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Radiochemical laboratory

Combined technology for radioactive contaminated soil remediation based on application of hydroseparation, chemical leaching and addition of natural organic and mineral absorbers
ISTC Project # B-859

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Project B-859

Technology for radioactive contaminated soil remediation based on application of hydroseparation, chemical leaching and addition of natural organic and mineral absorbers.

Goal of the research

Examine soil samples contaminated with ^{137}Cs and ^{90}Sr due to Chernobyl NPP accident:

– soils of agricultural regions,

– soils of the exclusion zone of Chernobyl NPP.

Great variety of soils characteristics:

– acidity,

– content of organic carbon and mineral part,

– type of humus,

– absorption capacity,

– sum of absorbed bases and K^{+}, Ca^{2+}, Mg^{2+} etc.

Obtained results

Table 1 - ^{137}Cs distribution throughout the uppermost layer (1 cm) fractions of the sandy and sandy-loam soils

Size, mm	Relative mass, %	Specific activity, Bq/g	Relative activity, %
> 0.05	80.10	1.30	33.46
0.05 - 0.005	20.05	33.0	58.83
< 0.005	0.9	18.80	6.9

Table 2 - ^{137}Cs distribution throughout the deeper soil layers of the sandy and sandy-loam soils

Depth, cm	Relative mass,%		Relative activity, %		
	> 0.05 mm	0.05 - 0.005 mm	> 0.05 mm	0.05 - 0.005 mm	< 0.005 mm
0-3	85.3	10.5	27.4	66.6	9.5
2-8	85.0	6.7	22.5	39.3	36.4

1 – Hydroseparation

Table 3 - ^{137}Cs content in silt fraction depending on soil type

Soil	^{137}Cs content in silt fraction, %
Sand & sod-podsol sand	25-50
Peat-clay highly-humus	> 80
Turf-humus	> 70
Peat-marsh	~ 80
Peat	> 60

Conclusion

- Hydroseparation allows to extract soil fraction < 0.05 mm – fine fraction
- Fine soil fraction contains:

  - organic substances (~ 5 – 15 % of total soil mass)

  - radionuclides (~ 50 – 80 % of total radioactivity)
- Decontamination factor, $K_d \approx 3$
- For different soil types these values may vary significantely
- Hydroseparation can be effectively applied for soils with high concentration of fine soil fraction
- Preliminary ultra-sound treatment of soil suspension in water could be used to disaggregate soil particles.

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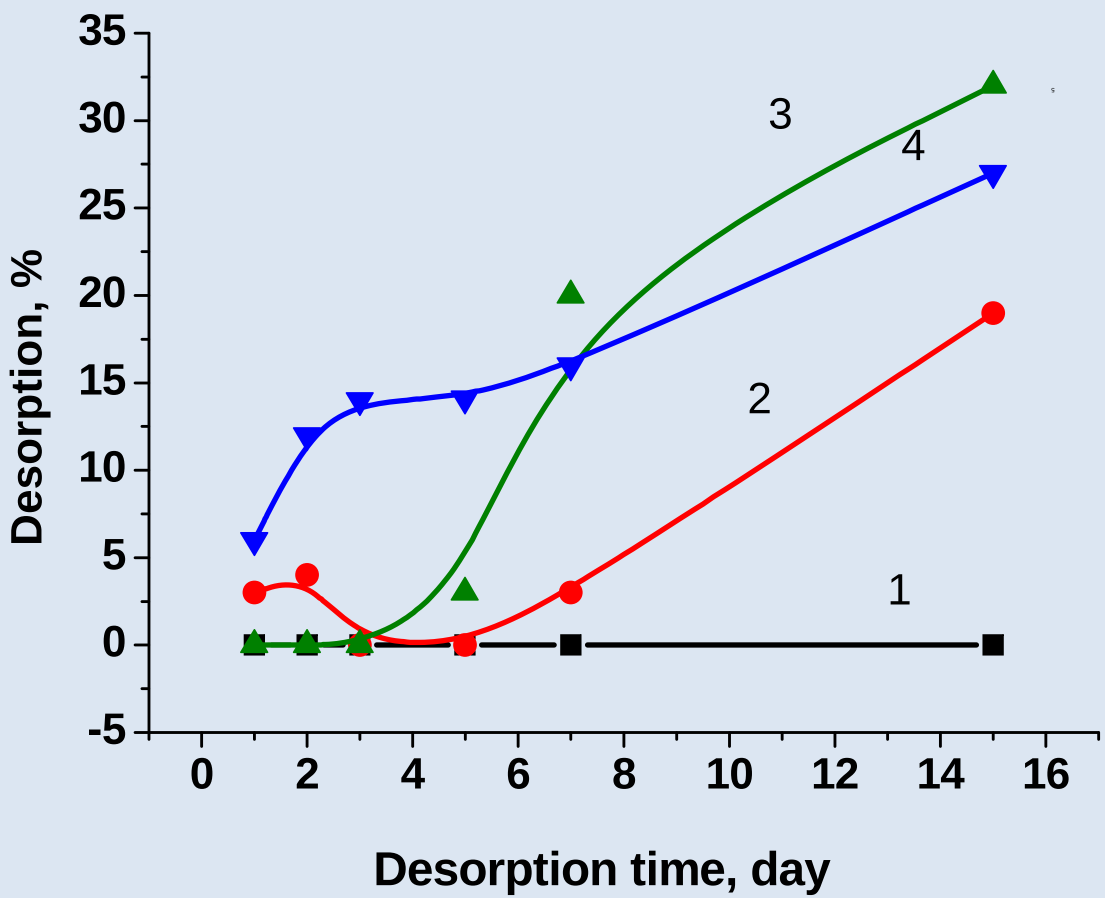
2 – Chemical leaching

