Variation of natural radionuclides in non-ferrous fayalite slags during a one-month production period.

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NuTeC Nucleair Technologisch Centrum

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European Commission

cost

NORM4BUILDING

Fayalite slag

Secondary smelter facility

- Uses input material of Annex VI of EURATOM Basic safety standards
- Wide variation of input materials
- Non-ferrous slag

Slag can be processed in:

- Supplementary cementitious material
- Road base constructions
- Inorganic polymers

Picture from: www.econet.ne.jp/en/

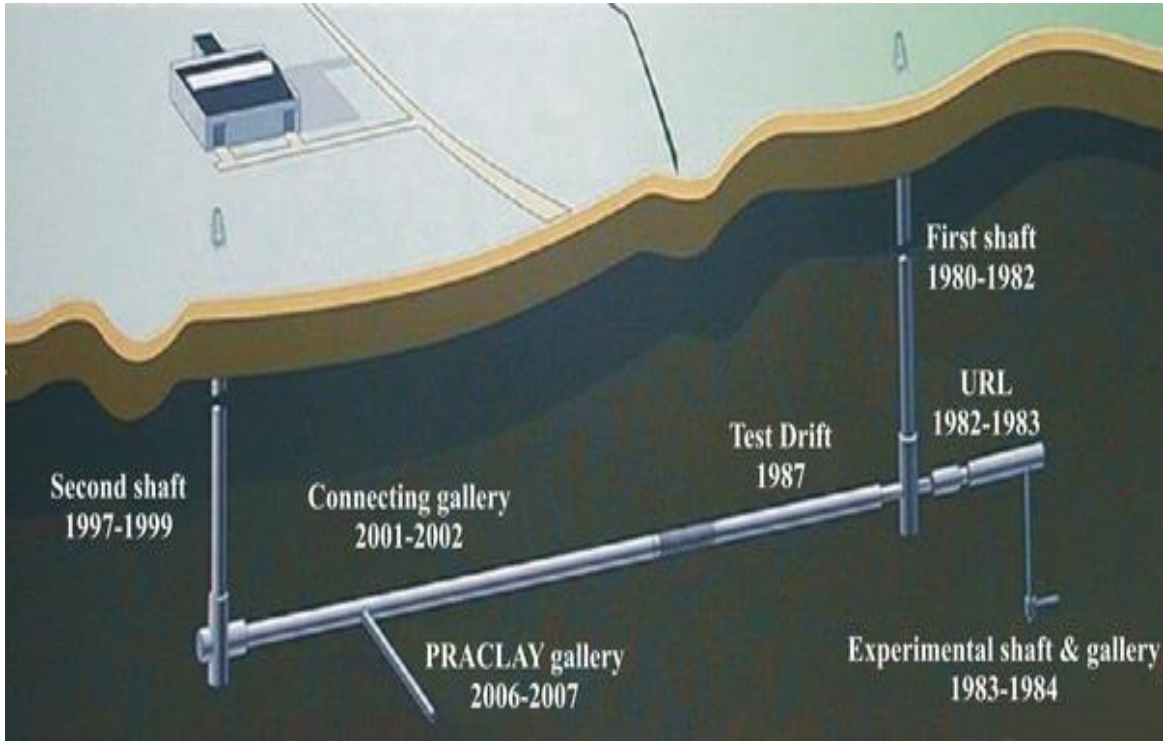
31 samples Non ferrous slag samples

- 3 Production batches of 1 day
  - Milled
  - Fine powder
  - Tapped
- >21 days in radon tight containers
- Measured using HPGe

