

# Radionuclides ratio in a soil profile for designation of NORM contaminated land

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*Natural radioactivity is a primordial property of the matter surrounding us. Natural radionuclides are present in almost all substances that we deal with ...*



*Therefore, the generic question is:*

**when is their presence significant from a radiation protection point of view ?**



# Is it NORM or it isn't ?

- NORM raw materials
- NORM residues
- NORM repository
- Land around NORM repositories
- Land affected by NORM industry activity /brownfields/
- Bottom sediments next to liquid NORM discharge points
- Legacy sites /e. g. former radium producing plants/





Activity concentration	
Ra-226 or Ra-228	
pCi/g	Bq/kg
3	111
5	185
30	1110
50	1850
2000	74000

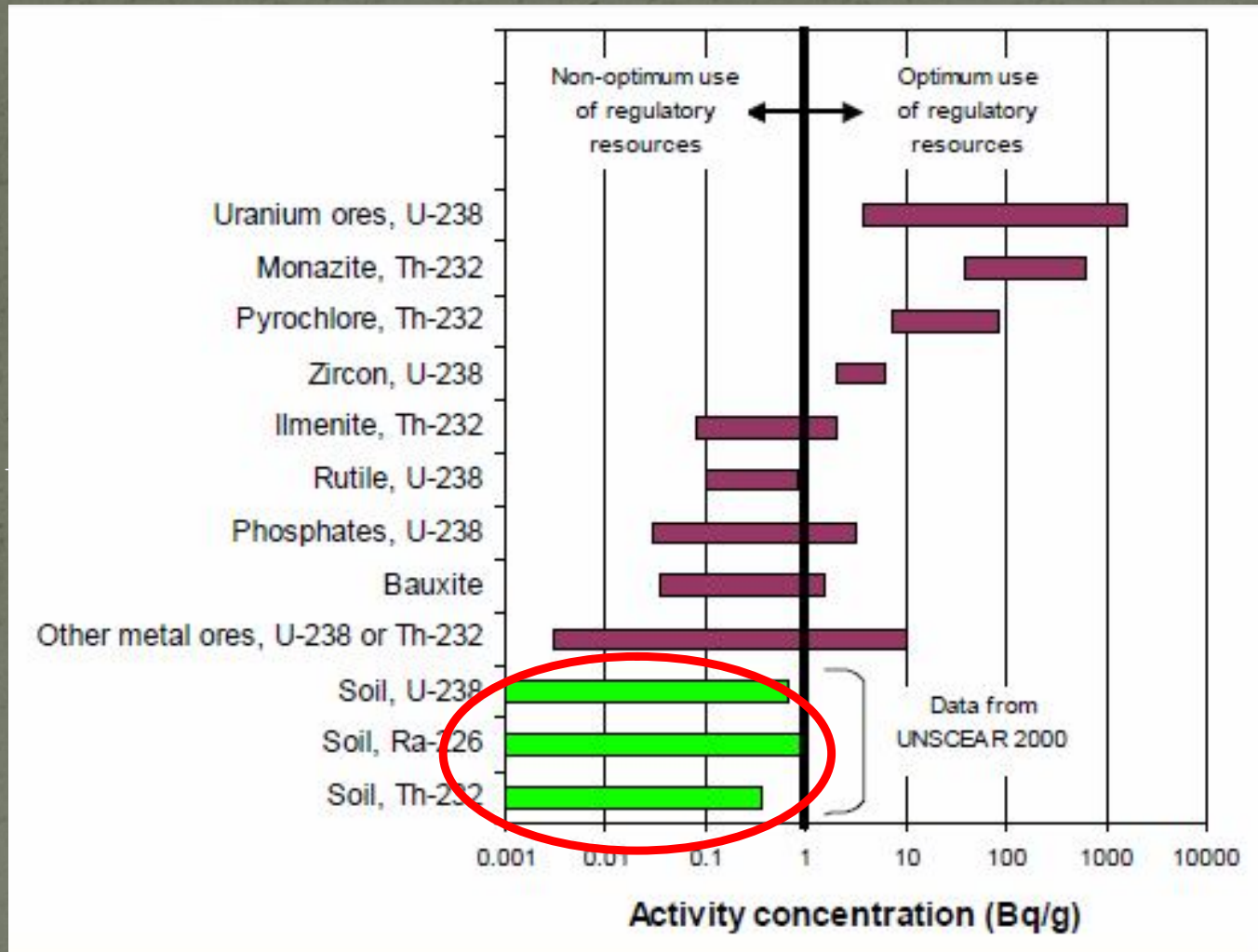
	Activity concentration	
	pCi/g	Bq/kg
U-238	27	1000
Th-232	27	1000
K	270	10000

