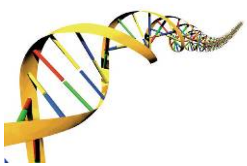
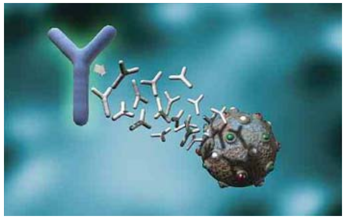
Stakes and Limits of Bioremediation

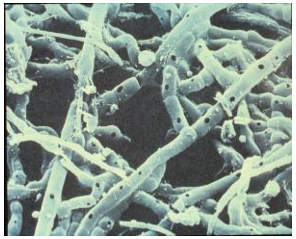
Bioremediation

The branch of biotechnology that uses biological processes to overcome environmental problems

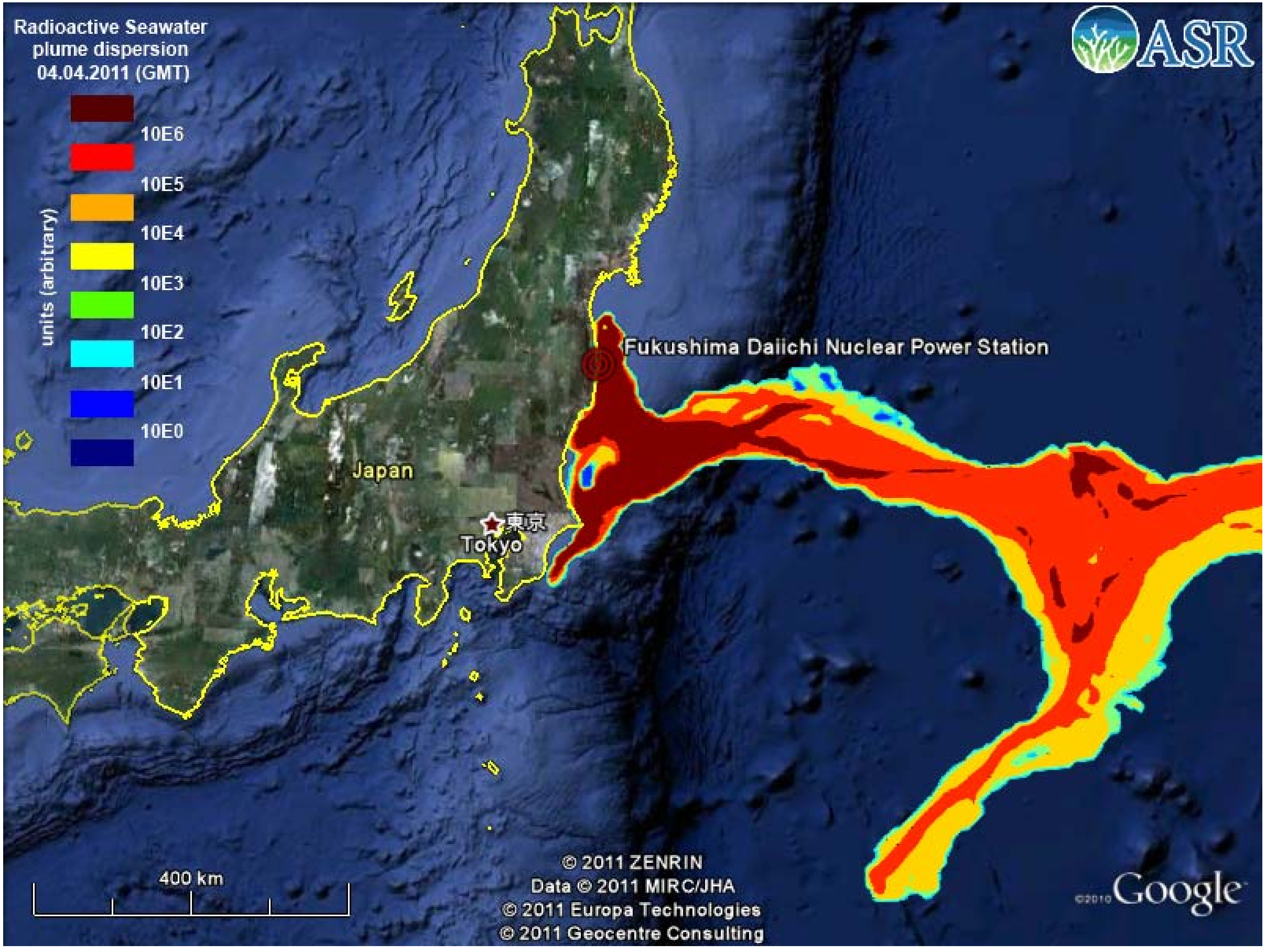
The use of biological agents, such as bacteria, fungi, or green plants, to remove or neutralize contaminants, as in polluted soil or water.
The use of green plants to decontaminate polluted soil or water is called **phytoremediation**.





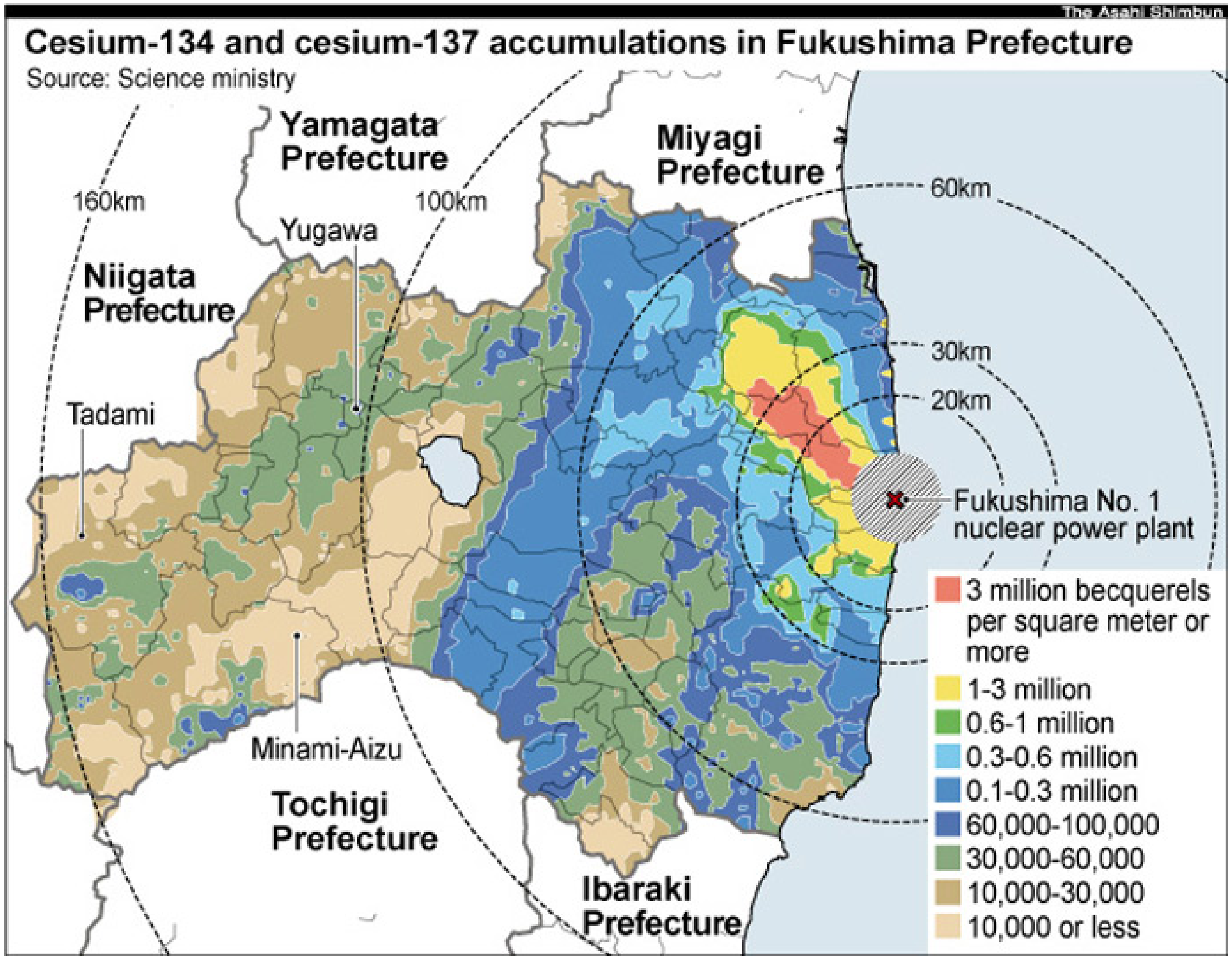


Bioremediation and the cleanup of contaminated environments

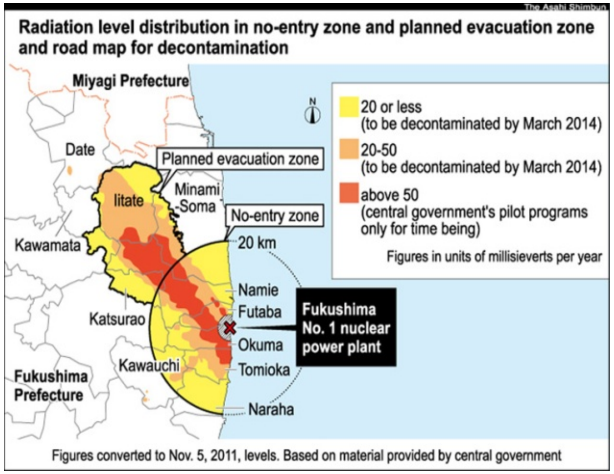

Radioactive Seawater plume dispersion 04.04.2011 (GMT)
units (arbitrary)
10E6
10E5
10E4
10E3
10E2
10E1
10E0
ASR
Fukushima Daiichi Nuclear Power Station
Japan
東京
Tokyo
400 km
© 2011 ZENRIN
Data © 2011 MIRC/JHA
© 2011 Europa Technologies
© 2011 Geocentre Consulting
Google

