Vertical profile of ^{210}Pb, ^{137}Cs and ^{40}K in Algerian soil samples

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Looking for…

- The first goal is to define the level of contamination due to nuclear weapon tests and nuclear accidents (^{137}Cs)

- The second goal is to define the sedimentation rate of soil layers (^{210}Pb: $t_{1/2}$=22.6y, ^{137}Cs: $t_{1/2}$=30.4y)

Challenging…

- the opportunity to study samples near Sahara Desert

Radioactivity

Natural

Primordial (e.g. ^{226}Ra, ^{235}U, ^{238}U, ^{232}Th, ^{40} K, ^{87}Rb) and cosmogenic (e.g. ^{3}H, ^{7}Be, ^{14}C, ^{81}Kr) radionuclides

Artificial

Anthropogenic radionuclides (e.g. ^{129}I, ^{137}Cs, ^{239}Pu)

- Nuclear accidents
- Weapon tests
- Industry
- Medical

^{210}Pb radioisotope

Product of ^{222}Rn decay with half-life $t_{1/2}$=22.26y

- ^{222}Rn (t ½= 3,8 d) inert daughter gas of ^{226}Ra, diffuses into the atmosphere coming out from ground minerals before their decay

- Escape of ^{222}Rn out of the soil depends on:
    - Mineralogical nature of the parental ^{226}Ra
    - Porosity of the soil
    - Humidity of the soil

- Finally: ^{222}Rn decays through a short-life series of Polonium, Lead and Bismuth isotopes into ^{210}Pb

Decay series of ^{238}U

	Uranium series	
Nuclide	**Half-life**	**Radiation**
^{234}Th	24 days	β ,γ
^{234m}Pa	1.2 min	β ,γ
^{234}U	2.5x10^{5}years	α ,γ
^{230}Th	8.0x10^{4}years	α ,γ
^{226}Ra	1.622 years	α ,γ
^{222}Rn	3.8 days	α ,γ
^{218}Po	3.05 min	α
^{214}Pb	26.8 min	β ,γ
^{218}At	1.5-2.0 sec	α
^{214}Bi	19.7 min	β, α
^{214}Po	1.64x10^{-4} s	α ,γ
^{210}Tl	1.3 min	β ,γ
^{210}Pb	22 years	β ,γ
^{210}Bi	5.0 days	β,α
^{210}Po	138 days	α ,γ
^{206}Tl	4.2 min	β
^{206}Pb	Stable	

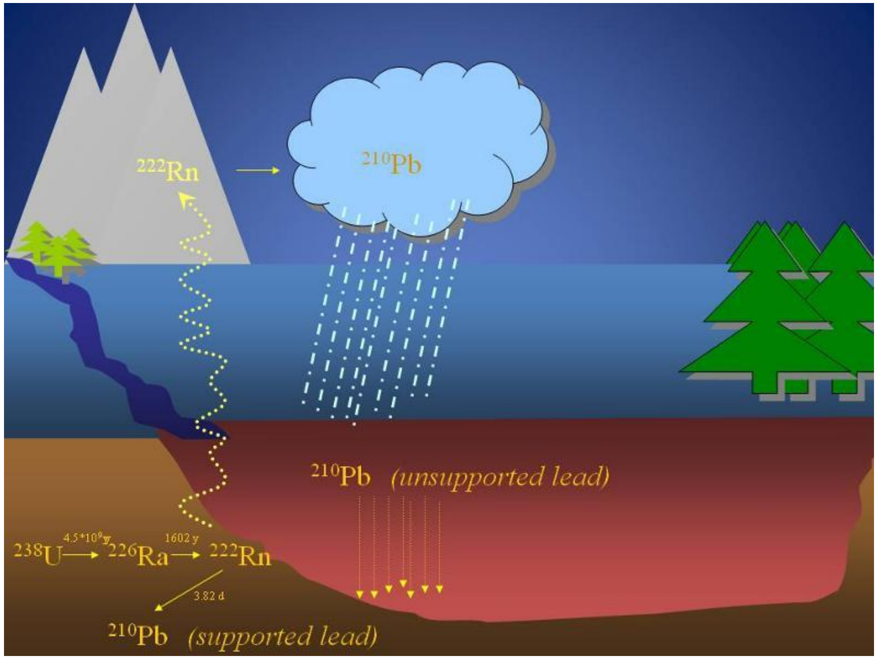
^{210}Pb at the ground

- **Mineral ^{210}Pb:** trapped within a mineral particle in the soil due to decay of radon before escape from the particle
- **Inerstitial ^{210}Pb:** absorbed on the surface of a mineral particle due to decay of ^{222}Rn after escape from the host particle, before diffusion into the atmosphere
- **Fallout ^{210}Pb:** attached to aerosol particles in the atmosphere, transport in the air and deposited on the soil through rainwater or dry deposition

^{210}Pb → strongly absorbed on the soil surface

enter ground's lower layers through migration process

The transport rate of a radionuclide at the soil depth profile is of the order of some centimeters per year



^{137}Cs

- Produced when Uranium or Plutonium absorb neutrons and forced into radioactive decay

- Half-life $t_{1/2}$= 30.17 y

- Sources of ^{137}Cs : ➡ nuclear weapon explosions' fallout

➡ nuclear reactor accidents

➡ nuclear reactor wastes

➡ nuclear fuel reprocessing wastes

^{137}Cs at the ground

- Fallout ^{137}Cs ⟹ not uniformly distributed

- Penetration depth of a nuclide at the soil profile ⟹ shows the easiness for a fallout nuclide to be absorbed or uptaken by the soil

- Estimation of ^{137}Cs mean concentration in soil ⟹ needs estimation of the ^{137}Cs migration depth through the soil column

- ^{137}Cs highest concentrations ⟹ upper 30 cm

EXPERIMENTAL

- DETECTOR
- MEASUREMENTS
- RESULTS

Detectors for ^{210}Pb (46.5 keV), ^{137}Cs (661.65 keV) and ^{40}K (1460.74 keV)