### Assumption:

1. above natural background,
2. radon exhalation < 0.74 Bq/m<sup>2</sup>/s

(AN ASSESSMENT OF THE DISPOSAL OF PETROLEUM INDUSTRY NORM IN NONHAZARDOUS LANDFILLS, U.S. Department of Energy, 1999)

# The rationale of 1 Bq/g



# The source of information

- Completeness of decay series
- Equilibrium / disequilibrium among natural radionuclides
- Distribution of artificial radionuclides originating from global fallout



# Radionuclides of concern

$^{226}\text{Ra}$   
1600 y

$^{222}\text{Rn}$   
3.823 d

$^{210}\text{Pb}$   
22.3 y

$^{210}\text{Po}$   
138.4 d

$^{228}\text{Ra}$   
6.7 y

$^{228}\text{Th}$   
1,9 y

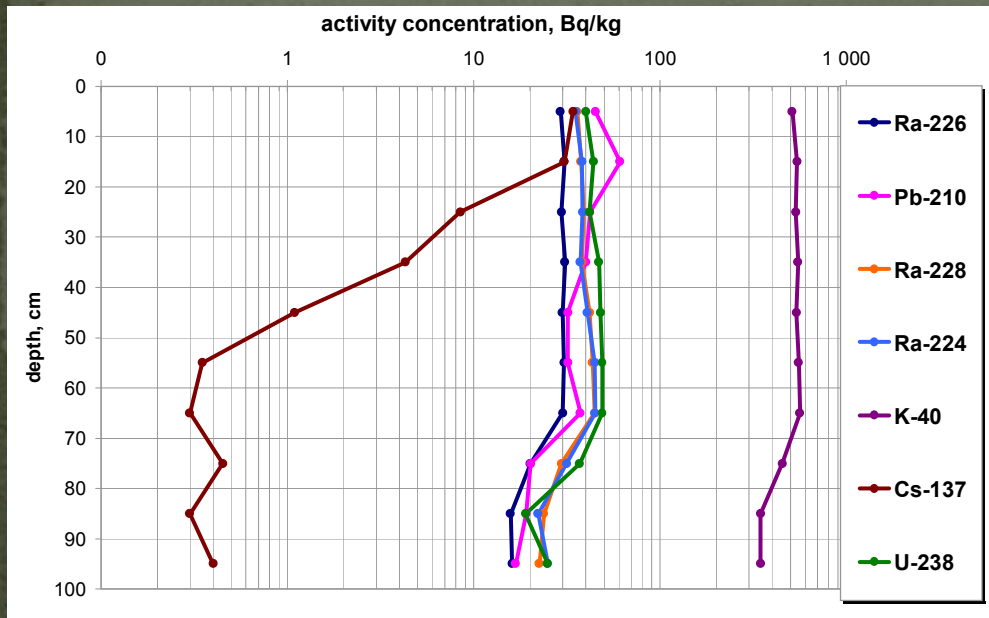
$^{137}\text{Cs}$   
32 y

In not altered state all of them create a specific pattern along vertical soil profile