Seuil de 5 mSv/an
1800 km^2

Seuil de 1 mSv/an
13000 km^2



Post-Fukushima context



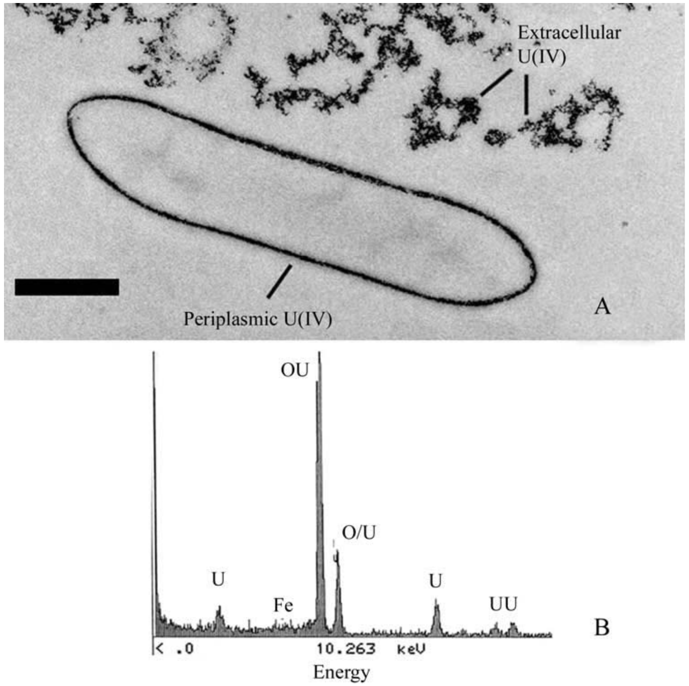
First option:
Use of physico-chemical approaches for decontamination
Removal of a soil layer (5-10 cm), deep plowing, adding K

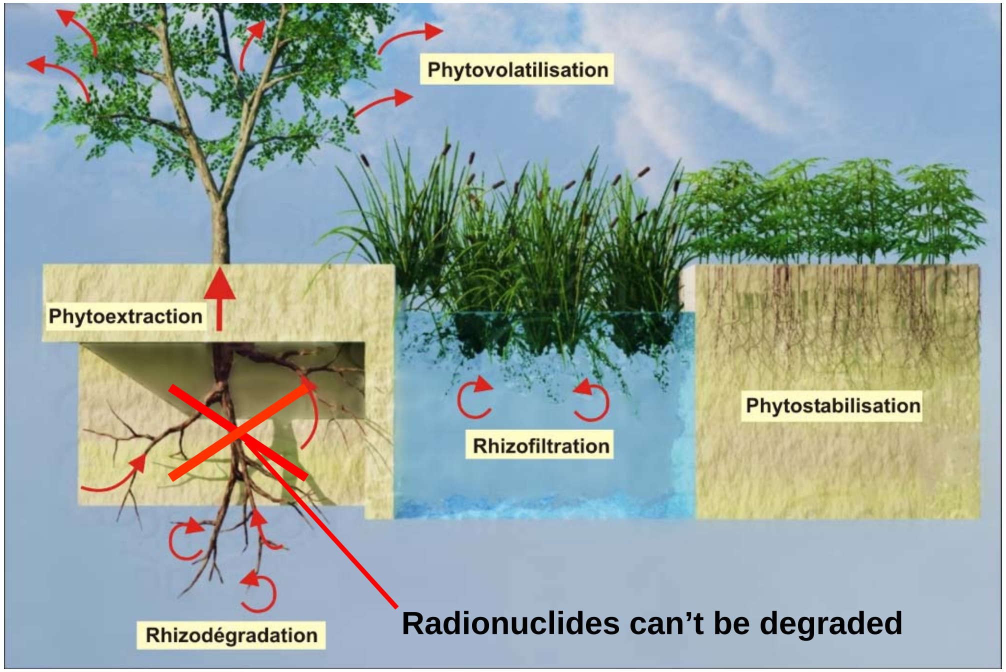
Cleanup < 6 mSv/year: 1.8 10^3 km^2 x 5 cm soil
→ 10^8 m^3 of $^{137/134}$Cs contaminated waste!!

No industrial means to stock and treat such an amount of contaminated material

Is bioremediation of radionuclides an option ?

There is no alternative for large scale remediation





Bioremediation can change their bioavaliability

Phytoremediation can stabilize and extract the contamination

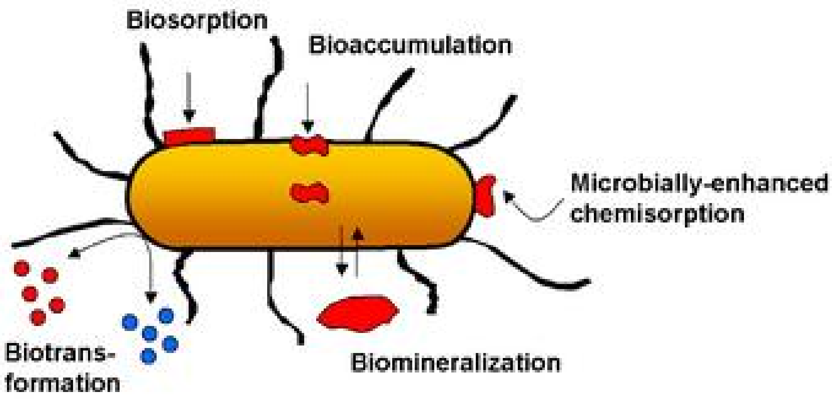
Major interest of bioremediation

• Works *in situ* with a minor impact on the environment compared to physical or chemical techniques; preservation of the landscape and of soil fertility for the future

• Can remediate large areas with moderate to low contamination and decreases erosion by wind and water
• Cost is moderate, generally 10 to 100 fold lower than other techniques and extended in time
• Well accepted by the population as a "green technology"

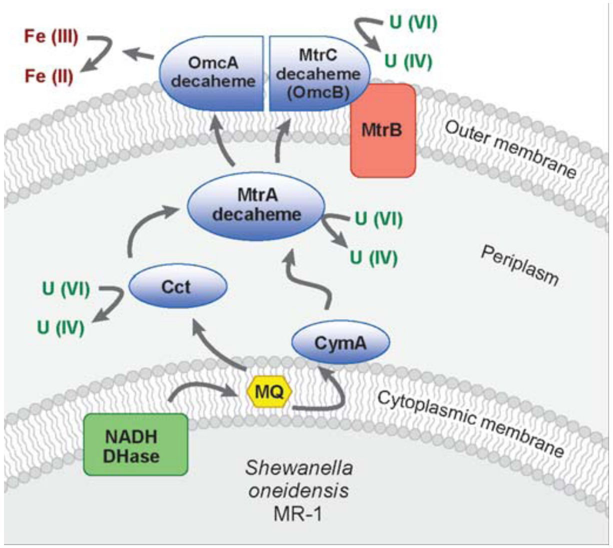
Recycling of biomass through the production of energy is economically interesting and creates an activity in areas where agronomy is impaired

Bioremediation using bacteria and electron transfers

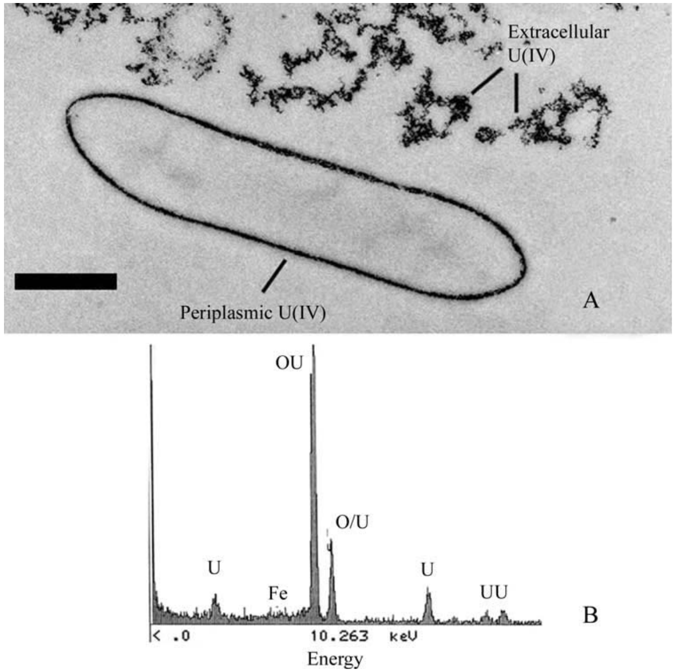


U(VI) soluble in water and toxic

U(IV) precipitation, non bioavailable

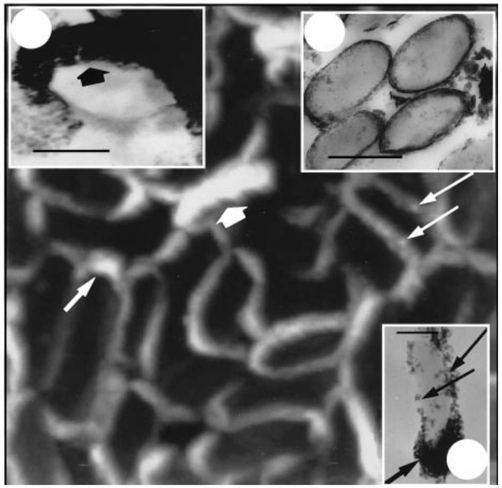


Geobacter metallireducens
Shewanella oneidensis
Desulfotomaculum reducens
Thermoterrabacterium ferrireducens

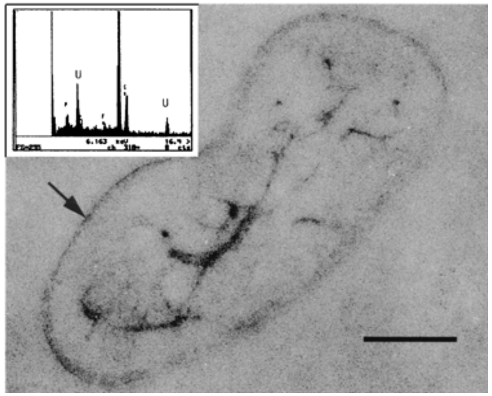


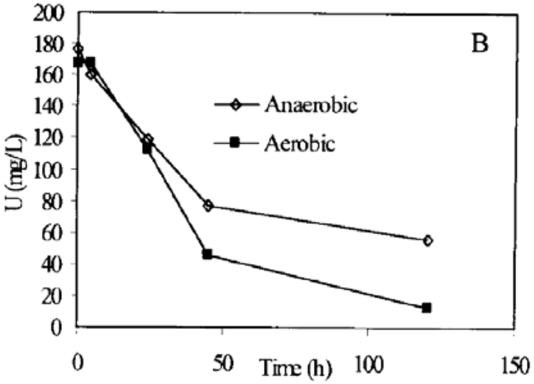
Bioprecipitation of U, Tc, Pd, Pu… using bacteria

U bioprecipitation due to a phosphatase activity leading to the formation of UO_2PO_4 complexes