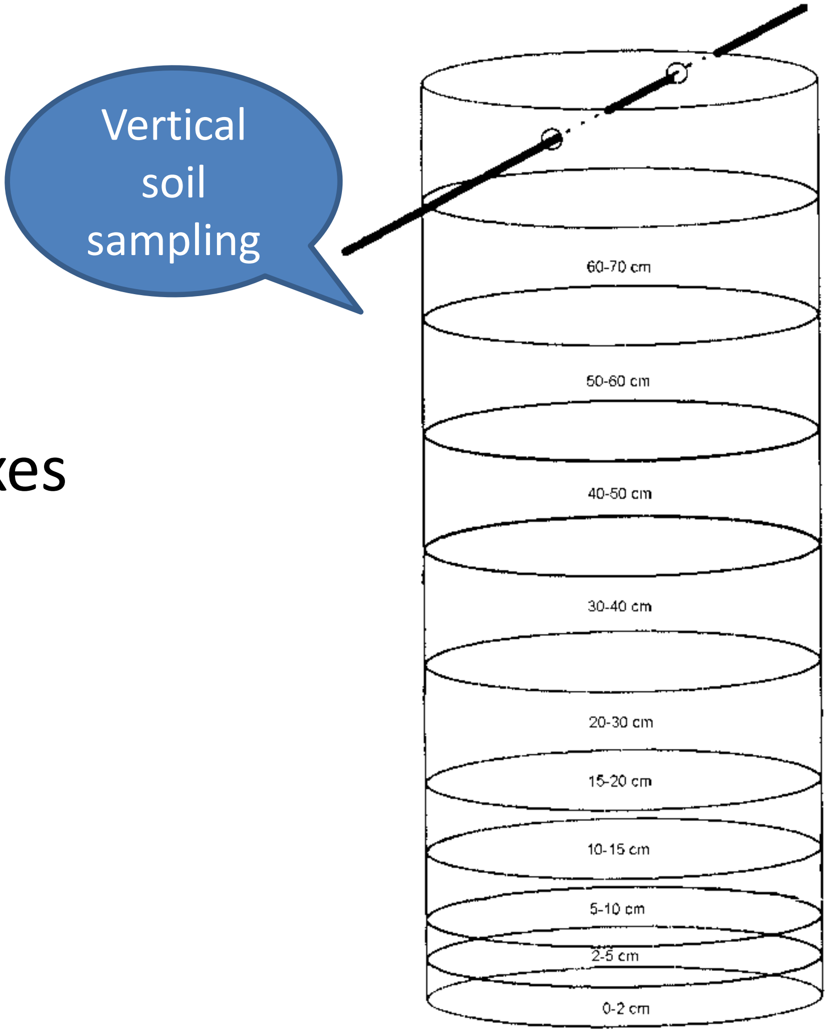
For ^{210}Pb (46,50 keV)
Ge planar detector with active area 2000 mm^2, thickness 20 mm, energy resolution (FWHM) 400 eV at 5.9 keV or 700 eV at 122 keV.

For ^{137}Cs (661.65 keV) and ^{40}K (1460.74 keV)
20% Efficiency HPGe Low background, high resolution 1.86 keV at 1.33 MeV

- Use of "box“ geometry at the analysis software
  radius: 5.8 cm, thickness: 2 mm
- Energy calibration using source with same geometry as the sample

Soil samples

- Samples collected using geological carrot descending 2, 3, 5 and 10 cm each time
- Sampling depth: 0 – 70 cm
- Sand grain size: ~ 0,4 mm
- Samples sealed into PVC boxes



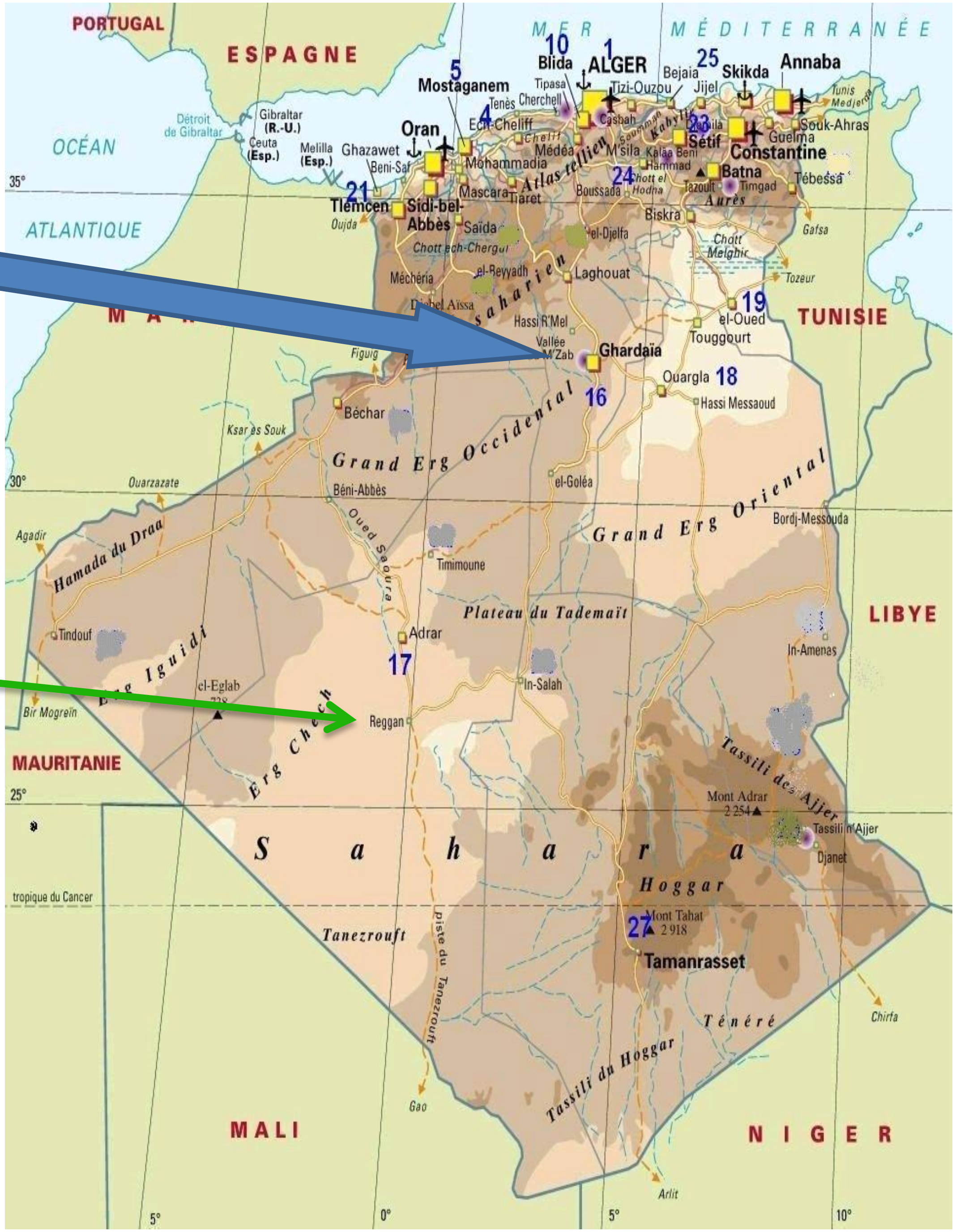
Soil sampling areas

Ghardia at Algeria

~500 km south of Algiers

Ghardia is 500 km northeastward **Reggane**

Reggane 1960-1961:
French nuclear tests
(4 atmospheric, 13 underground)



Soil samples

- Ghardia: rocky area with sand

- Most of the French surface nuclear tests in 1960-1961 release radioactivity in the environment in the form of glassy materials produced by the melting of the soil or the sand near the ground zero