Kinetics of ^{137}Cs desorption from silt soil fraction in the presence of K^+ and Cs^+_{stable} cation



T = 20 ° C

1 – [K^+, Cs^+_{stable}] = 10^{-5} mole/l

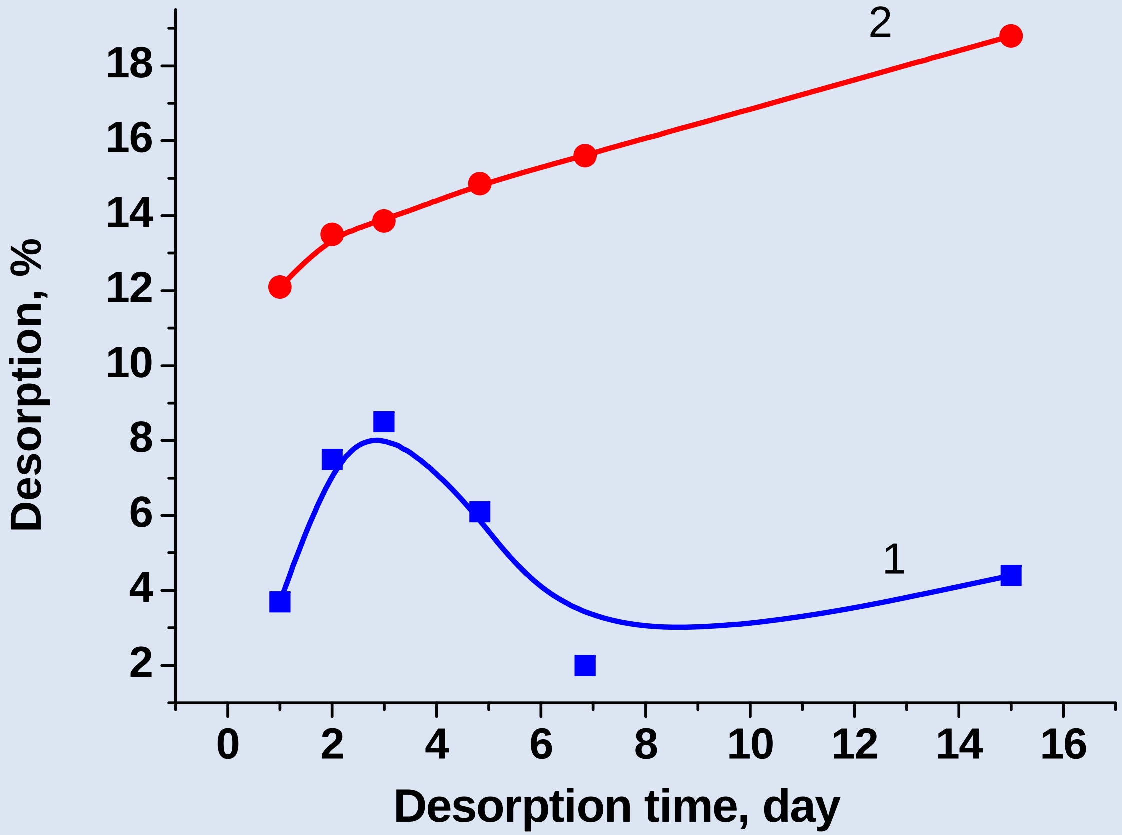
2 – [Cs^+_{stable}] = $1 \cdot 10^{-3}$ mole/l