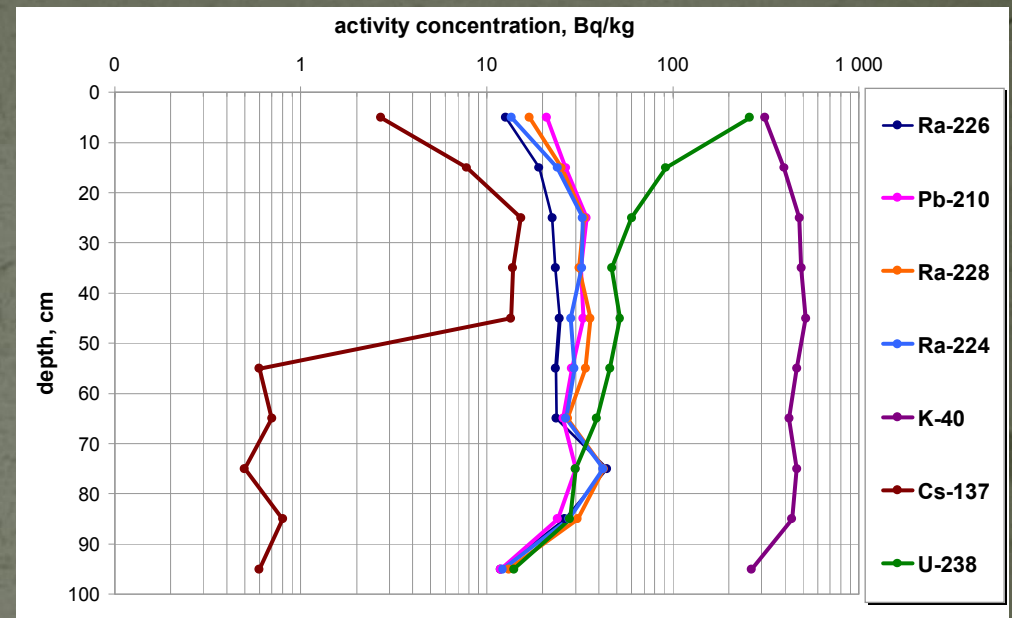




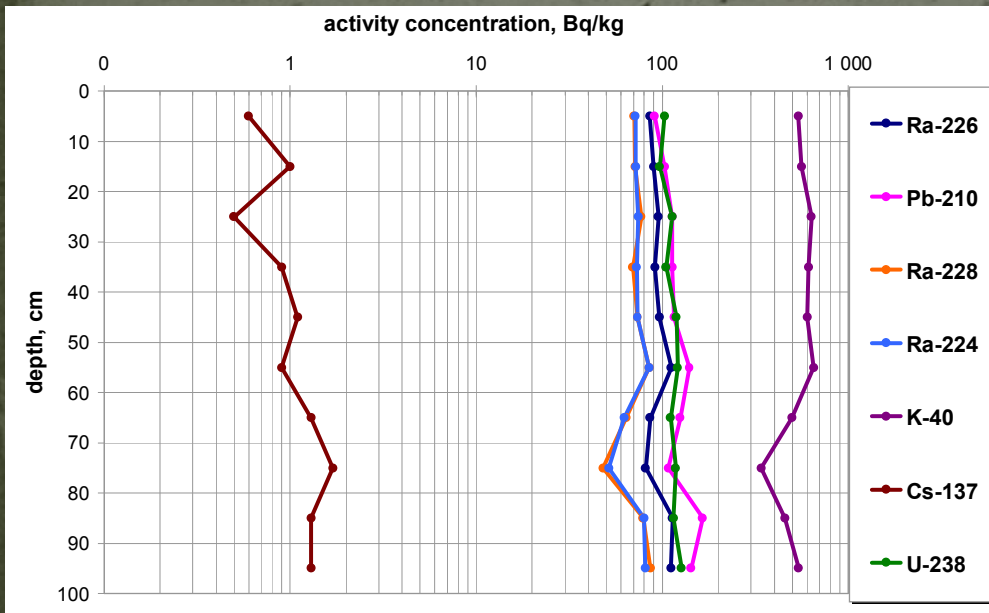
# Soil profiles sampled next to different NORM sites



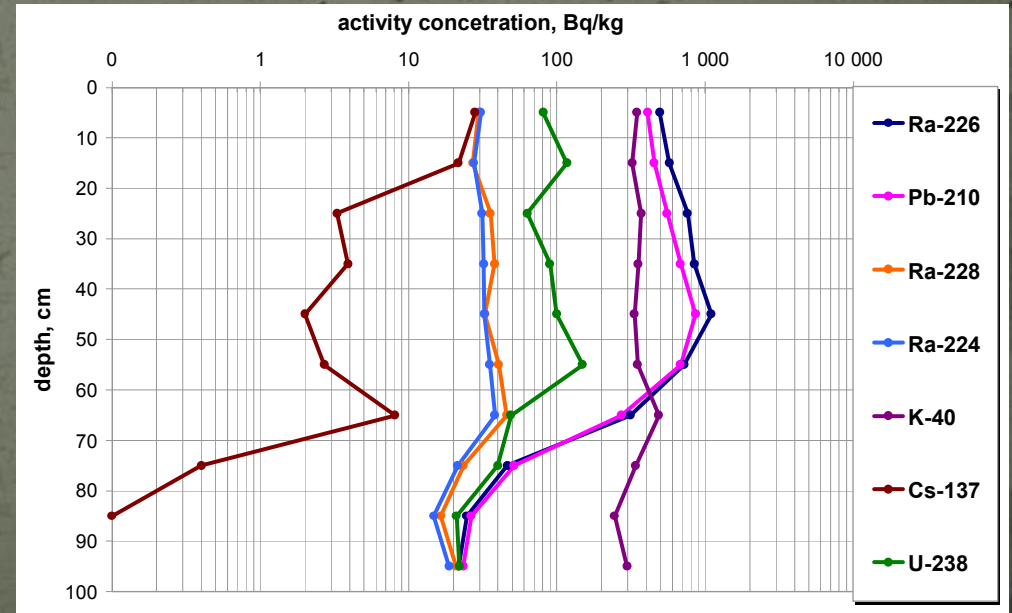
Unaltered soil (Racibórz)