- Soil samples collected at the 1st of June 2012 and measured after some months

- **Sample 1: $(S16)_1$**

  Collected 20 km north of Ghardia

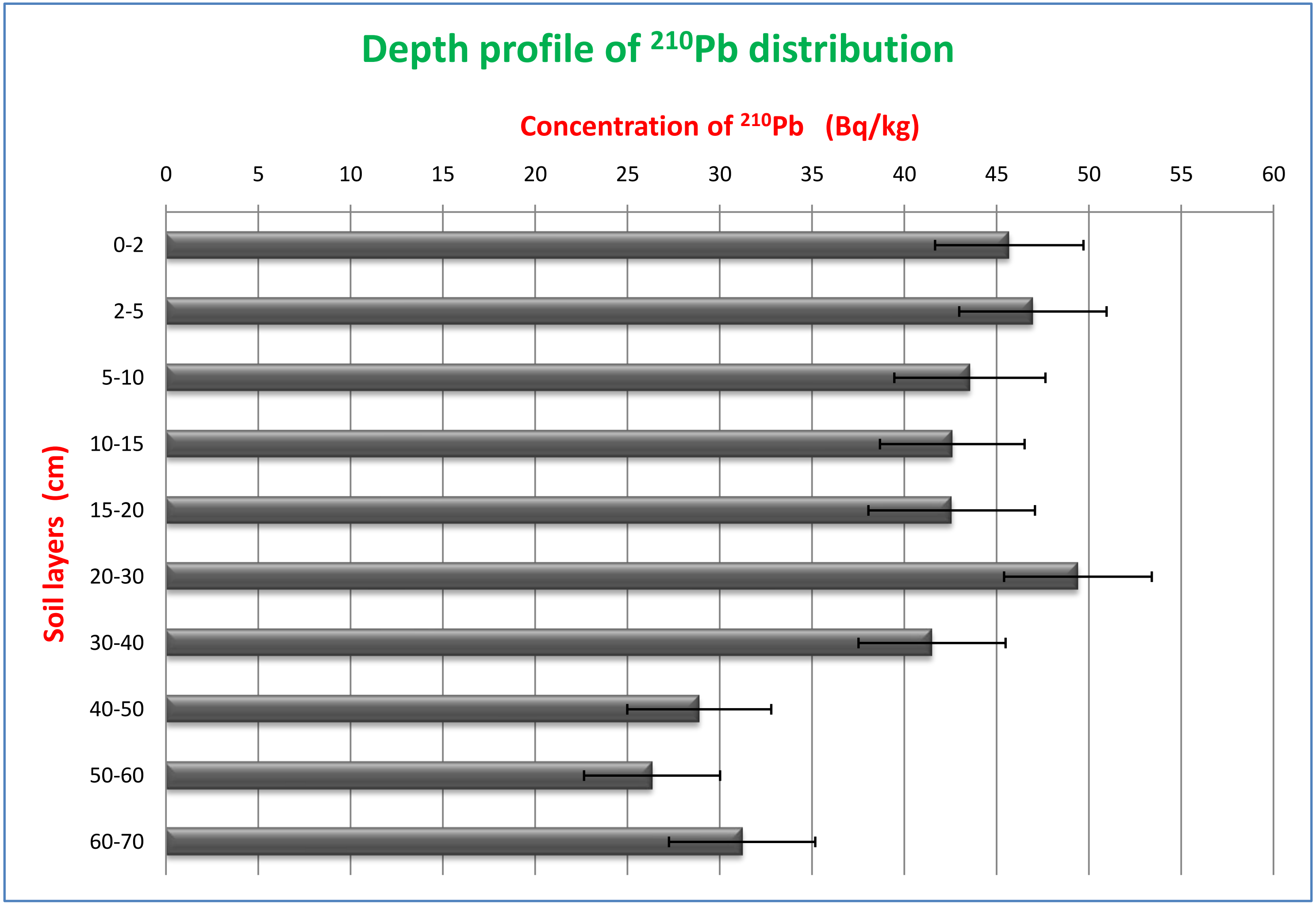
  region: **rocky with sand**

- **Sample 2: $(S16)_2$**

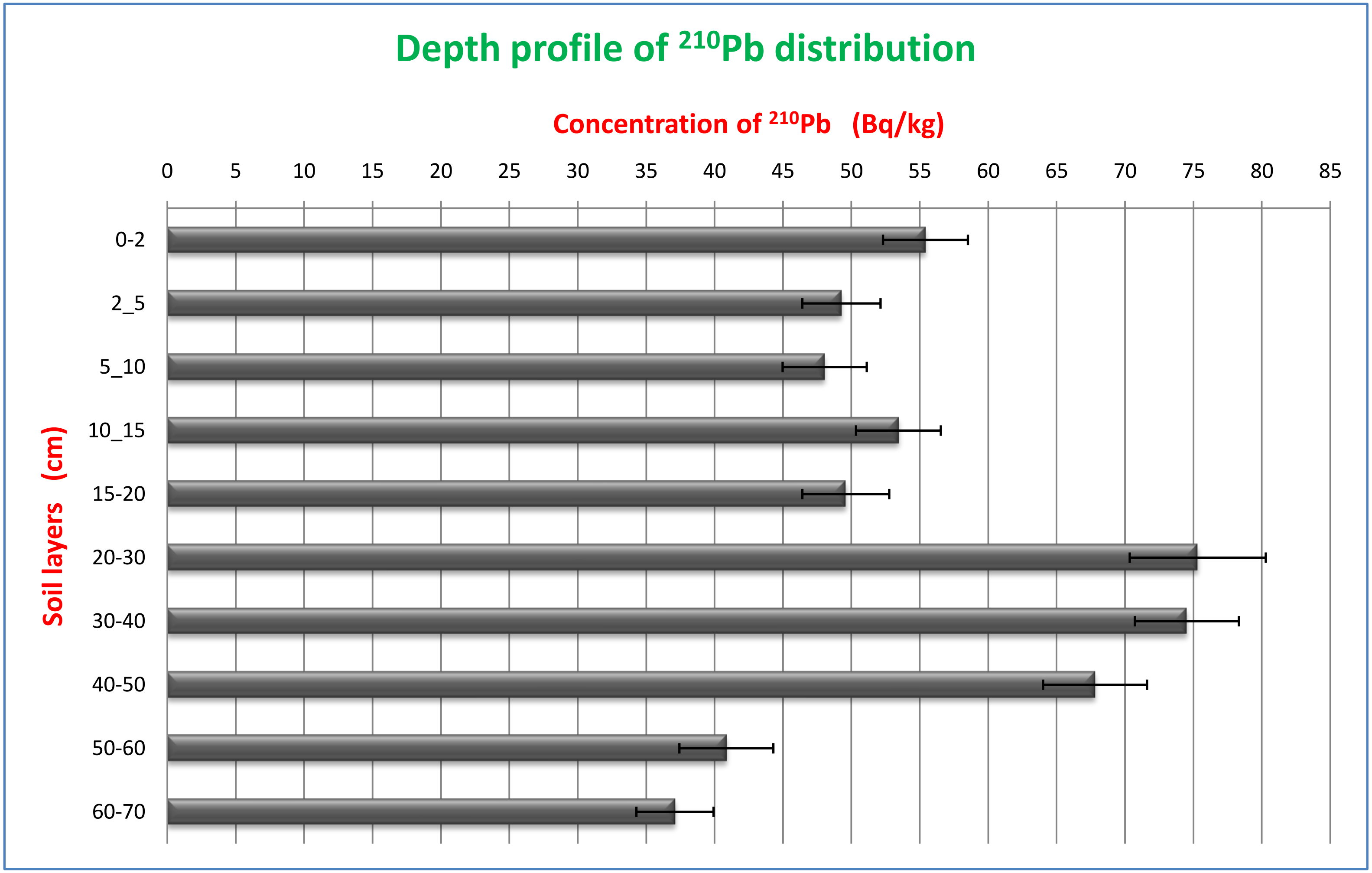
  collected about 70 km northern of the collection place of $S(16)_1$

  region: **porous with rocks and sand**

Sample 1: $(S16)_1$



Sample 2: $(S16)_2$



Results and discussion

Sample 1: $(S16)_1$

- Samples collection area is **rocky with sand** → soil layers do not mix with each other