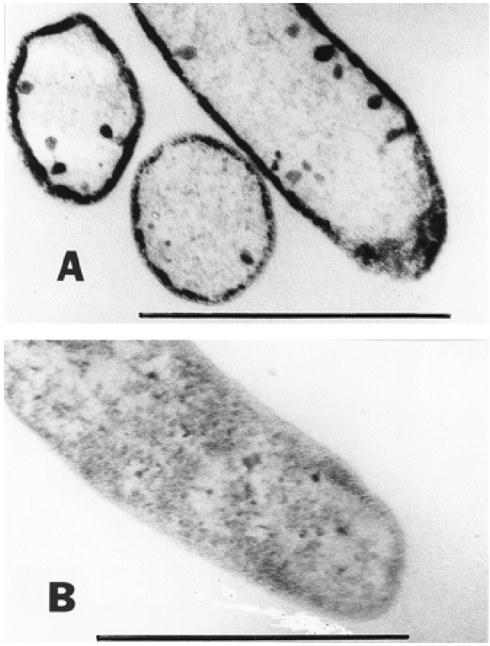


Pseudomonas CRB5 : granules of U in the cytoplasme associated with polyphosphates

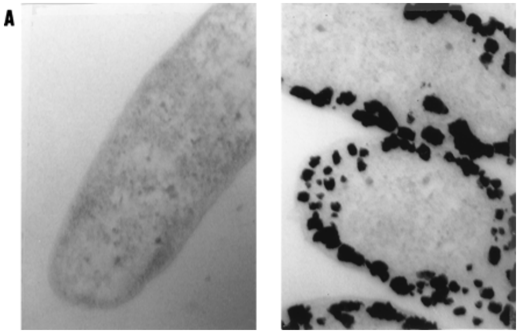




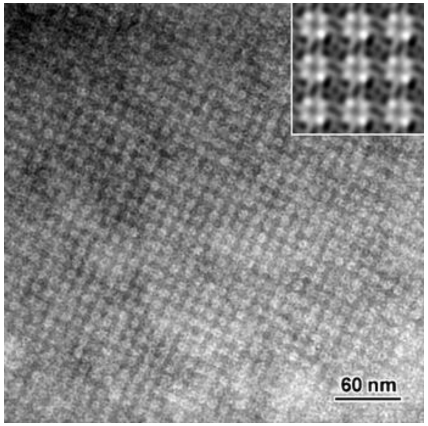
Tc Reduction and accumulation at the cell wall of *Shewanella*



Pd accumulation in sulfate-reducing bacteria



Bioprecipitation of U, Tc, Pu… using bacteria



Metal binding by bacteria from uranium mining waste piles and its technological applications

K. Pollman et al. (2006) Biotechnology Advances 24, 58– 68

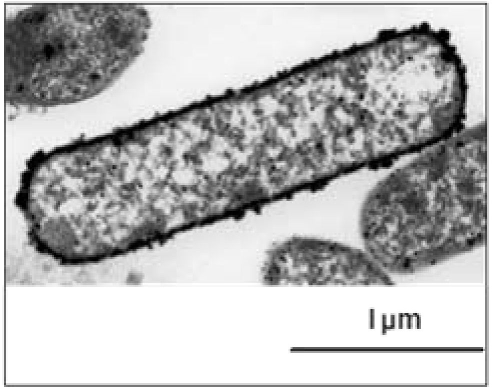


Fig. 4. TEM micrograph of Pd nanoclusters deposited on the cell surface of *Bacillus sphaericus* JG-A12.

Bacillus sphaericus

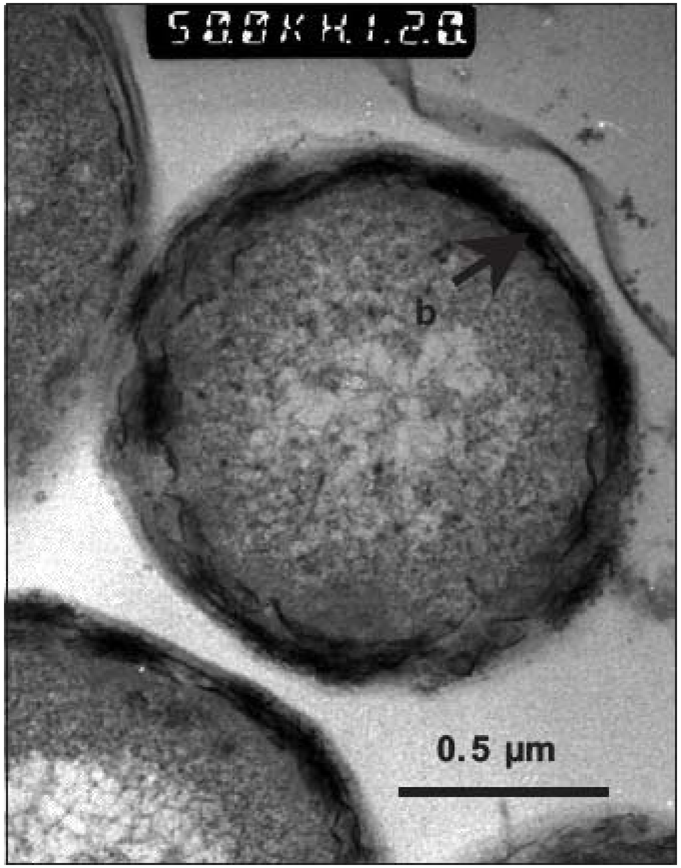
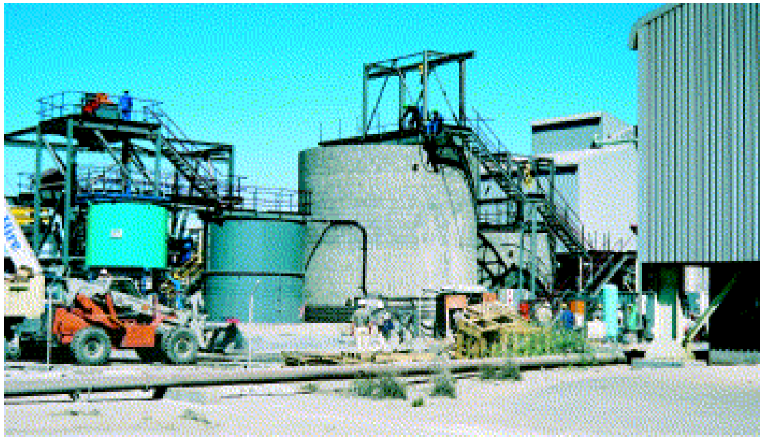
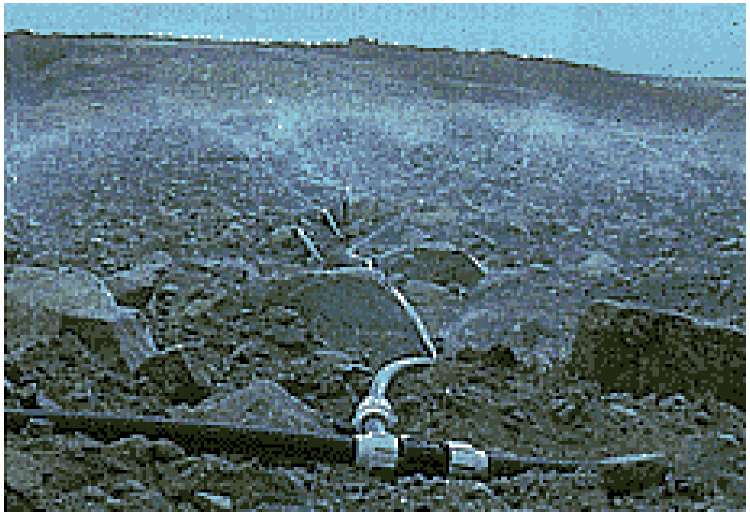


Fig. 2. TEM micrograph of uranium accumulated on the cell surface of *Bacillus sphaericus* JG-A12.

Bacterias can be integrated in various polymers and included in a filtration chain



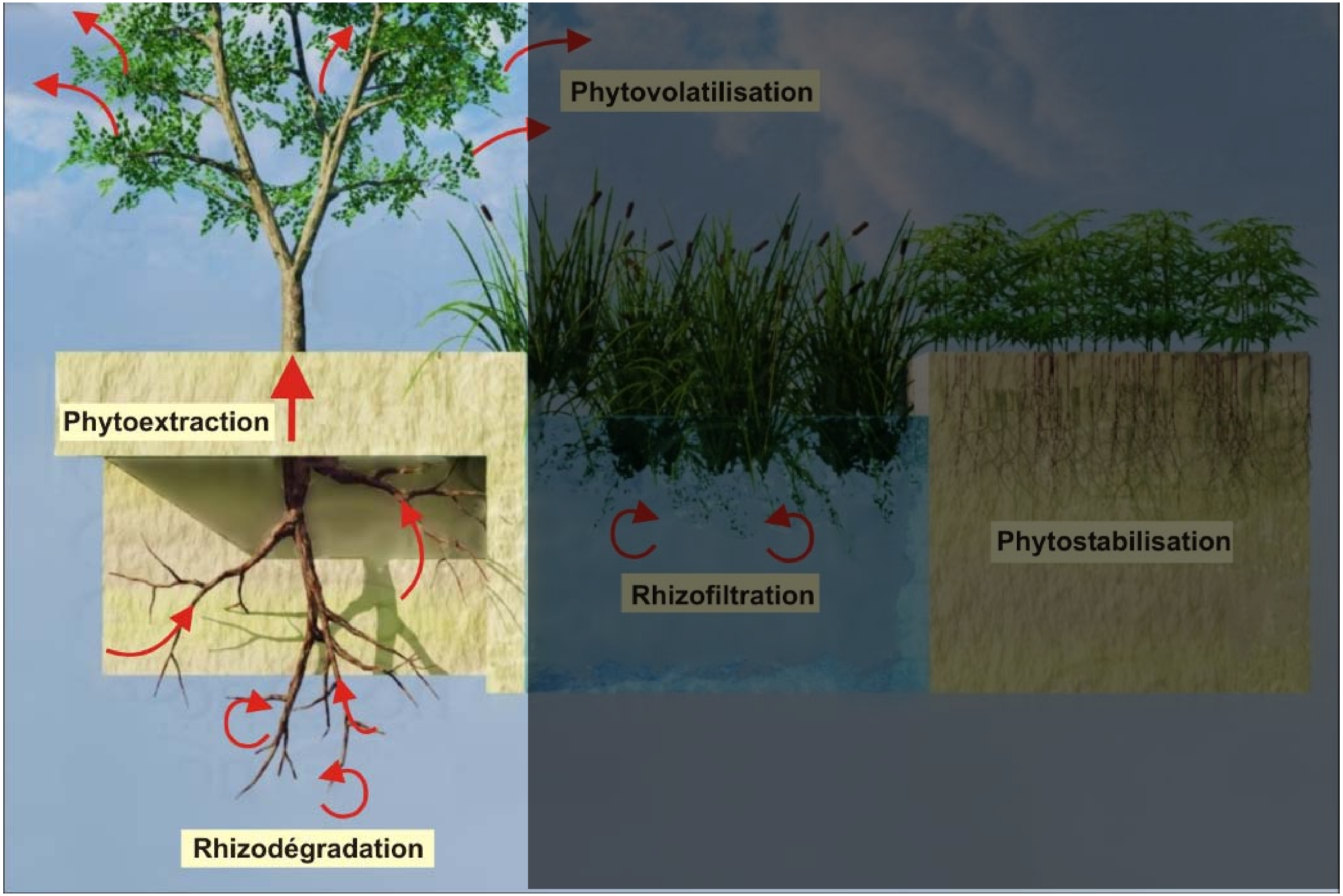
Composite ceramic tanks for thermophile bacteria 300 m^3
Perring, South Africa gold extraction from (arseno)pyrite