T = 60 ° C

3 – [K^+] = $1 \cdot 10^{-5}$ mole/l

4 – [Cs^+_{stable}] = $1 \cdot 10^{-5}$ mole/l

Desorption of ^{137}Cs from sandy loam soil in the presence of Fe(III) hydroxo complexes

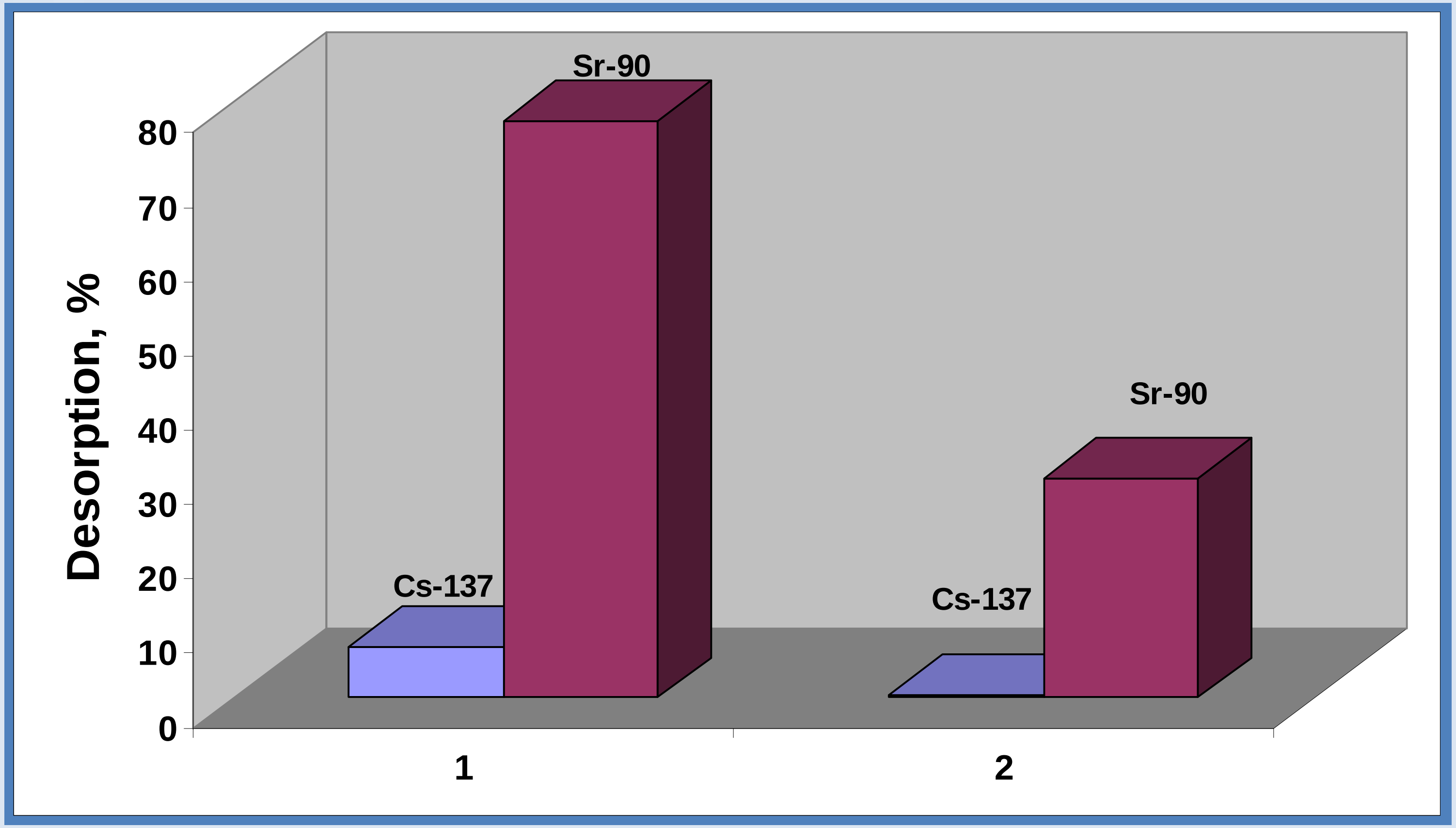


pH 3,5