- rocky ground → movement of ^{210}Pb through diffusion and transport is difficult

Expect maximum concentrations at the upper layers because of the higher ^{210}Pb concentrations from fallout

But: observe uniform distribution of ^{210}Pb at lower layers also → vertical movement of ^{210}Pb downwards

This situation is valid for the movement of radionuclides under the ground
Movement length is of the order of few centimeters per year

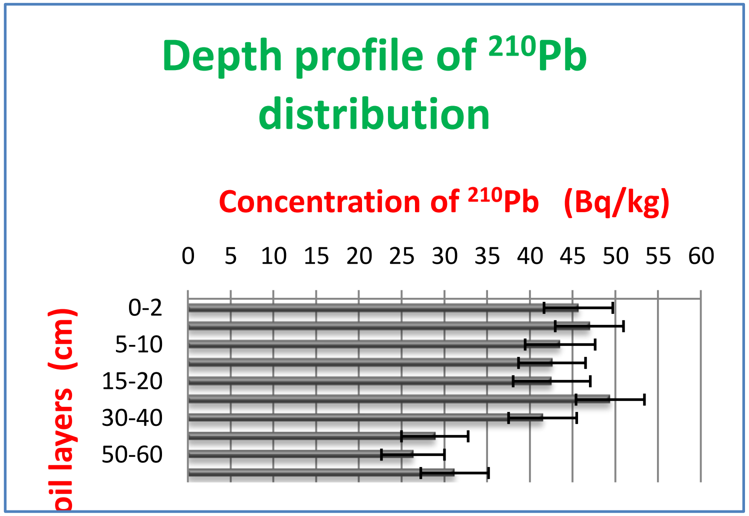
Results and discussion

Sample 1: $(S16)_1$

- at the lower layers the concentration of ^{210}Pb decreases

- uniform distribution again

- the reduction may be due to the rocky ground that makes the transportation of radionuclides at the lowest layers difficult



Results and discussion

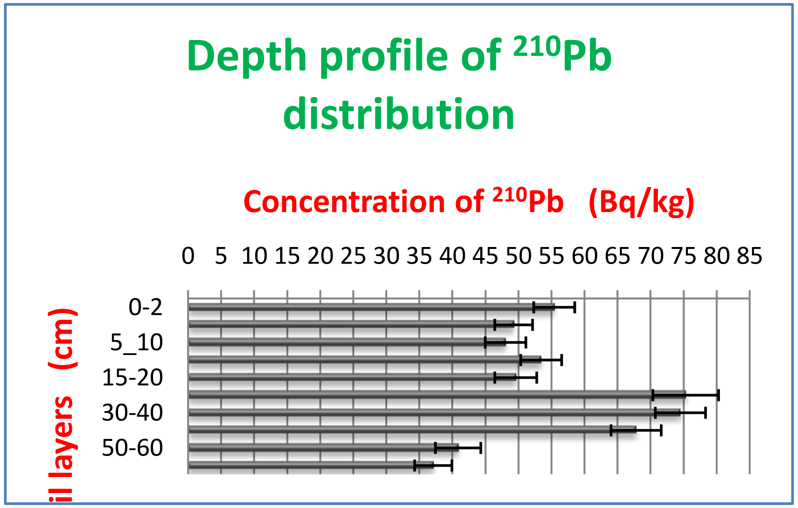
Sample 2: $(S16)_2$

- maximum of ^{210}Pb concentration at 20 – 50 cm

- The ground of the samples collection area is **porous with rocks and sand**

→ Easier movement of radionuclides in the soil → uniformly distributed above and below the max

- This vertical distribution refers more to the effect of sedimentation rate (movement of the layers in the soil) and less to the vertical diffusion and dispersion of the isotope ^{210}Pb