Picture from: www.econet.ne.jp/en/

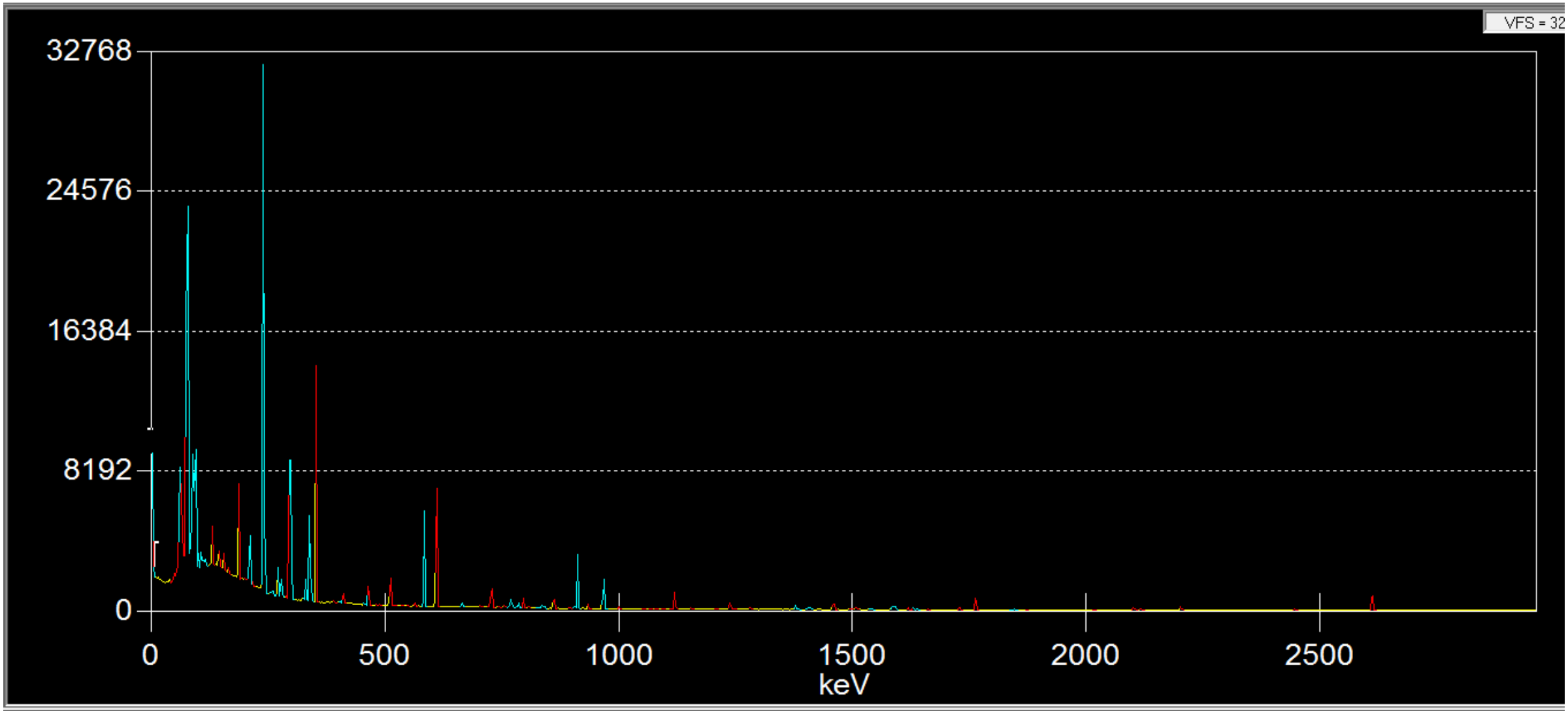
Radiological characterization

Table on detector details				
	Ge-3	Ge-4	Ge-5	Ge-8
Crystal type	P-type, coaxial	P-type, coaxial	P-type, planar	P-type, planar
Relative efficiency	60%	100%	50%	19%
Shielding	10 cm copper + 14 cm lead	7.5 cm copper + 15 cm lead	5 cm copper + 15 cm lead	5 cm copper + 15 cm lead
Samples measured	Slag 5	Slag 4, 6, 9, 11, 14, 20, 22, 26, 29, 31	Slag 1, 2, 3, 7, 12, 15, 17, 18, 19, 21, 23, 27,30	Slag 8, 10, 13, 16, 24, 25, 28
Dead time	0.54%	0.01-0.02%	0.04-0.05%	0.01%
FWHM of QA at 661.6	1.554	1.572	1.315	1.231
FWHM of QA at 1173.3	1.820	1.891	1.670	1.572
FWHM of QA at 1332	1.891	1.964	1.753	1.637