The vicinity of PFG waste dump



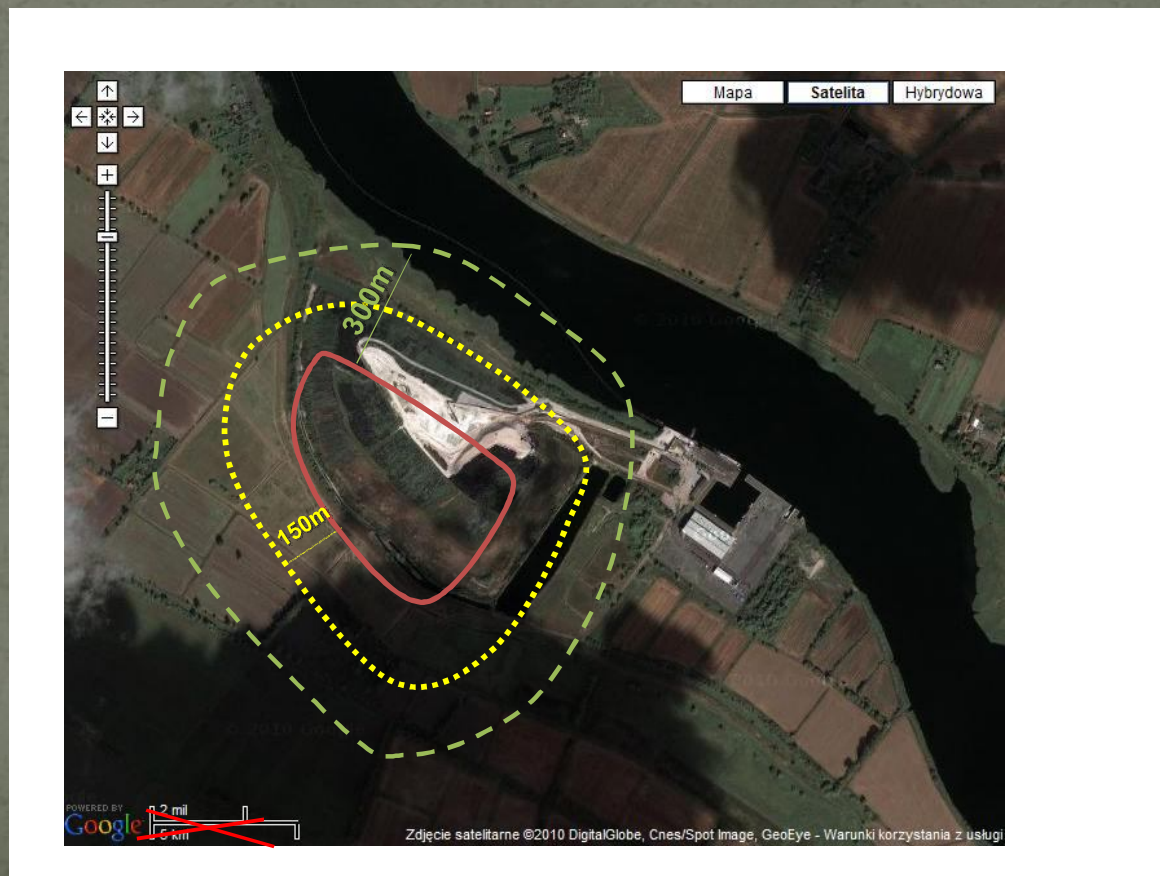
CCP waste dump after land reclamation



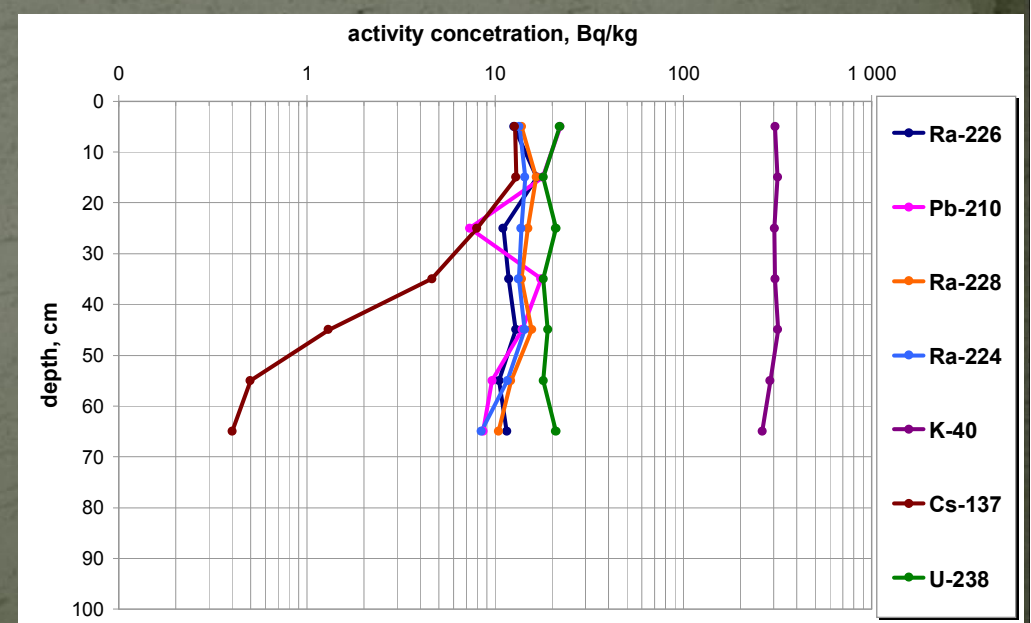