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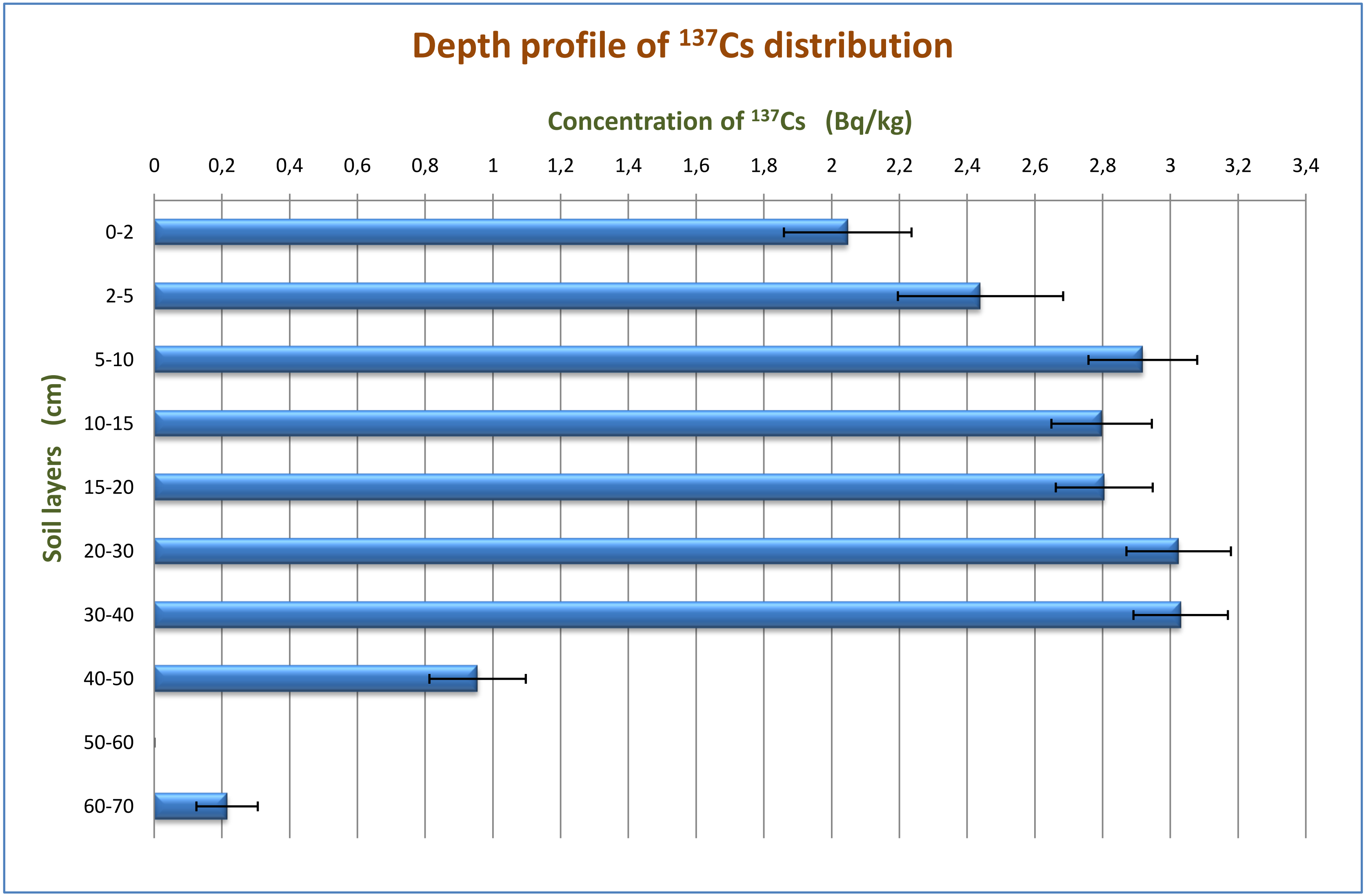
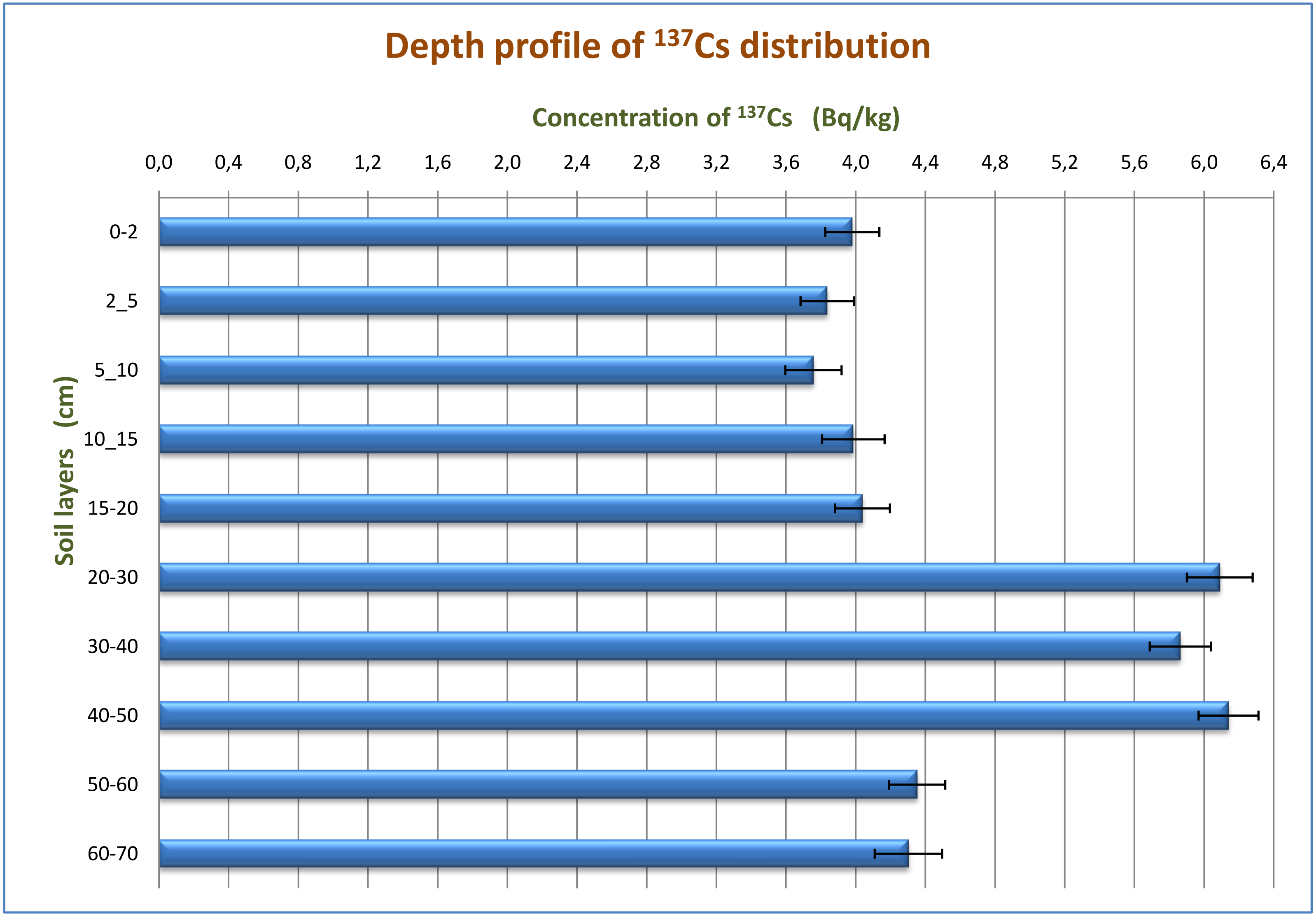