Picture from: www.sckcen.be/nl

Radiological characterization - spectrum



Spectrum of a non-ferrous slag measured on detector Ge-8 for 4 days acquired with genie 2000 (Canberra)

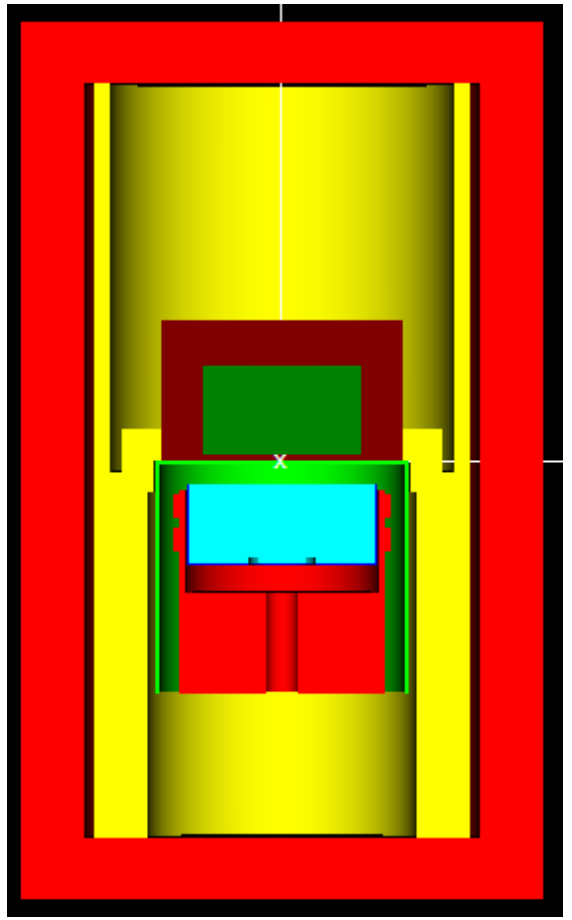
Radiological characterization – gamma lines

Radionuclide	Energy (keV)	Probability of emission (%)
^{234}Th	63.3	3.75
	92.38	2.18
	92.8	2.15
^{234m}Pa	766.361	0.323
	1001.026	0.847
^{214}Pb	241.997	7.268
	295.224	18.414
	351.932	35.6
^{214}Bi	609.312	45.49
	768.356	4.892
	806.174	1.262
	934.061	3.1
	1120.287	14.91
	1155.19	1.635
	1238.111	5.831
	1280.96	1.435
	1377.669	3.968
	1401.5	1.33
	1407.98	2.389
	1509.228	2.128
	1729.595	2.844
	1764.494	15.31
	1847.42	2.025
	2118.55	1.158
	2204.21	4.913
	2447.86	1.548
^{210}Pb	46.539	4.252

Radionuclide	Energy (keV)	Probability of emission (%)
^{228}Ac	209.248	3.97
	328.004	3.04
	409.46	2.02
	463.002	4.45
	755.313	1.03
	772.291	1.52
	794.942	4.31
	911.196	26.2
	968.96	15.9
	1588.2	3.06
	1630.618	1.52
^{224}Ra	240.986	4.12
^{212}Pb	238.632	43.6
^{212}Bi	1620.738	1.51
^{208}Tl	277.37	6.6
	583.187	85
	763.45	1.8
	860.53	12.4
	2614.511	99.755
^{235}U	143.767	10.94
	185.72	57
	163.356	5.08
	205.316	5.02
^{40}K	1460.822	10.55