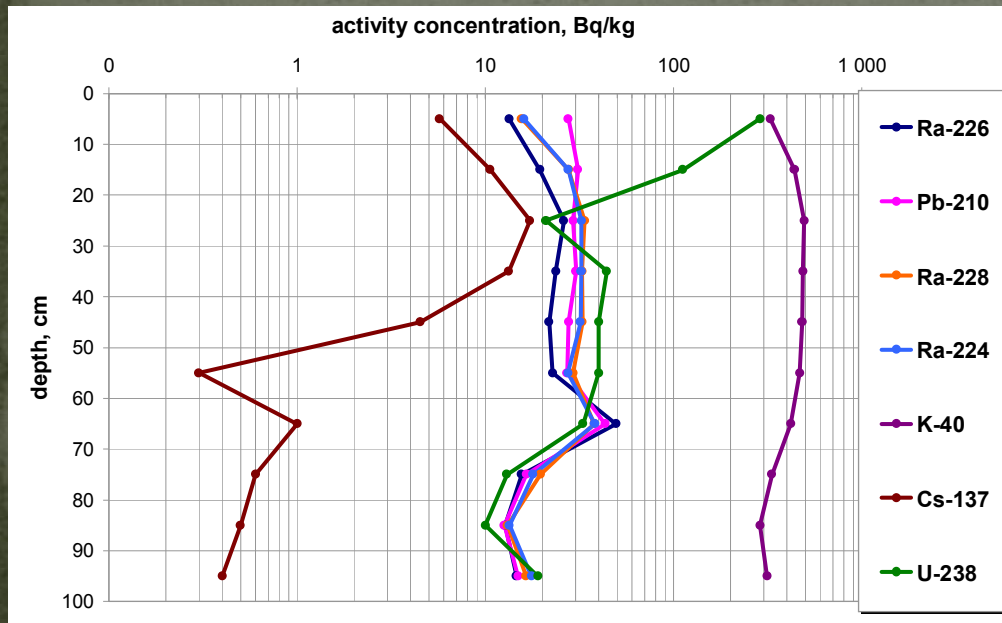
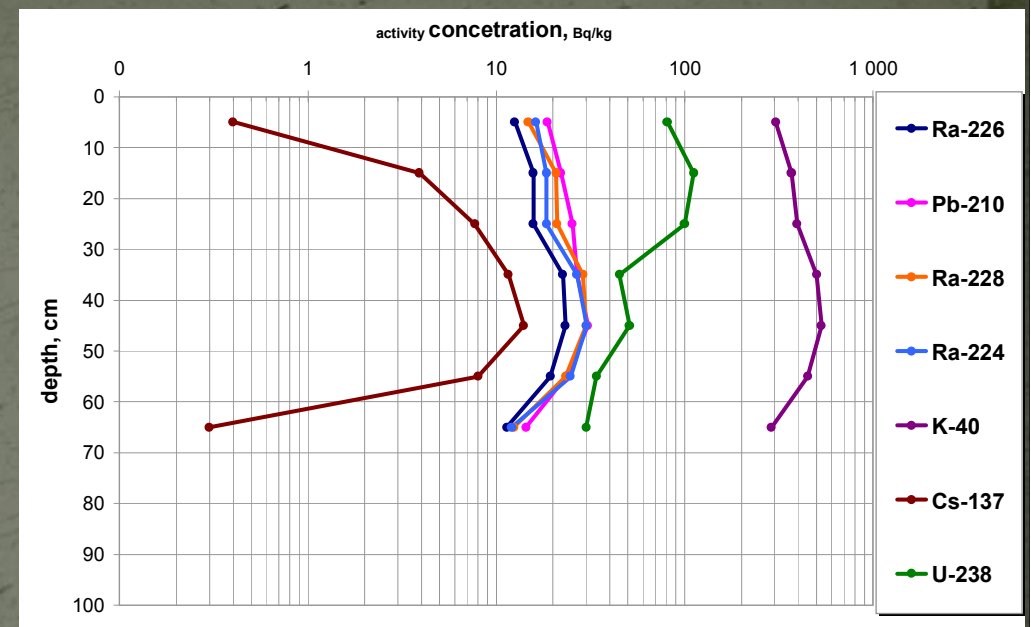
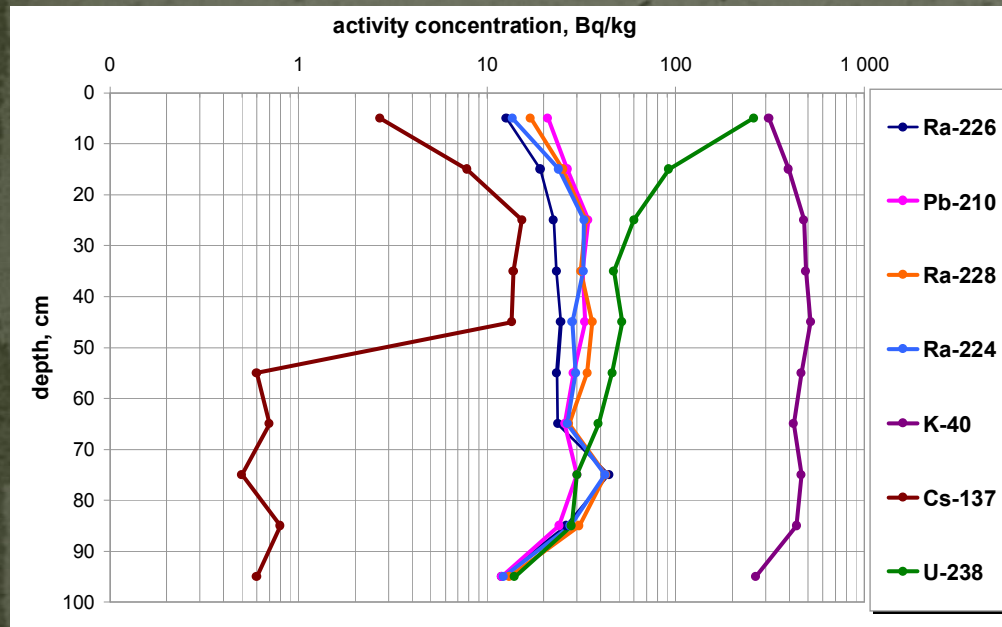
Arable land affected by mine water discharge