Sample 2: $(S16)_2$



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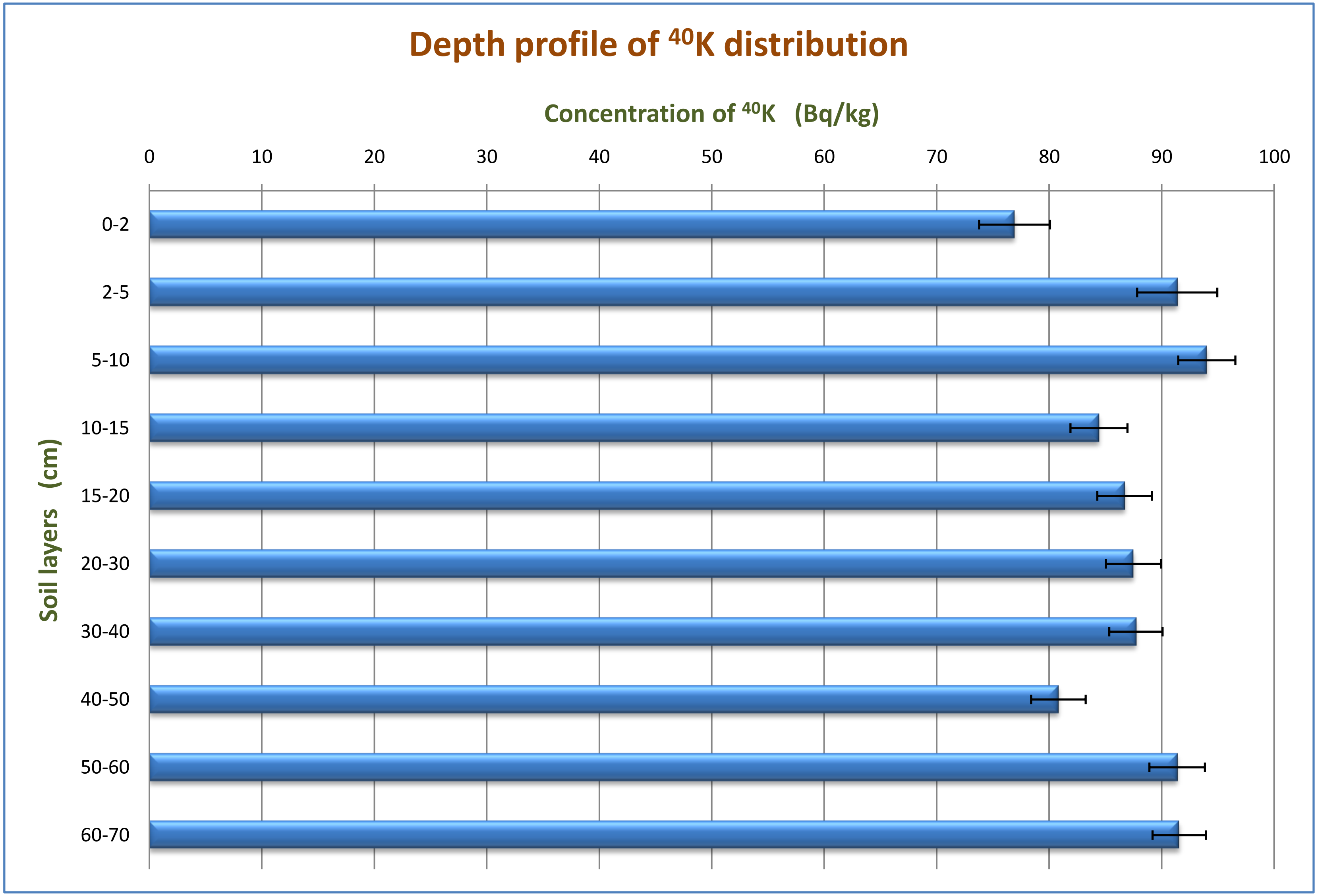
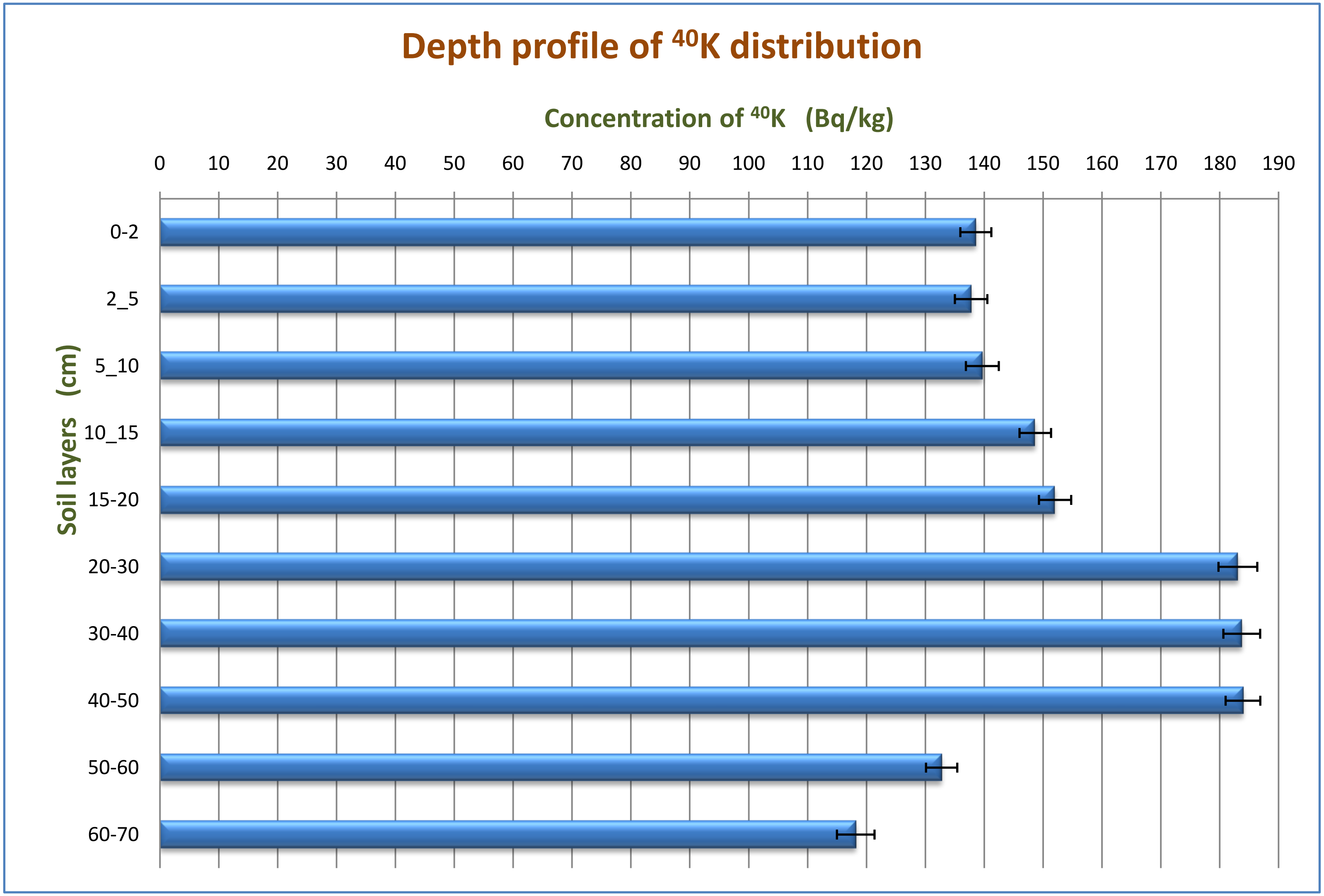


Sample 2: $(S16)_2$



Results and discussion

<u>Comparison of concentrations of ^{137}Cs and ^{40}K at the two samples</u>

- Concentration values of ^{137}Cs and ^{40}K at sample 1 are lower than the corresponding values in sample 2

	Sample 1	**Sample 2**
^{137}Cs	max: ~3 Bq/kg min: ~0.2 Bq/kg	max: ~6 Bq/kg min: ~4 Bq/kg
^{40}K	max: ~90Bq/kg min: ~75 Bq/kg	max: ~180 Bq/kg min: ~140 Bq/kg

Explanation: the nature of the soil samples from the two areas

Soil sample 1 is rocky with sand and soil sample 2 is porous with stones and sand

- ^{137}Cs concentration values are smaller than most ^{137}Cs values observed in Europe