1 – [Fe(III)] = $1{\cdot}10^{-4}$ mole/l

2 – [Fe(III)] = $5{\cdot}10^{-3}$ mole/l

Desorption of ^{137}Cs and ^{90}Sr from sod-podsol and peat soils

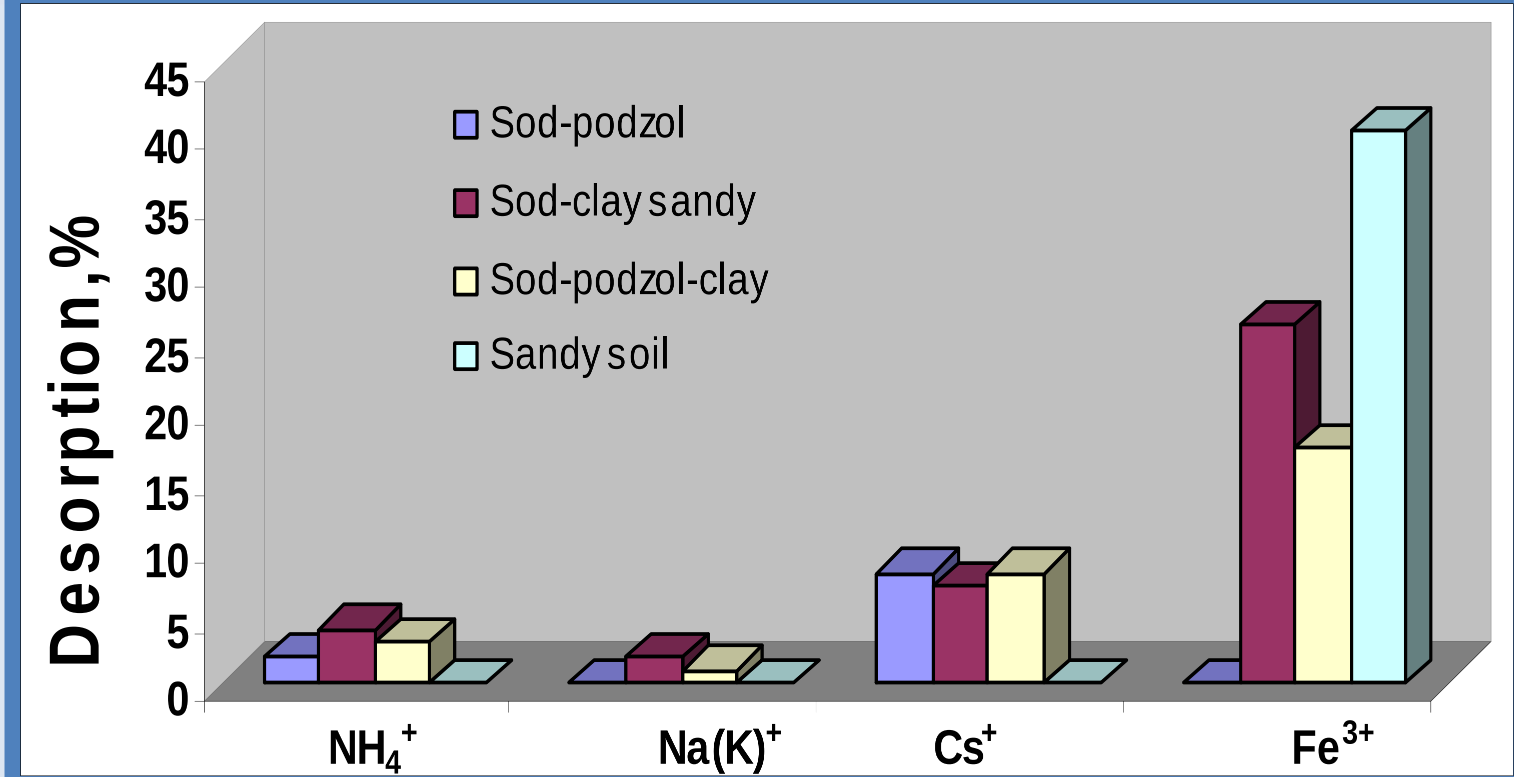


Desorption solution - 1 mole/l KCl