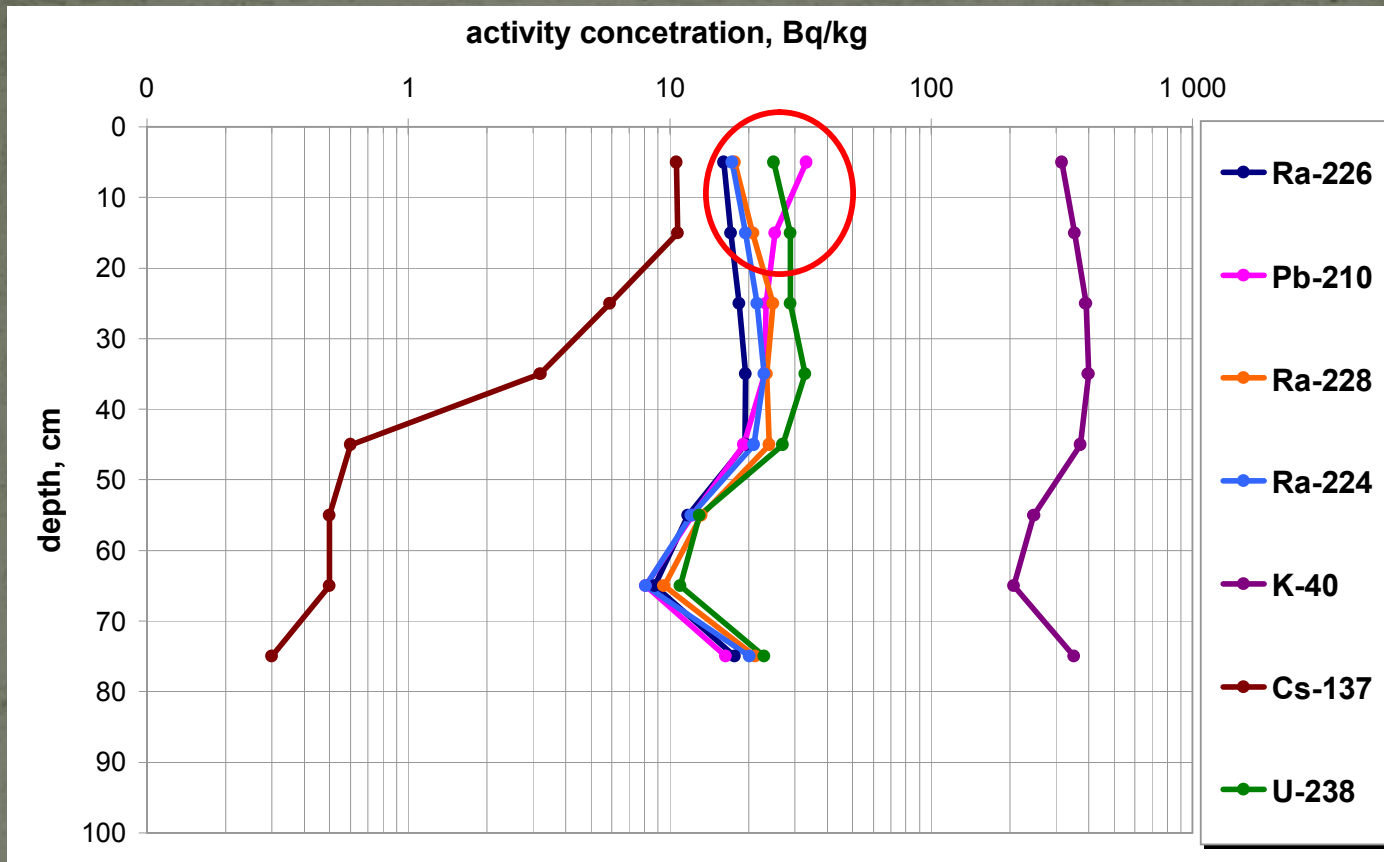
## WIŚLINKA PHOSPHOGYPSUM STACK DISPOSAL