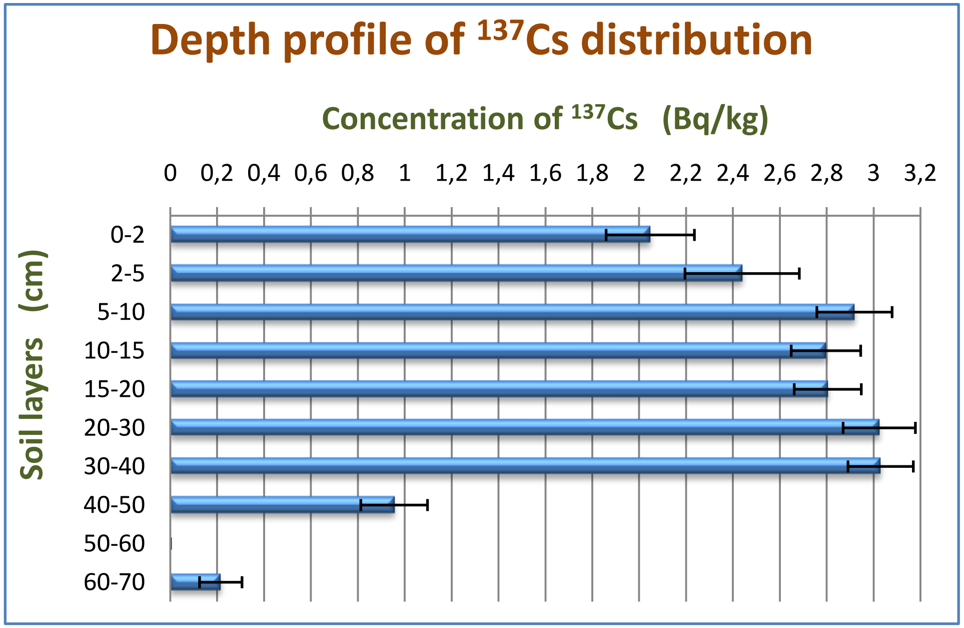
Results and discussion

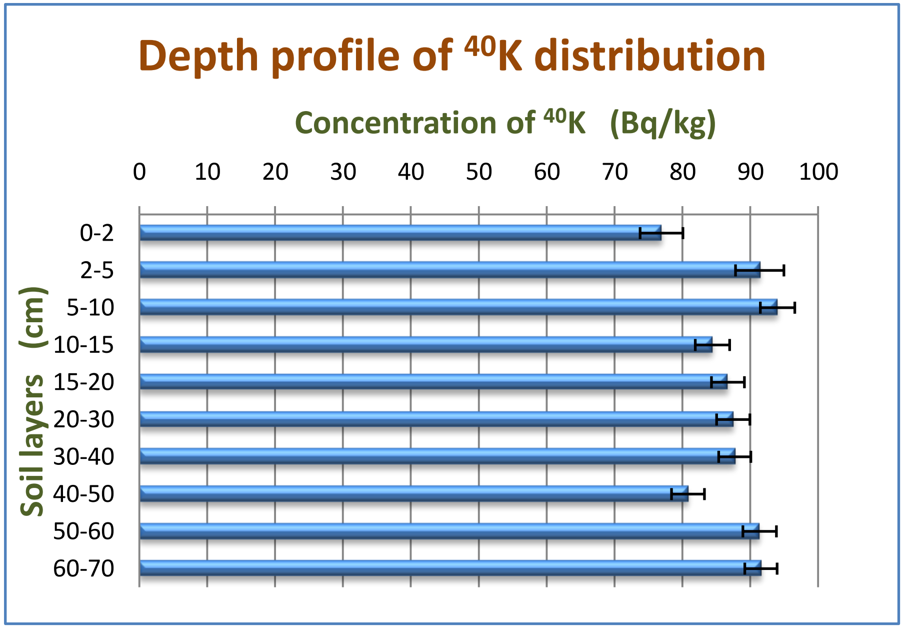
Comparison of concentrations of ^{137}Cs and ^{40}K per sample

Depth profiles of ^{137}Cs and ^{40}K in sample 1 have almost the same format

Explanation: ^{137}Cs and ^{40}K have the same chemical behavior because are both alkalis

Move in the soil in a similar manner





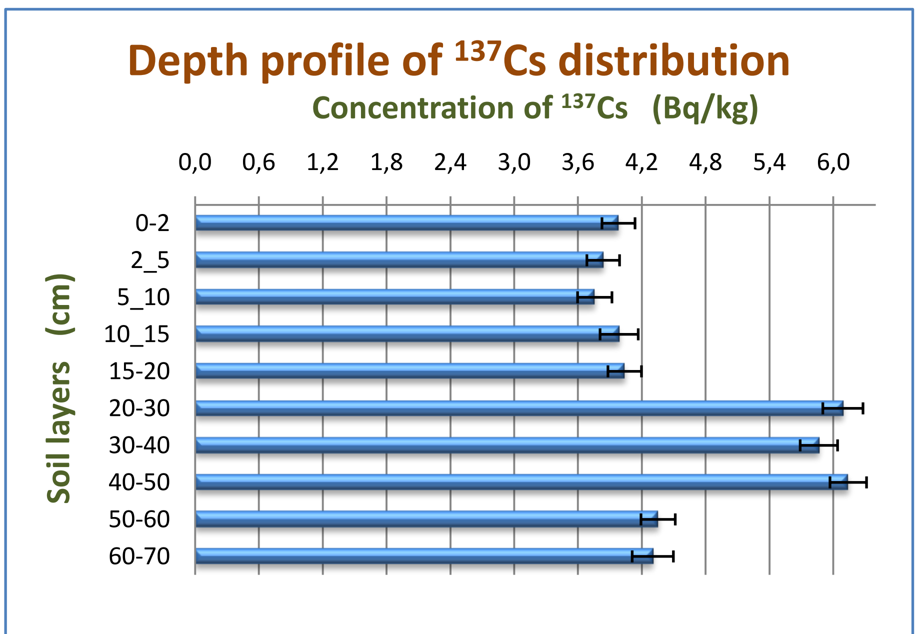
Results and discussion

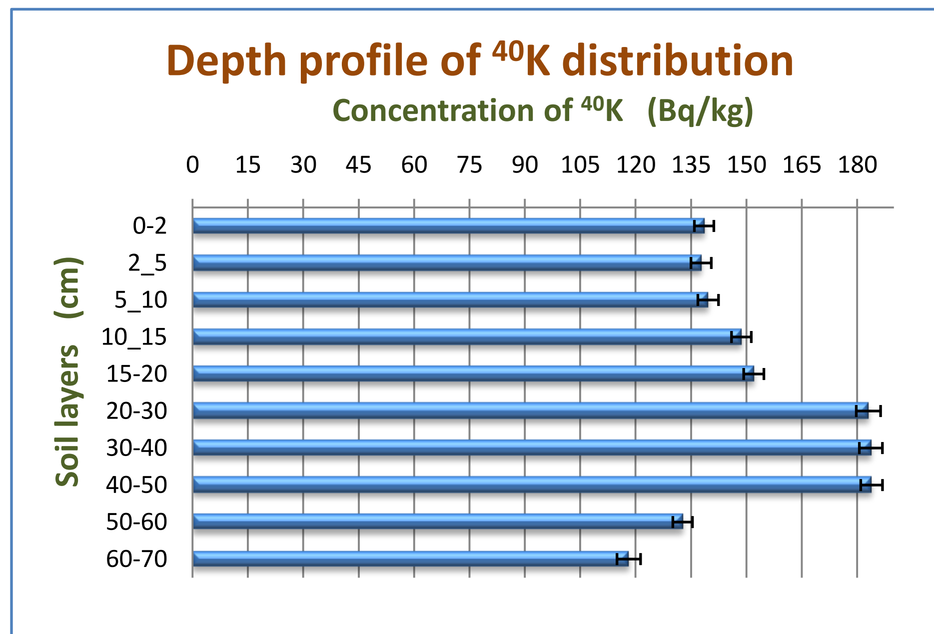
Comparison of concentrations of ^{137}Cs and ^{40}K per sample

