in stream-water-quality restoration for filtering sediment, nutrients, and pesticides entering from upland agricultural fields.

Hydraulic control - the use of vegetation to influence the movement of ground water and soil water, through the uptake and consumption of large volumes of water. Hydraulic control may influence and potentially contain movement of a ground-water plume, reduce or prevent infiltration and leaching, and induce upward flow of water from the water table through the unsatured zone.



SPECIES WHICH ACTS ON CONTAMINATED SOILS

PHYTOTECHNOLOGIES

How does it work

Operating mechanisms

- Rhizodegradation
- Phytodegradation
- Phytoextraction
- Phytovolatilization
- Evapotranspiration
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Click on the links below to view the corresponding data sheets; the name of each species is followed by the name of the contaminants on which it has effect.

- *Acer-pseudoplatanus*-Zn-Cd-Pb
- *Agrostis-castellana*-As-Pb-Mn-Zn-Cu-Hydrocarbons
- *Agrostis-stolonifera-heavy-metals-arsenic-hydrocarbons*
- *Agrostis-tenuis*-Cu-Zn-Pb-Arsenic
- *Alnus-glutinosa*-Zn-Cd-Pb-Cu
- *Amaranthus-tricolor*-Radionuclides-Hydrocarbons-Cadmium
- *Arundo-donax*-Cd-Ni-As-Pb-Zn-Nutrients
- *Brassica-napus*-Heavy-Metals-Organics
- *Cannabis-sativa*-Cd-Cr-Ni-Pb-Zn-Organics-Radionuclides
- *Cynodon-dactylon*-Organics-Cr-Pb-Zn-Cu
- *Eucalyptus-globulus*-Cd-Zn-Cu-Pb-As-Organics
- *Festuca-arundinacea*-Heavy-Metals-Organics
- *Festuca-rubra*-Cd-Cu-Pb-Zn-Organics
- *Fraxinus-excelsior*-Cd-Pb-Zn-Cu-Organics
- *Helianthus-annuus*-Pb-Cd-Cr-Ni-Radionuclides
- *Holcus-lanatus*-As-Pb-Zn-Cd
- *Linum-usitatissimums*-Cu-Cd-Pb
- *Medicago-lupulina*-Cu-Pb-Ni-Zn
- *Medicago-sativa*-Cd-Cr-Cu-Ni-Zn-Organics
- *Phalaris-arundinacea*-heavy-metals-organics-nutrients
- *Phragmites-australis*-heavy-metals-organics-nutrients
- **POPULUS spp.**
- *Pteris vittata-As*
- *Robinia-pseudoacacia*-heavy-metals-organics
- **SALIX spp.**
- *Tamarix* spp.
- *Zea-mays*-heavy-metals-organic-contaminants

The photographs in the data sheets are published with the reference to the source, we thank all the authors.

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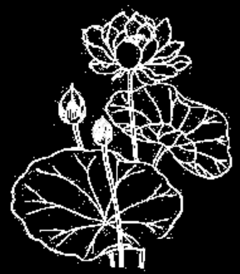

SPECIES WHICH ACTS ON CONTAMINATED WATER

PHYTOTECHNOLOGIES

How does it work

Operating mechanisms

- *Rhizodegradation*
- *Phytodegradation*
- *Phytoextraction*
- *Phytovolatilization*
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- *Phytostabilization*

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QUALITY CONTROL PORTFOLIO IRET-CNR

Click on the links below to view the corresponding data sheets; the name of each species is followed by the name of the contaminants on which it has effect.
Some of the species listed below, although they are not water plants, they can be grown hydroponically.

Amaranthus-tricolor-Radionuclides-Hydrocarbons-Cadmium

Arundo-donax-Cd-Ni-As-Pb-Zn-Nutrients

Cannabis-sativa-Cd-Cr-Ni-Pb-Zn-Organics-Radionuclides

Eucalyptus-globulus-Cd-Zn-Cu-Pb-As-Organics

Helianthus-annuus-Pb-Cd-Cr-Ni-Radionuclides

Phalaris-arundinacea-heavy-metals-organics-nutrients

Phragmites-australis-heavy-metals-organics-nutrients

POPULUS spp.

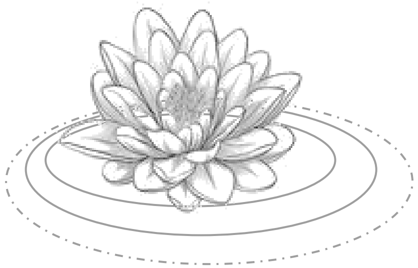
Pteris vittata-As

Robinia-pseudoacacia-heavy-metals-organics

SALIX spp.

Tamarix spp.

Zea-mays-heavy-metals-organic-contaminants



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