# Hydrological protection zone around PFG heap (0-150 m)



# Control area, 2 km from waste heap



# Radium relationships in broken decay chains\*

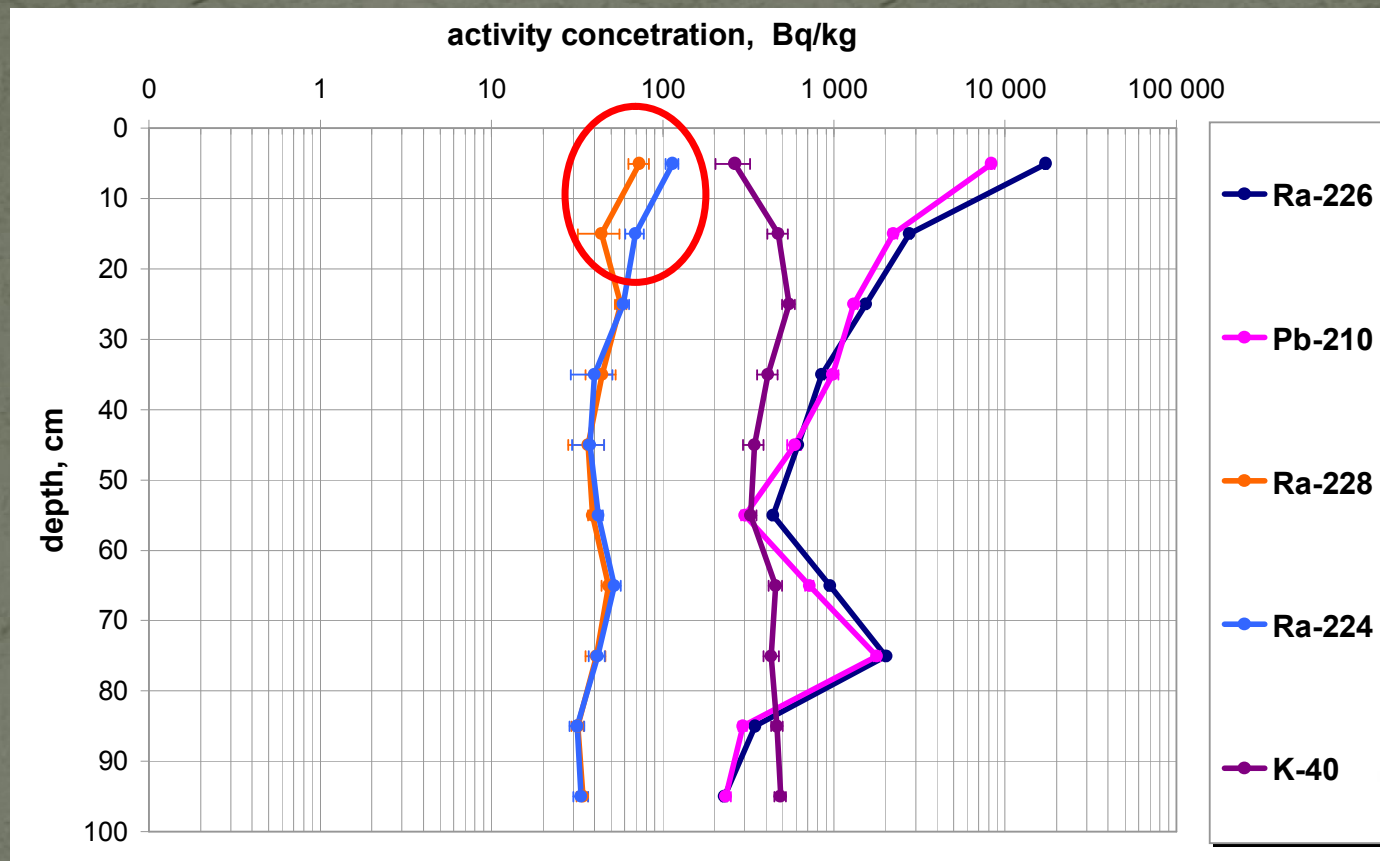


in  $t=0$   $Pb-210=0$  and  $Th-228 = 0$

\*B. Michalik, J. Brown, P. Krajewski. *The fate and behaviour of enhanced natural radioactivity with respect to environmental protection. Environmental Impact Assessment Review* 38 (2013) 163–171

# A fingerprint of coal mining industry...

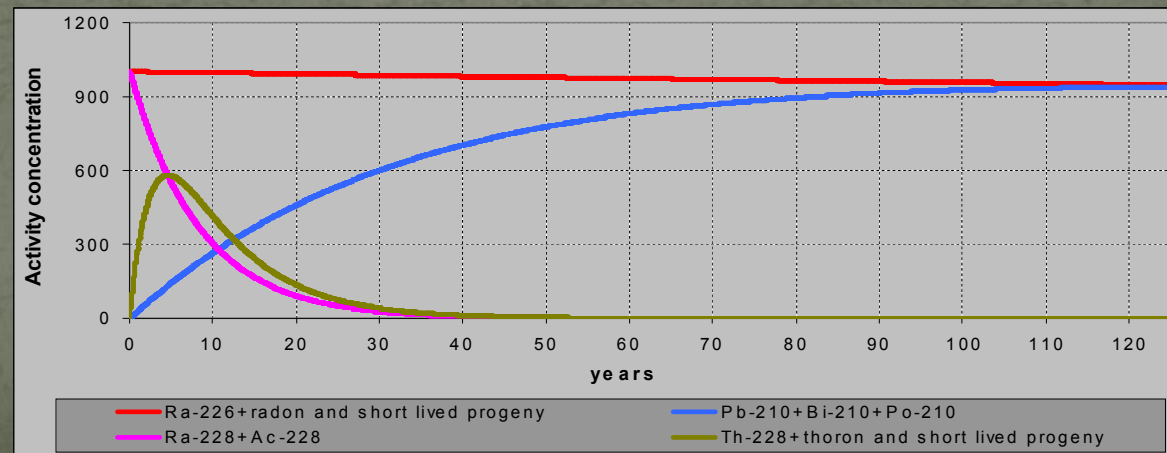
- Ra-224 < or > Ra-228 ☞ Ra-228 fractionation
- Ra-226 >>> Pb-210 ☞ Ra-226 fractionation
- Ra-226 >>> Ra-228 ☞ both radium isotopes (Ra-228 and Ra-226) fractionation (in the past)



Radium precipitation from radium rich water - formation water common in petroleum and underground coal mining industry

# Additional advantage: dating

Radionuclide	time range /years/
Ra-224/Ra-228	up to 10
Ra-228/Ra-226	up to 50
Pb-210/Ra-226	up to 120
Cs-137	before/after 1986