1 – content of organic substance 1 - 5 %

2 – content of organic substance 10 - 20 %

Desorption of ^{137}Cs from the mineral type soils by solutions containing inorganic cations



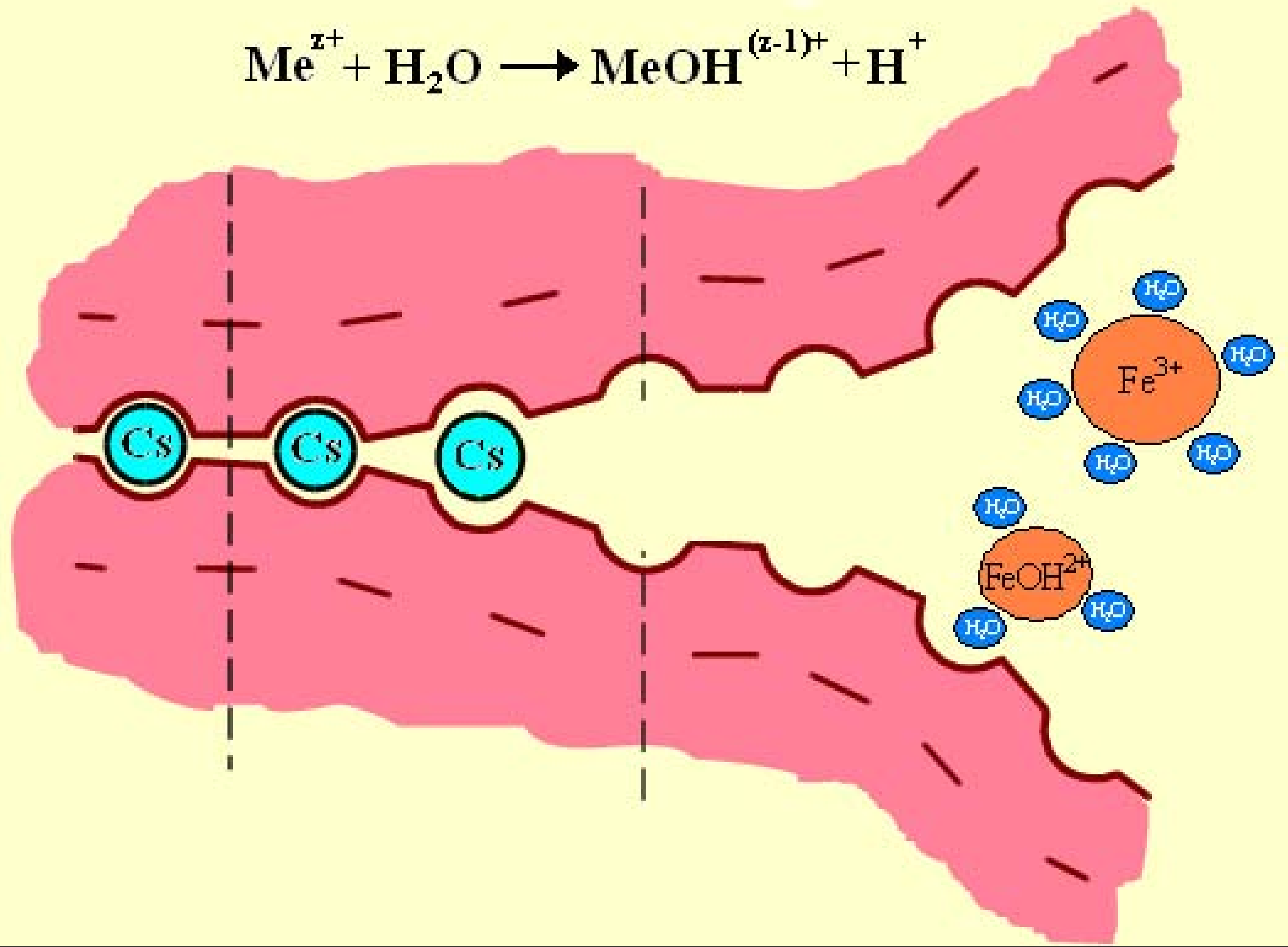
Solution composition:

0,01 mole/l $FeCl_3$

0,1 mole/L KNO_3, $NaNO_3$, $CsNO_3$, NH_4NO_3

The effect of multicharged cations on radionuclides leaching from soil

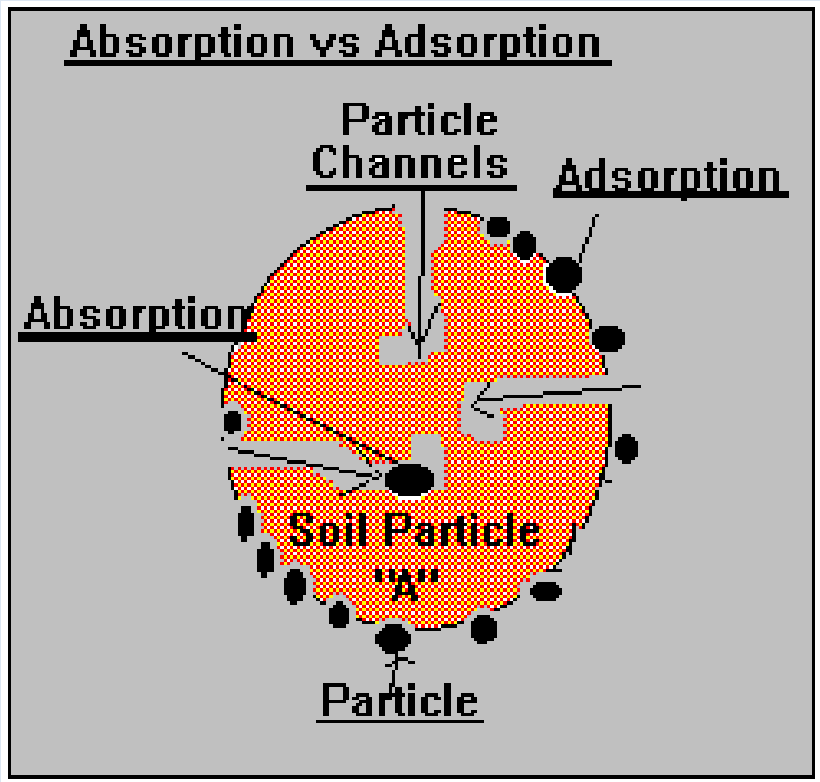
$$Me^{z+} + H_2O \longrightarrow MeOH^{(z-1)+} + H^+$$



Conclusion

- Kinetics of ^{137}Cs radionuclide extraction from soils and silt soil fraction is very slow. Notable result achieved after 7 days