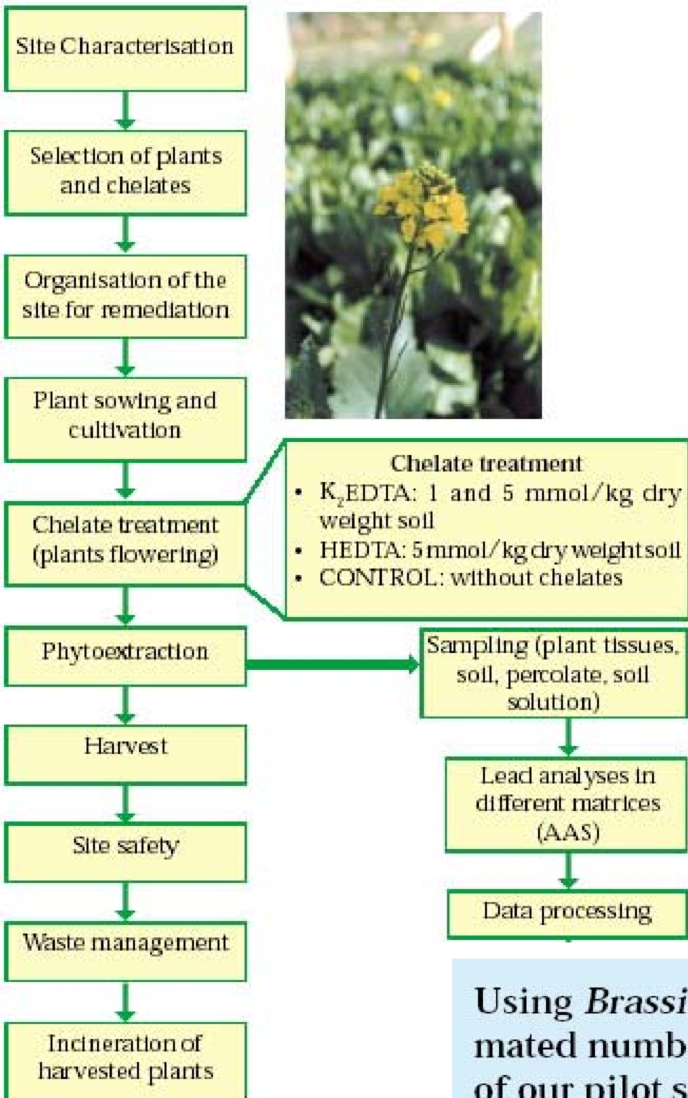
Bacterias can also be used directly on the field for bioleaching or biostabilization

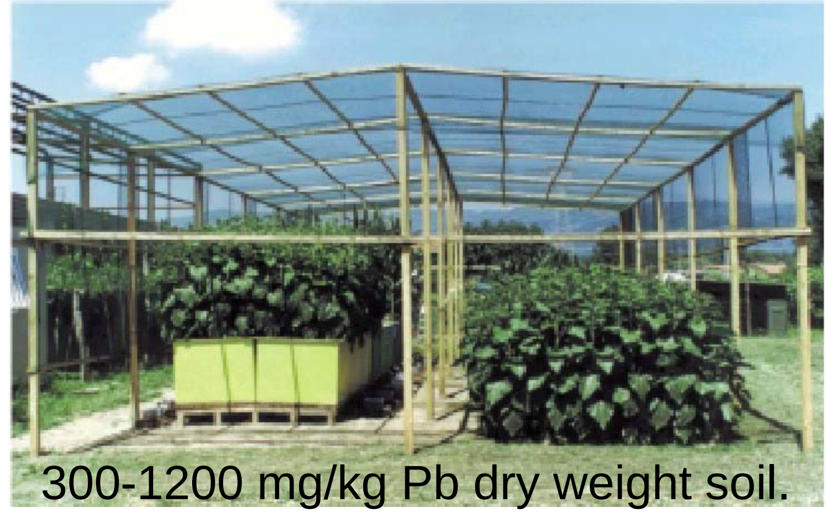
Bioleaching of U from minerals containing 0.05% à 0.15% U_3O_8

Phytoextraction of radionuclides
Ext = Biomass x TC



PhyLeS Project





	Phytoextraction coefficient (PhC)
+ K_2EDTA, *B. juncea* cv. 426308	2.7
+ HEDTA, *B. juncea* cv. Chao Chow	1.78
+ K_2EDTA, *B. juncea* cv. Chao Chow	0.82
+ K_2EDTA, sunflower	0.34
+ HEDTA, sunflower	0.34
Control, *B. juncea* cv. 426308	0.18
Control, *B. juncea* cv. Chao Chow	0.06
Control, sunflower	0.03

x90

Using *Brassica juncea* cv. 426308 and 5 mmol HEDTA/ kg d.w. soil, the estimated number of years needed to phytoremediate a soil comparable to that of our pilot system is ≅ 20

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Journal of Environmental Radioactivity 72 (2004) 41–45
JOURNAL OF ENVIRONMENTAL RADIOACTIVITY
www.elsevier.com/locate/jenvrad

Bioavailability Is essential

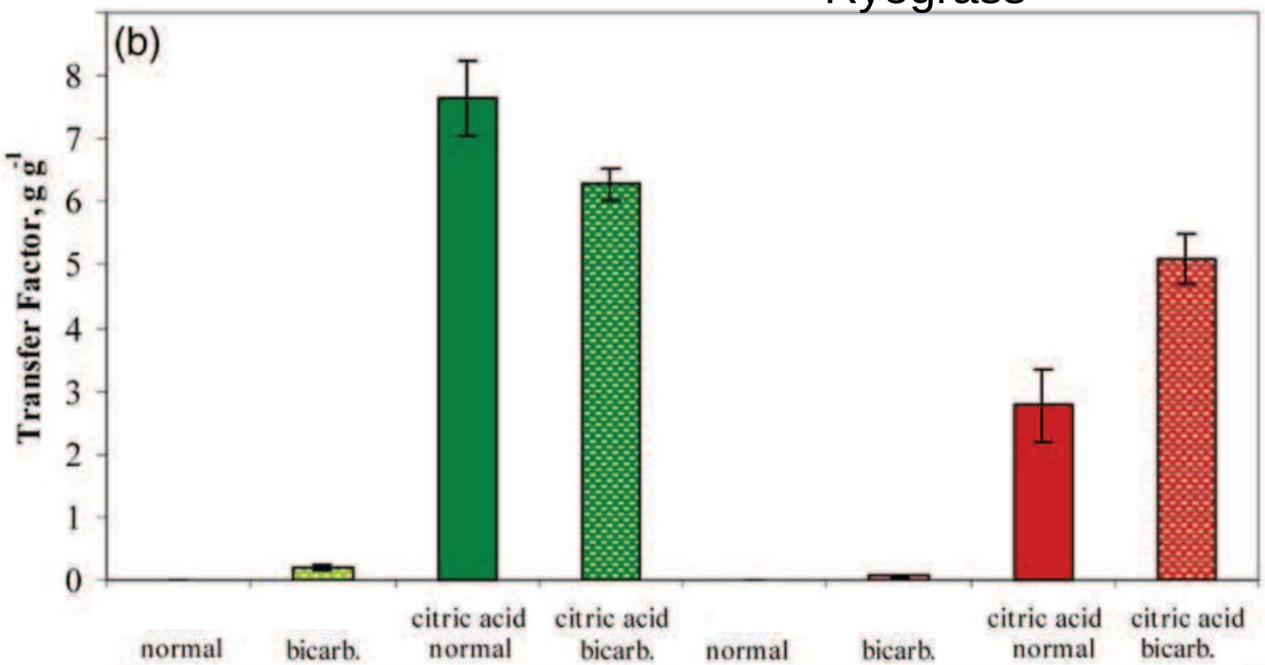
Phytoextraction for clean-up of low-level uranium contaminated soil evaluated

H. Vandenhove *, M. Van Hees

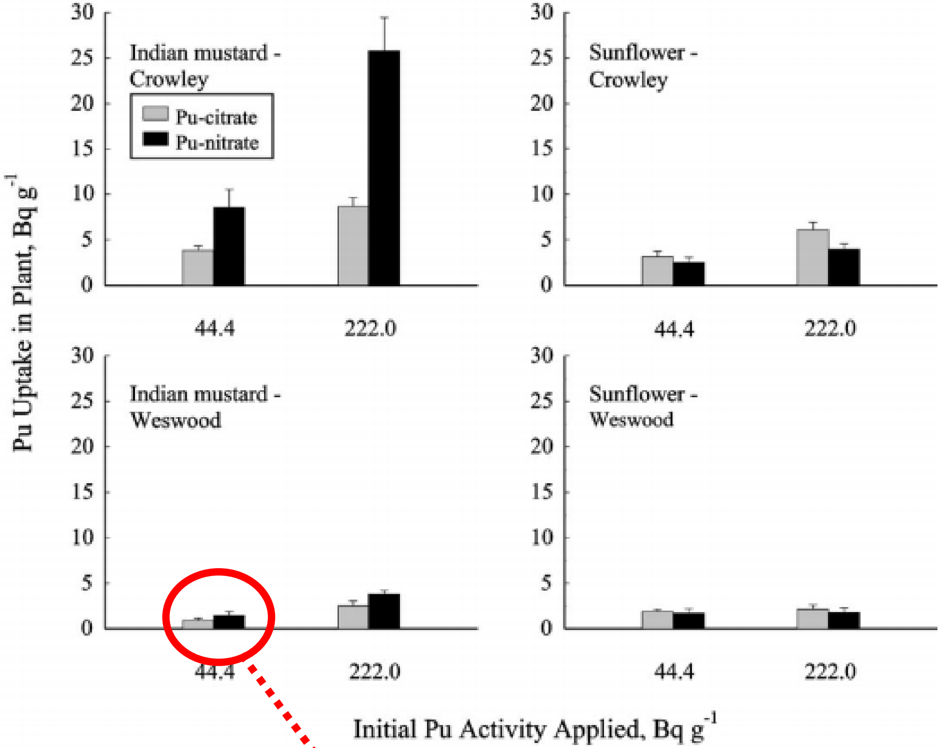
Belgian Nuclear Research Centre, SCK·CEN, Radioecology Section, Radiation Protection Department, Boeretang 200, B-2400 Mol, Belgium