# Dating discrepancy

## Limitations !!!

- Continuous precipitation (short time dating)
- Radionuclides migration (fractionation) due to environmental processes (long time dating)

Example: Surface samples taken at site contaminated between 1970 and 80 due to discharge mine water

Sample No.	$^{228}\text{Ra}/^{226}\text{Ra}$	$^{228}\text{Ra}/^{228}\text{Th}$	$^{226}\text{Ra} / ^{210}\text{Pb}$
5628	$36 \pm 2$	$37 \pm 2$	$22 \pm 4$
5630	$30 \pm 2$	$32 \pm 2$	$23 \pm 3$
5436	$34 \pm 3$	$36 \pm 3$	$11 \pm 1$
5437	$36 \pm 3$	$38 \pm 3$	$14 \pm 1$
5438	$38 \pm 3$	$39 \pm 3$	$8 \pm 1$
5439	$38 \pm 3$	$40 \pm 3$	$7 \pm 1$



# Summary

- When the source of contamination is identified the radionuclides ratio in a soil profile let one know the case history ....
- If not, all observed differences from the natural pattern of radionuclides distribution along a soil profile suggest a human alteration of the natural environment



*Thank you for your attention!*

Silesian Centre for Environmental Radioactivity

[www.radiometria.gig.eu](http://www.radiometria.gig.eu)