Depth profiles of ^{137}Cs and ^{40}K in sample 2 have almost the same format

Explanation: ^{137}Cs and ^{40}K have the same chemical behavior because are both alkalis

Move in the soil in a similar manner





Results and discussion

<u>Comparison of concentrations of ^{137}Cs and ^{40}K at the two samples</u>

In sample 2

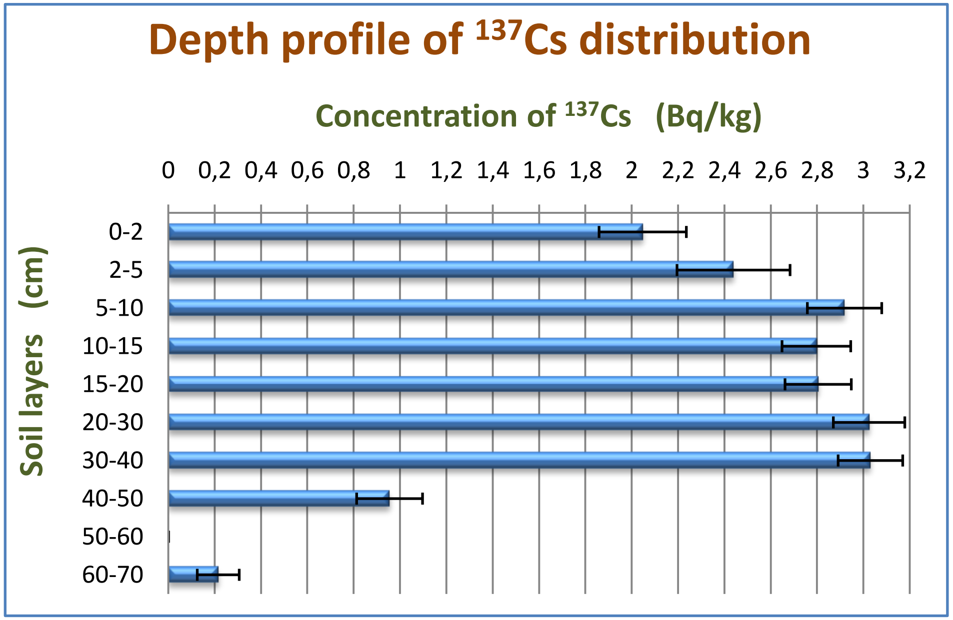
maximum of ^{137}Cs and ^{40}K concentration at 20 – 50 cm

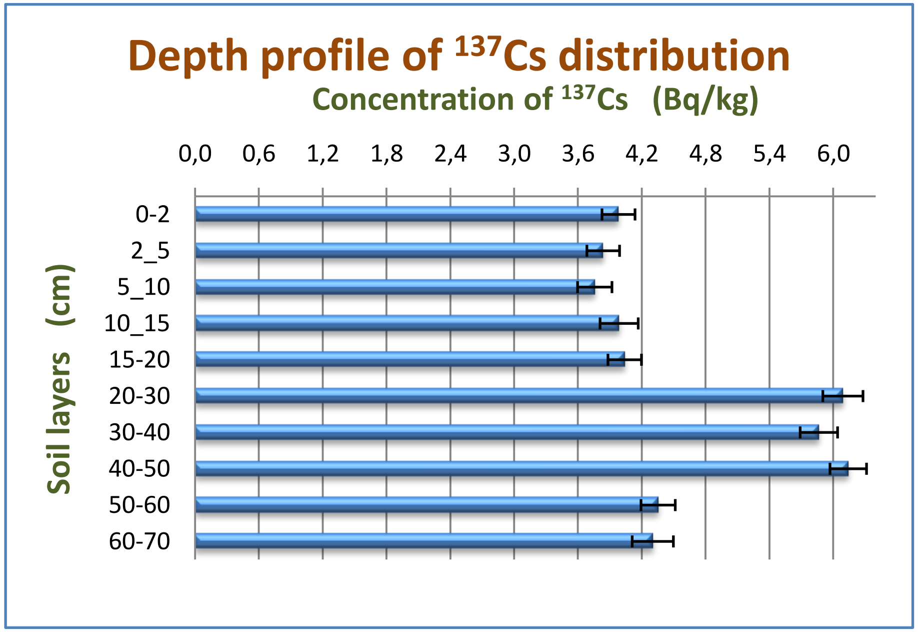
explanation

Easier movement of radionuclides in the soil – porous with stones and sand

This vertical distribution refers more to the effect of sedimentation rate (movement of the layers in the soil) and less to the vertical diffusion and dispersion of the isotope ^{137}Cs

At sample 1 the diffusion and transport of radionuclides is more difficult and has smaller rate than sample 2





Summary

- Maximum and minimum values of the activity of the two samples:

	Sample 1	Sample 2
^{210}Pb	max: ~50 Bq/kg min: ~27 Bq/kg	max: ~75 Bq/kg min: ~37 Bq/kg
^{137}Cs	max: ~3 Bq/kg min: ~0.2 Bq/kg	max: ~6 Bq/kg min: ~4 Bq/kg
^{40}K	max: ~90Bq/kg min: ~75 Bq/kg	max: ~180 Bq/kg min: ~140 Bq/kg

➢ Similar vertical distribution profiles of ^{210}Pb, ^{137}Cs and ^{40}K at every sample

➢ ^{137}Cs concentration values are smaller than most ^{137}Cs values observed in Europe

➢ In sample 2, maximum of ^{210}Pb, ^{137}Cs and ^{40}K concentration at 20 – 50 cm

➢ Concentration values of ^{210}Pb, ^{137}Cs and ^{40}K at sample 1 are lower than their corresponding values in sample 2

Sample 1: rocky with sand and soil

Sample 2: porous with stones and sand

} Smaller diffusion and transport rates of radionuclides in soil 1

Summary

- The first goal was to define the level of contamination due to nuclear accidents (^{137}Cs)

  ^{137}Cs concentration values are smaller than most ^{137}Cs values observed in Europe

  Probably due to high transferred mass rates form Sahara desert to Europe especially during spring season every year

- The second goal was to define the sedimentation rate of soil layers (^{210}Pb, ^{137}Cs)

  This is our next step

The end

Thanks for your attention