Indian mustard

Ryegrass



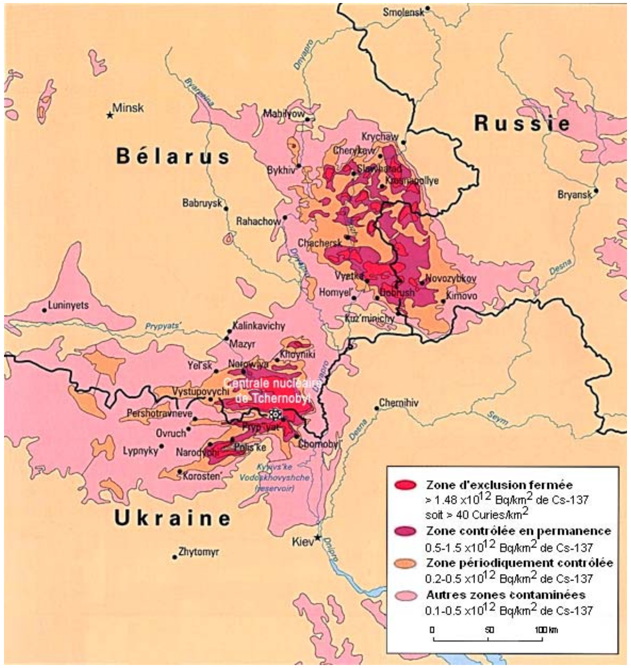
Bioavailability Is essential



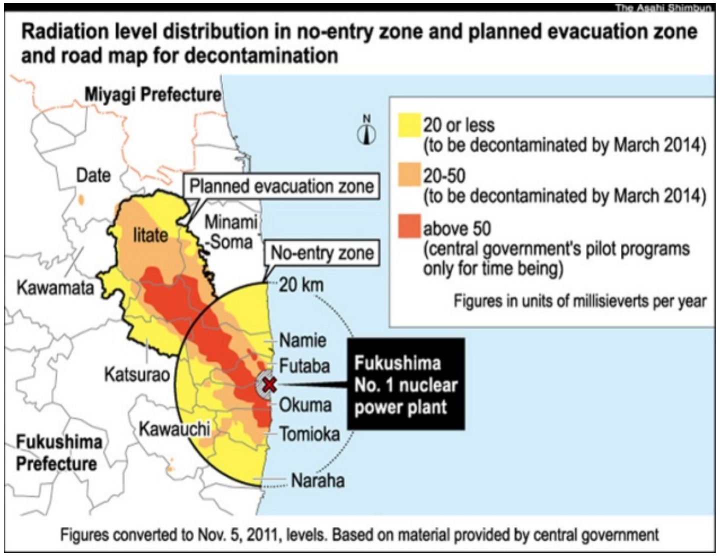
Uptake of ^{239}PU by Indian mustard (*Brassica juncea*) and sunflower (*Helianthus annuus*) from different soils as affected by Pu–nitrate with DTPA applications

Pu source	Activity level of Pu (Bq g^{-1})	Amounts of DTPA applied	Pu uptake[a]			
			Crowley soil (Bq g^{-1})		Weswood soil (Bq g^{-1})	
			Indian mustard	Sunflower	Indian mustard	Sunflower
$^{239}Pu(NO_3)_4$	44.40	0	8.63 ± 1.92 a	2.47 ± 0.50 b	1.50 ± 0.40 b	1.77 ± 0.43 b
		10	208.69 ± 30.68 a	137.48 ± 6.38 b	90.95 ± 10.61 c	15.02 ± 2.66 d
		50	247.11 ± 33.13 a	269.15 ± 33.53 ab	163.93 ± 8.26 c	41.38 ± 7.61 d
$^{239}Pu(NO_3)_4$	222.0	0	25.88 ± 3.59 a	4.09 ± 0.49 b	3.84 ± 0.38 b	1.84 ± 0.45 b
		10	338.77 ± 16.28 a	168.98 ± 11.42 b	273.57 ± 19.66 c	65.82 ± 4.64 d
		50	788.48 ± 104.55 a	907.83 ± 47.67 b	349.85 ± 64.27 c	112.17 ± 7.80 d

With DTPA, increase in uptake by 30 to 100 fold



Cs is the most extended contaminant



Cs moves slowly in soils

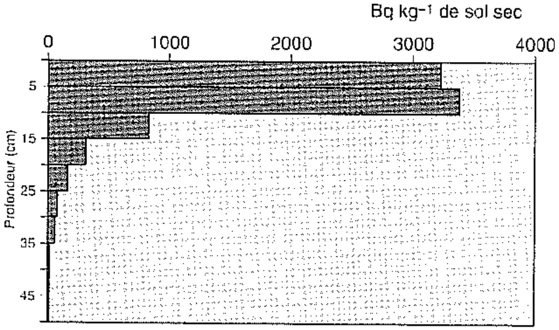
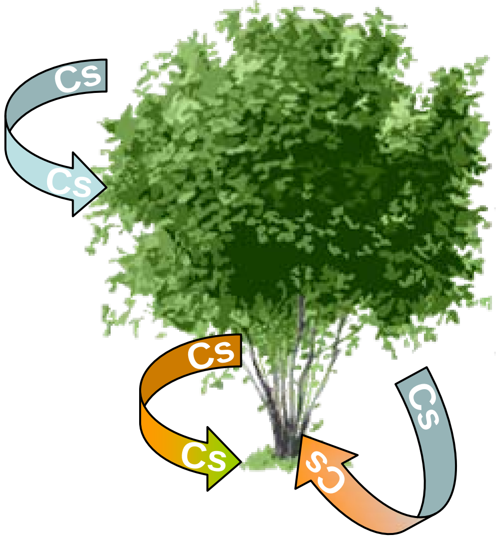


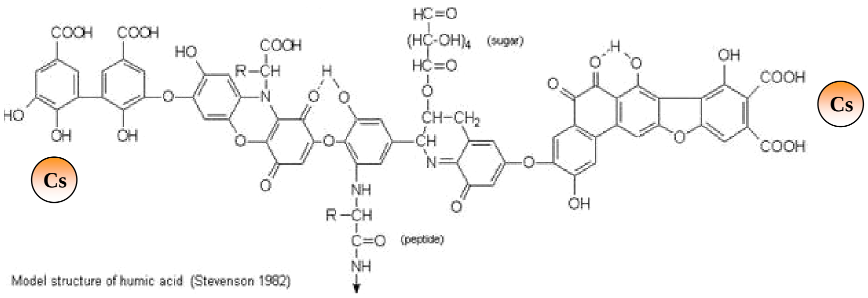
Figure 5.3. Répartition en profondeur du ^{137}Cs dans un sol de vigne 30 ans après son apport dans les 10 premiers centimètres de la couche de surface (Grauby, 1993).

Plants recycle soil Cs



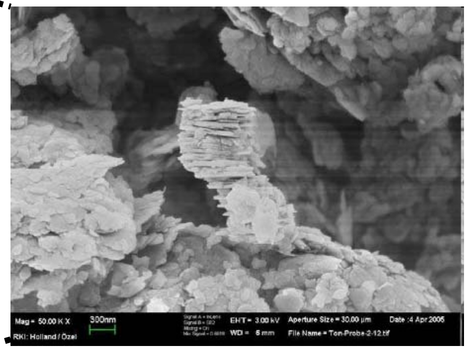
Cs interacts with soil particles

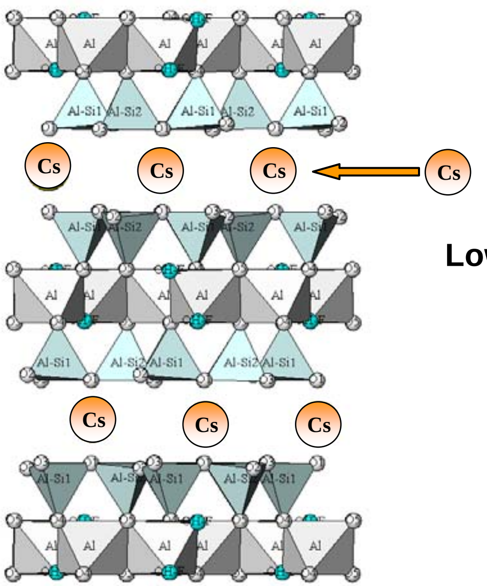
exchangeable



Model structure of humic acid (Stevenson 1982)

Strongly fixed





Low hydration energy

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Environmental Pollution, Vol. 97, No. 1 2, pp. 11 15, 1997

0269-7491/97 $17.00 + 0.00
PII: S0269-7491(97)00090-0

DIFFERENCES IN ROOT UPTAKE OF RADIOCAESIUM BY 30 PLANT TAXA

Martin R. Broadley and Neil J. Willey*

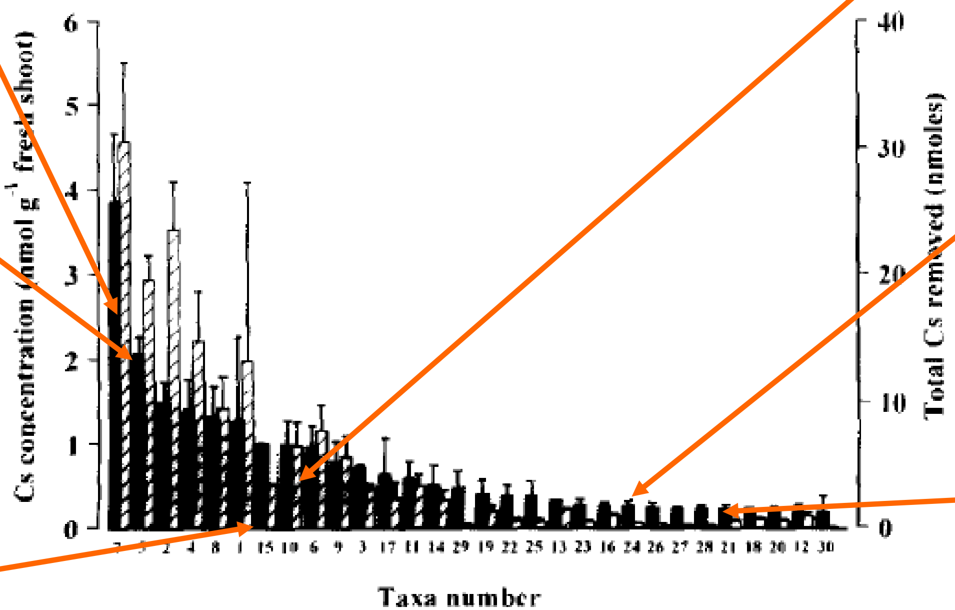


Fig. 1. Shoot Cs concentration and total Cs removed after 6 h exposure to 20 ml of radiolabelled 10 μmol CsCl (Error bars represent standard error of the mean; for taxa numbering, see Table 1).