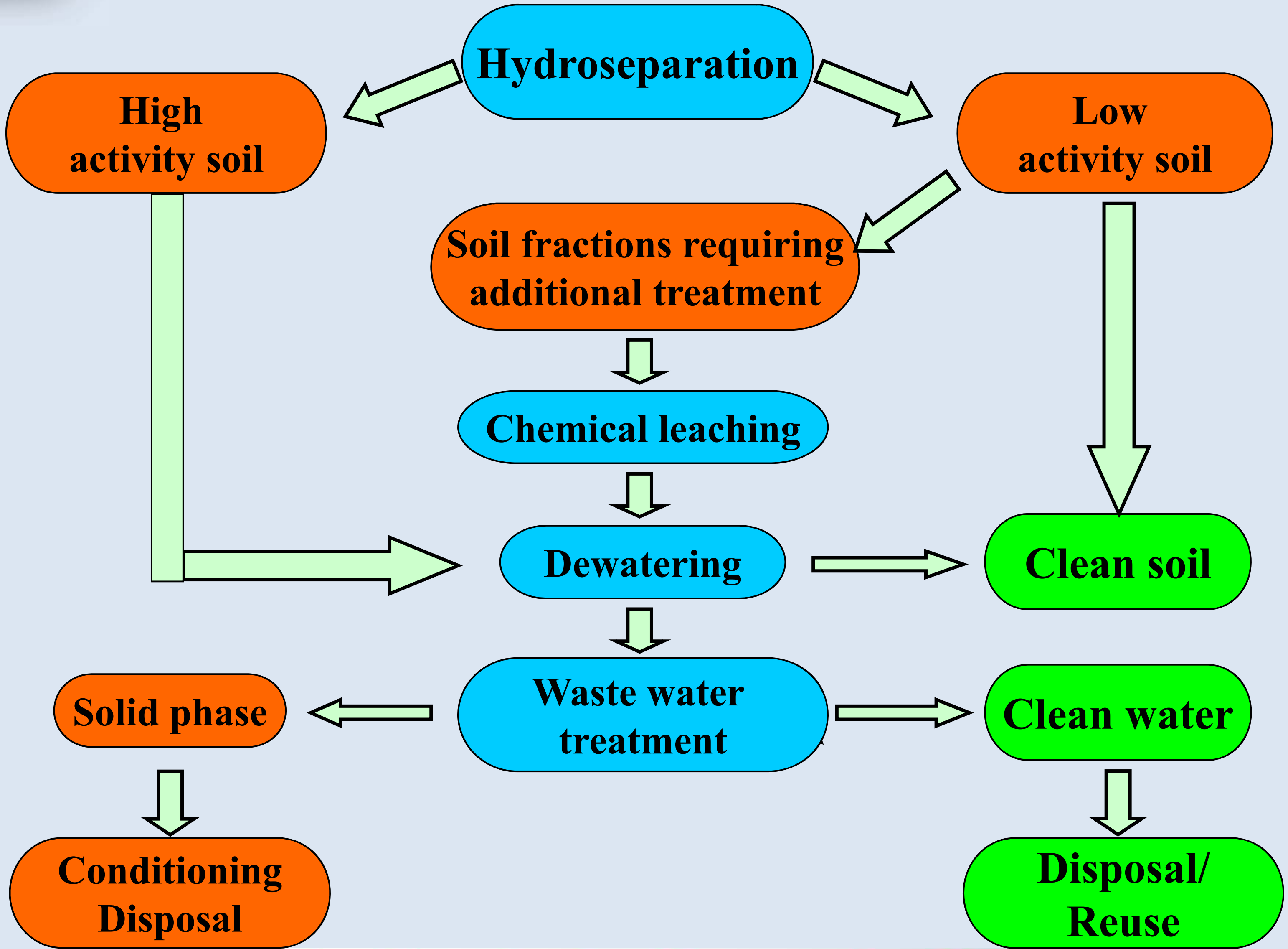
- Organic substance and clay content effects on efficiency of the radionuclide desorption. Maximum extraction of ^{137}Cs can be reached for sandy soil (≈ 40 %)



Conclusion

- The presence of Fe(III) hydroxo complexes increases ^{137}Cs extraction
- Degree of ^{137}Cs extraction changes in the following sequence $Fe^{3+} > Cs^{+} > NH^{4+} \approx K^{+} \approx Na^{+}$ from 40 to 2 % respectively
- Higher temperatures increase ^{137}Cs extraction by ~ 50 %
- Combination of hydroseparation and chemical leaching can give maximum decontamination factor $K_d \approx 4 – 5$

3 – Combined technology for radioactive contaminated soil remediation



Hydroseparation

1 – Investigation of radionuclides distribution in soil fractions

- high activity soil
- low activity soil – clean and requiring additional treatment

2 – Optimization of hydroseparation technologies:

- membrane processes
- filtration
- centrifugation and gravitation

3 – Comparison of hydroseparation and dry fractioning methods

4 – Preliminary ultra-sound treatment of soil suspension in water could be used to disaggregate soil particles.