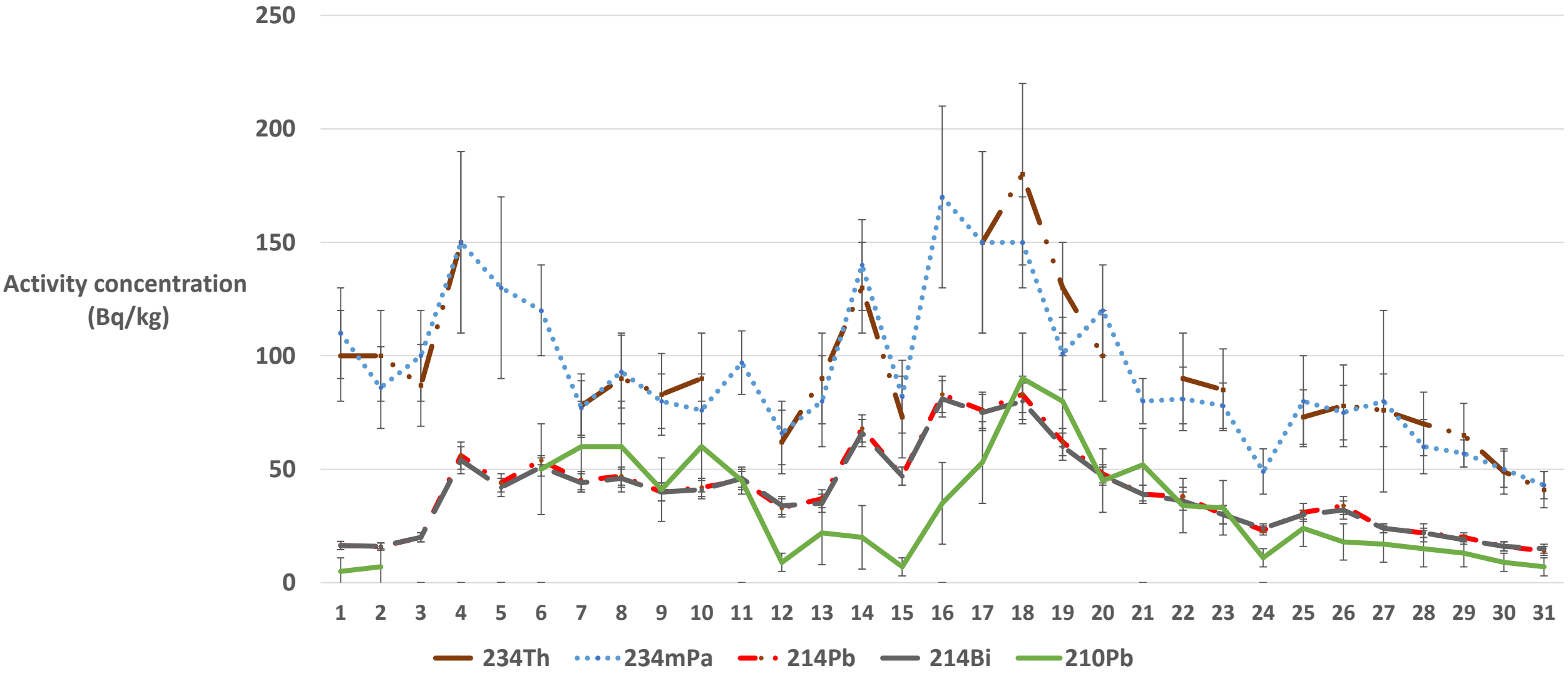
Radiological characterization – full energy peak efficiencies

- EGSnrc
  - Electron Gamma shower national research council of Canada
- Input
  - Geometry of set-up
  - Sample composition
  - Radionuclides