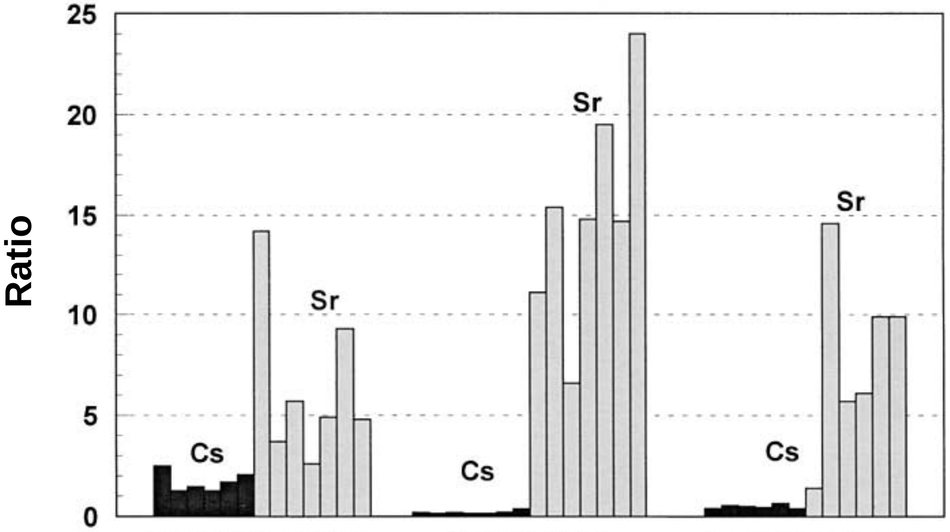
Cs phytoextraction
the Brookhaven example

kBq/kg **^{90}Sr 0.02 – 1.4, ^{137}Cs 0.02-110**

Amaranthus retroflexus

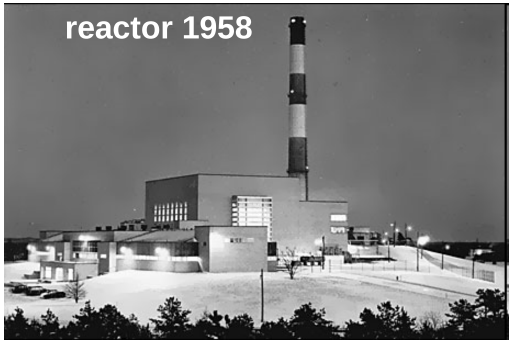
Brassica juncea

Phaseolus acutifolius



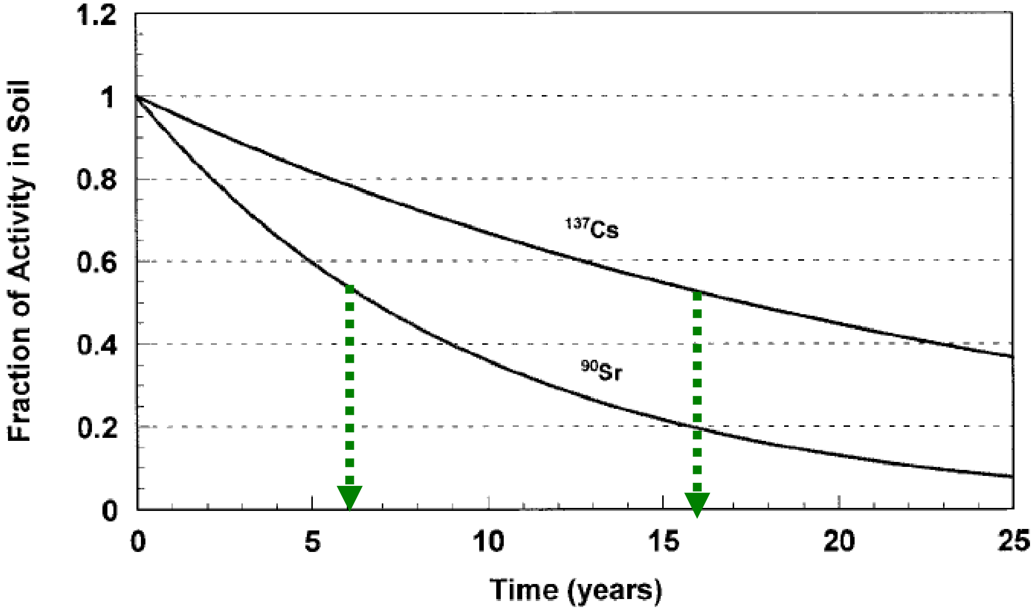
Fuhrmann *et al.* ***J Environ Qual*** 2002

Cs phytoextraction; the Brookhaven example



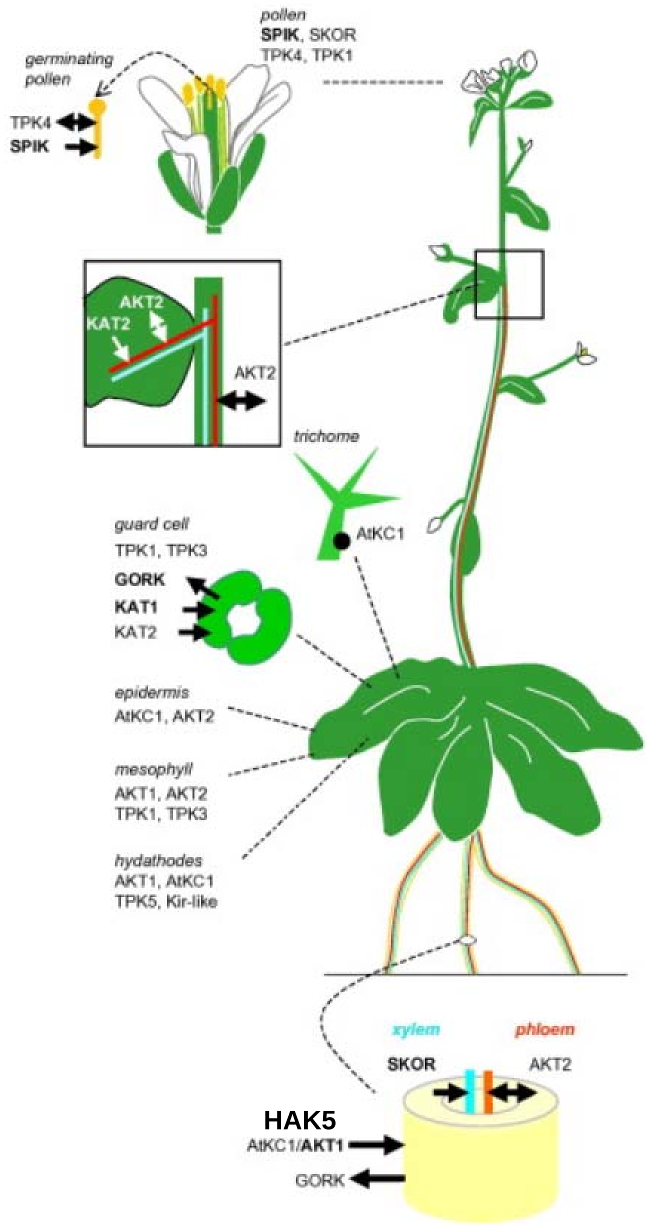
kBq/kg ^{90}**Sr 0.02 – 1.4,** ^{137}**Cs 0.02-110**

Amaranthus retroflexus



Soil plant transfer of Cs
What are the molecular processes ?