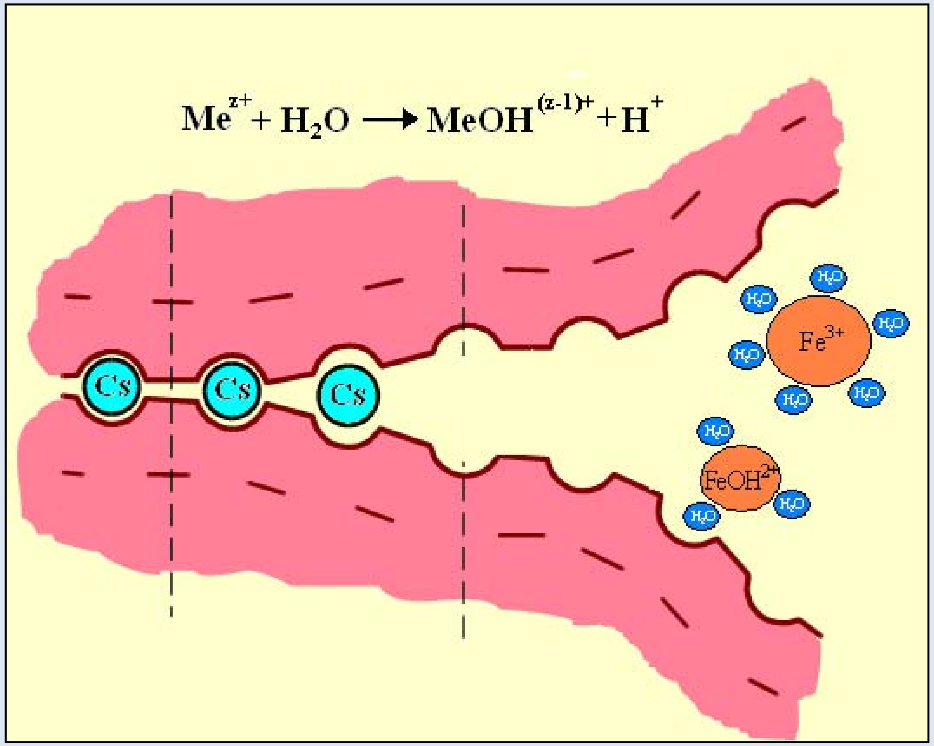
Chemical leaching

1 – Isotope exchange

^{137}Cs sorption in the presence of Cs_{stable} is very low (< 20 %) → desorption into such solution should be high (> 80 %). In practice the desorption value was < 27 %.

Explanation – kinetics problems, e.g. interlayer localization of cesium.

One of the possible solution of this problem can be incorporation of hydroxo complexes into the interlayer space.



Chemical leaching

2 – Isomorphous exchange

- most simple and cheap reagents selection
- effect of temperature and pH

3 – Oxidation process

- chemical oxidation
- high temperature oxidation (to be determined)

Waste water treatment

1 – Phase separation technologies

- Coagulation
- Floculation
- Flotation
- Sedimentation
- Mechanical filtration

2 – Sorption processes

- Selective sorbents
- Carbon
- Ion-exchange

3 – Membrane technologies

- Microfiltration
- Ultrafiltration
- Nanofitration

4 – Red/Ox processes

- Ultraviolet
- Ozone
- Electrooxidation

Dewatering

- Microfiltration, ultrafiltration
- Pressfiltration
- Centrifugation

Proposed steps for Fukushima

Radionuclide distribution studies

Fractioning technologies studies

- Comparison of hydroseparation and dry fractioning methods
- Optimization of fractioning technologies
- Centrifugation
- Gravitation
- Filtration
- Membrane processes

Chemical leaching studies

- Isotope exchange
- Isomorphous exchange
- Oxidation process

Waste water treatment technologies

- Phase separation
- Absorbers
- Membranes
- Coagulation
- Red/Ox processes

Wet fraction treatment (dewatering)

- Microfiltration
- Ultrafiltration
- Pressfiltration
- Centrifugation

Creation of pilot installation

Thank you
for your attention!