Screening genes to understand the processes of Cs uptake in plants

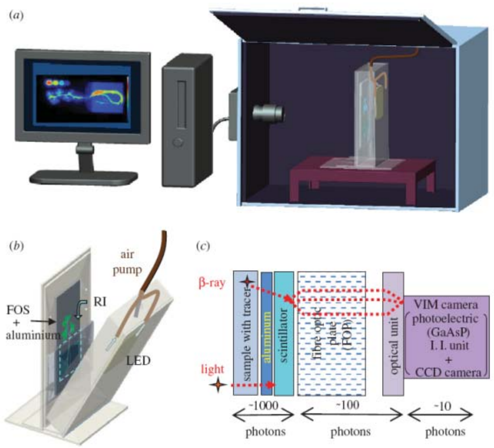


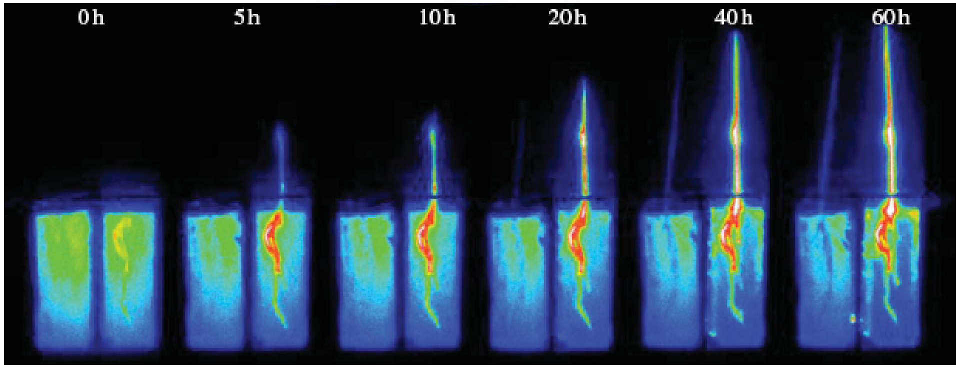
GORK ←
AKT1 ←
AKT2 ←
AtKC1 ←

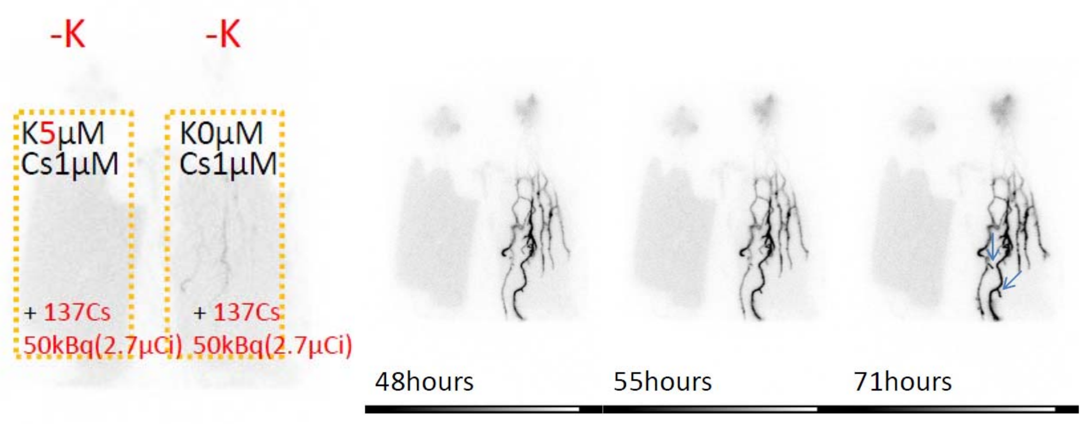
SKOR ←
AKT2 ←
GORK ←
AKT1 ←
AtKC1 ←

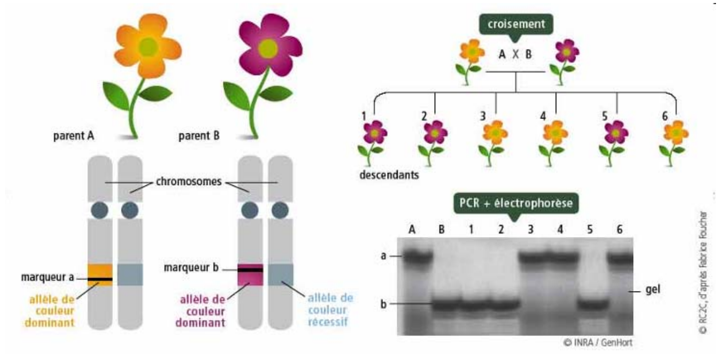
Arabidopsis

Screening genes to understand the processes of Cs uptake in plants

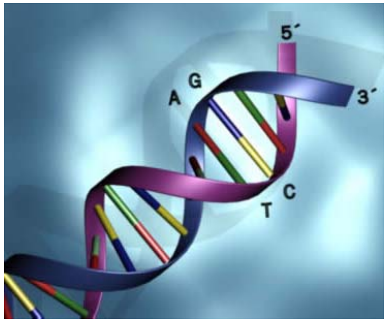




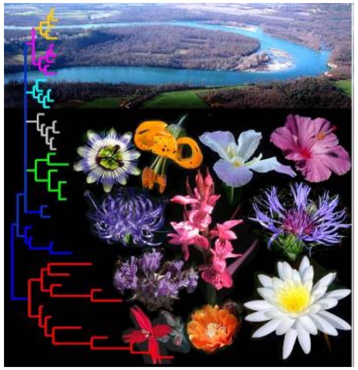


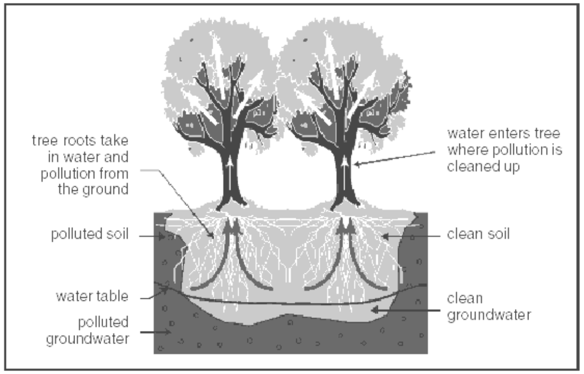


Genetics



Identification of molecular markers





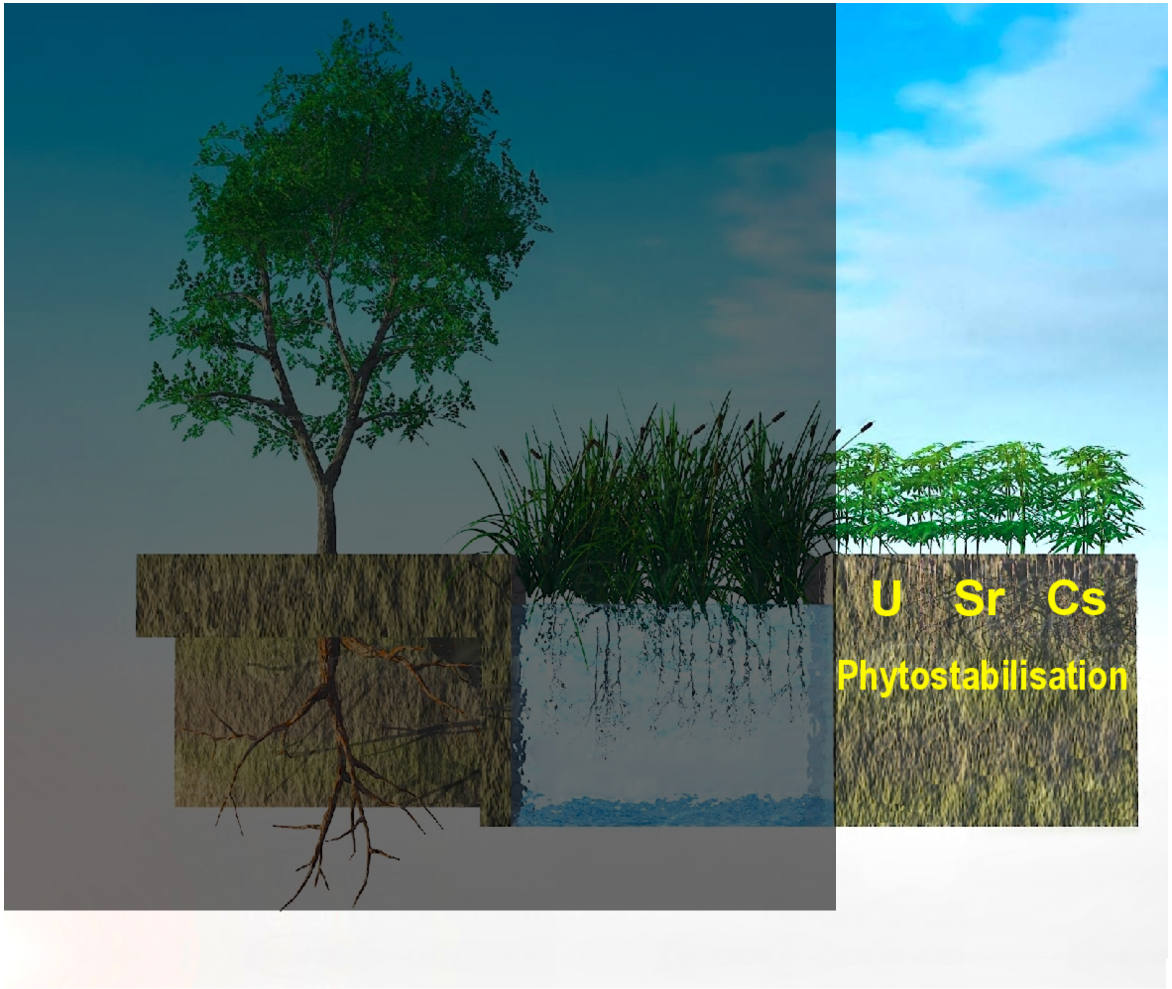
Safe food

Phytoremediation

Biodiversity

Biotechnologies

Phytostabilization



Phytostabilisation of arsenic

La Combe du Saut, projet DIFPOLMINE

DIFPOLMINE
Diffuse Pollution
from Mining Activities

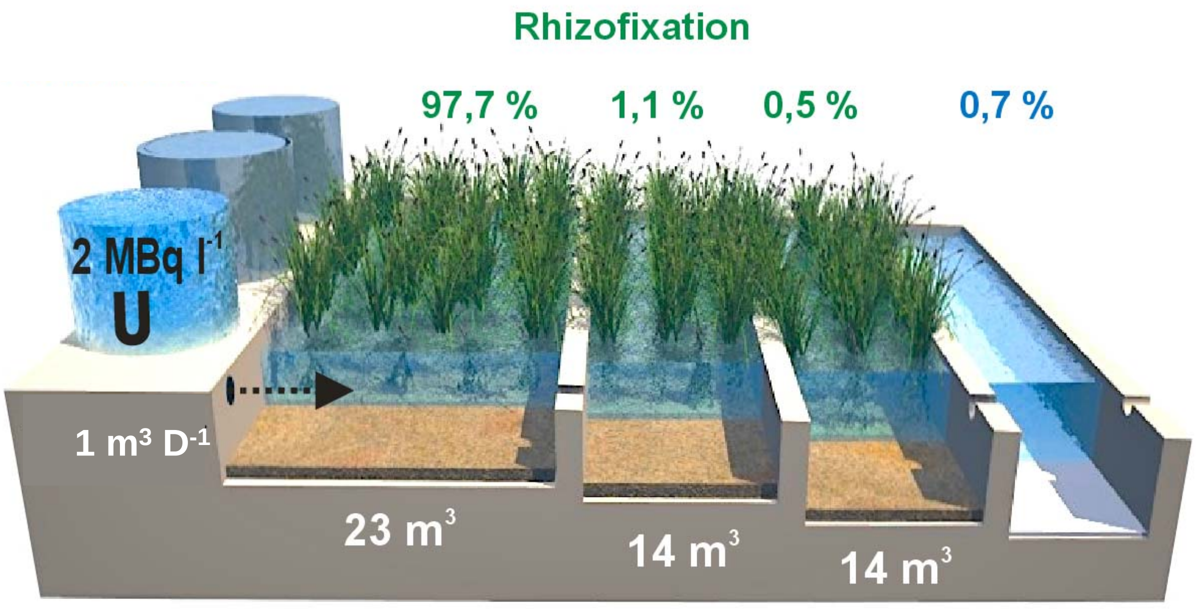
Figure 33. La Combe du Saut in December 2006.

Phytostabilization

Rhizofiltration

Phytoremediation of Uranium by successive ponds

Ex situ



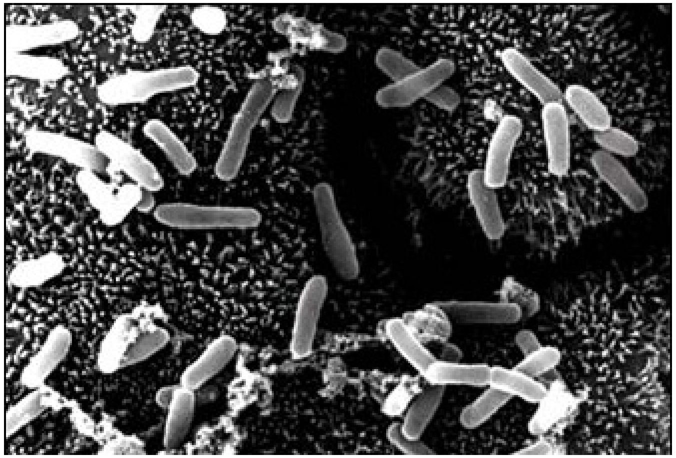
Timofeeva-Ressovskaia. ***Proc. Inst Biol.*** 1963

Phytoremediation of Uranium in Tchernobyl and Ashtabula

Ashtabula (OHIO) (U, Tc, TCE)

Tchernobyl (U)

Injection of polylactate ester, acetate

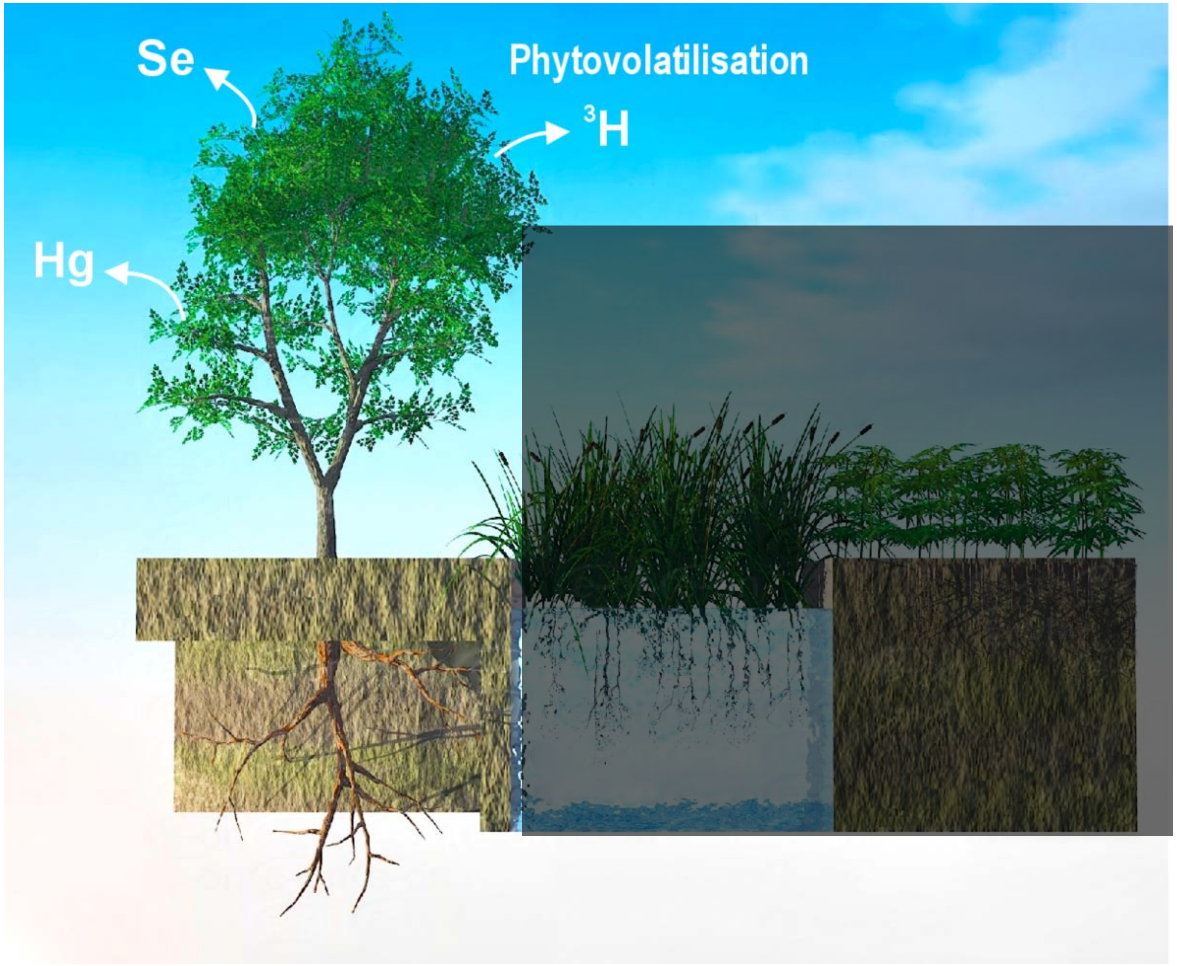


Geobacter U(VI) → U(IV)

rhizofiltration *In situ*

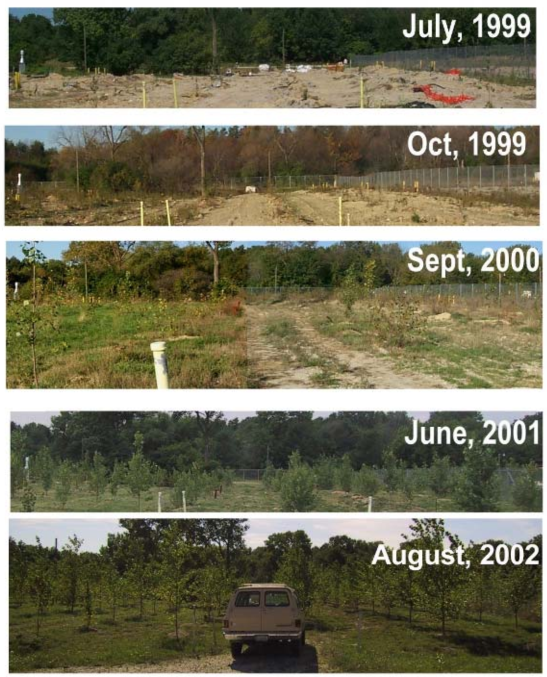
TF 5000-30000 in roots at pH 5,5

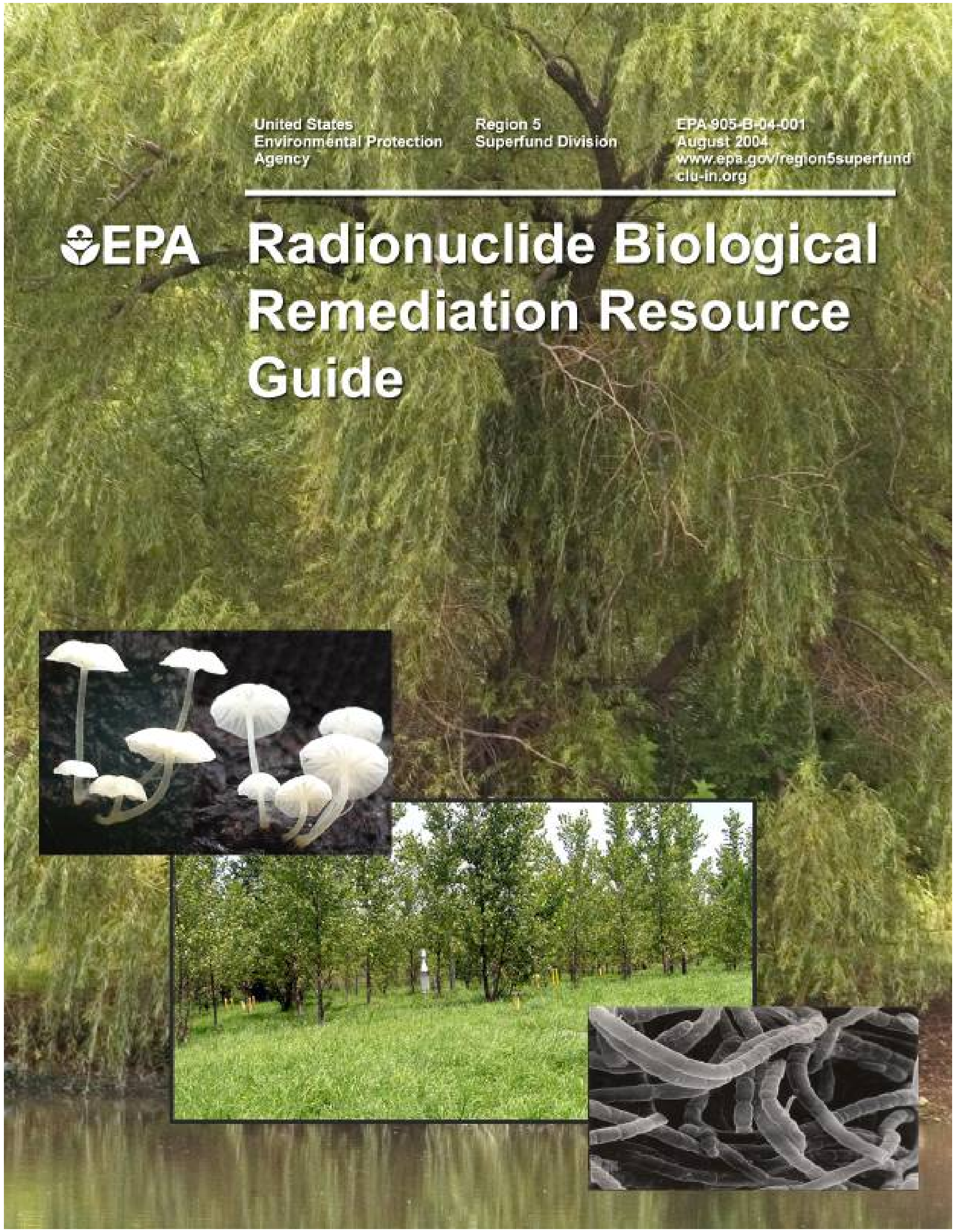
Phytovolatilization



Phytovolatilization

Enrico Fermi, December 1942
First controled chain reaction

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Environmental Protection
Agency
Region 5
Superfund Division
EPA 905-B-04-001
August 2004
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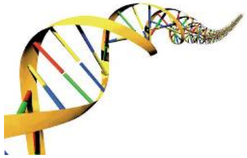
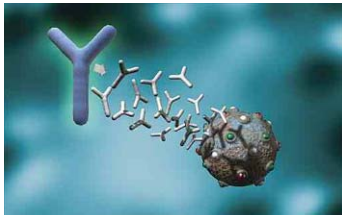
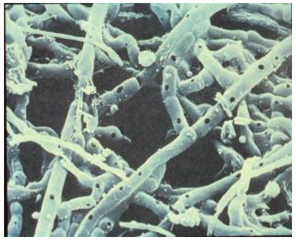
EPA
Radionuclide Biological
Remediation Resource
Guide

Limits of bioremediation

- Duration of the treatment needs to be improved to reach a result in less than a decade
- Contamination must be moderate
- Each case needs a new scenario, a multiparametric system
- Highly dependent on the environment
- Exploitation of biomass increases the economic attractivity of the technique
- Ideally must be combined with a cogenerating energy technology
- Needs further researches to improve efficiency
- Poorly attractive to private industry due to a stochastic demand

Thanks for your attention !