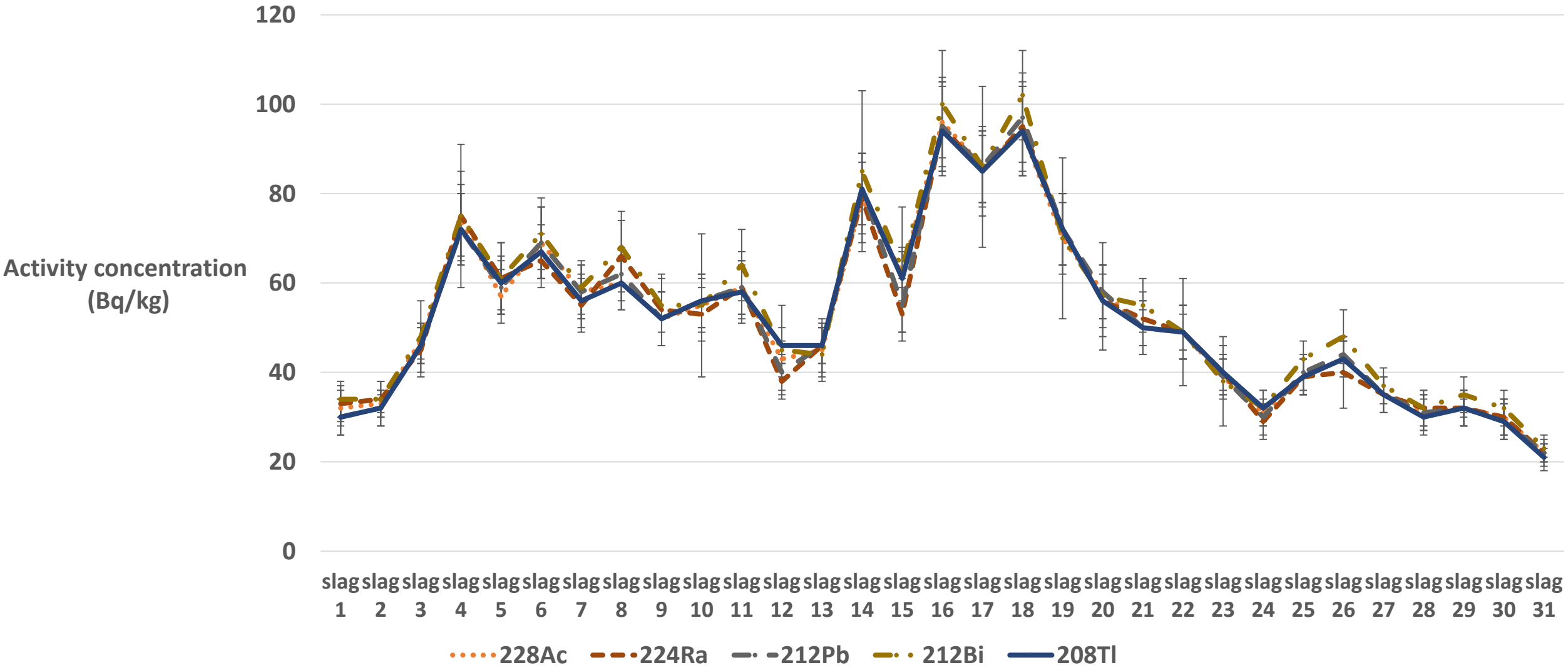


Picture of measurement set up in EGSnrc

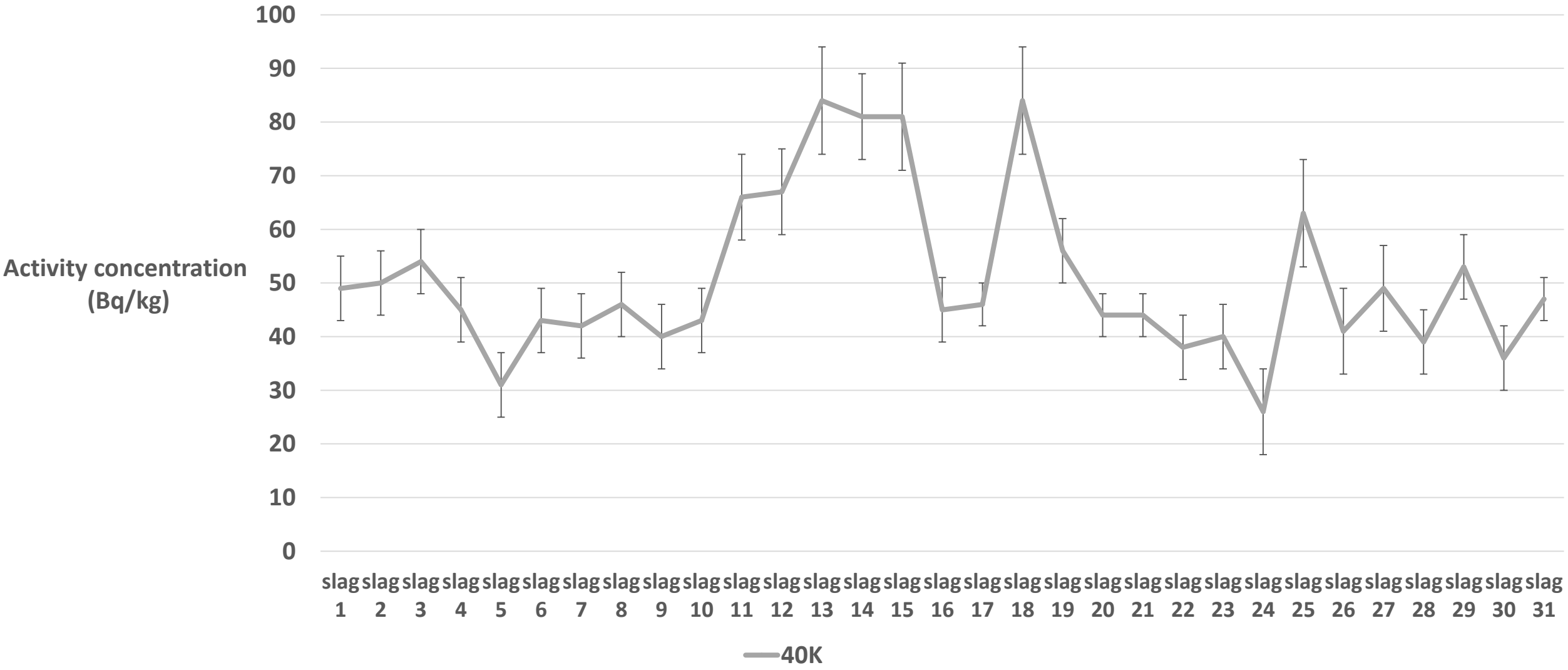
Results ^{238}U decay chain



Results ^{232}Th decay chain



Results ^{40}K


Activity concentration (Bq/kg)
100
90
80
70
60
50
40
30
20
10
0
slag 1
slag 2
slag 3
slag 4
slag 5
slag 6
slag 7
slag 8
slag 9
slag 10
slag 11
slag 12
slag 13
slag 14
slag 15
slag 16
slag 17
slag 18
slag 19
slag 20
slag 21
slag 22
slag 23
slag 24
slag 25
slag 26
slag 27
slag 28
slag 29
slag 30
slag 31
40K

Comparison with other slags (Bq/kg)

	^{226}Ra	^{232}Th	^{40}K
Variation in this study	**14-83**	**22-96**	**26-84**
Cu slag [1]	**490-940**	**41-60**	**530-760**
Ni slag [1]	**52**	**78**	**76**
Sn slag [1]	**1000-1200**	**230-340**	**330**
Pb slag [1]	**270**	**36**	**200**
Furnace slags [2]	**15-347**	**1 78**	**20-536**

[1] Lehmann, R. (1996). Strahlenbelastung durch natürliche radionuklide in baumaterialien, fossilen brennstoffen und Dungemitteln. *Bundesamt Für Strahlenshutz, Berlin*, 135 – 156.

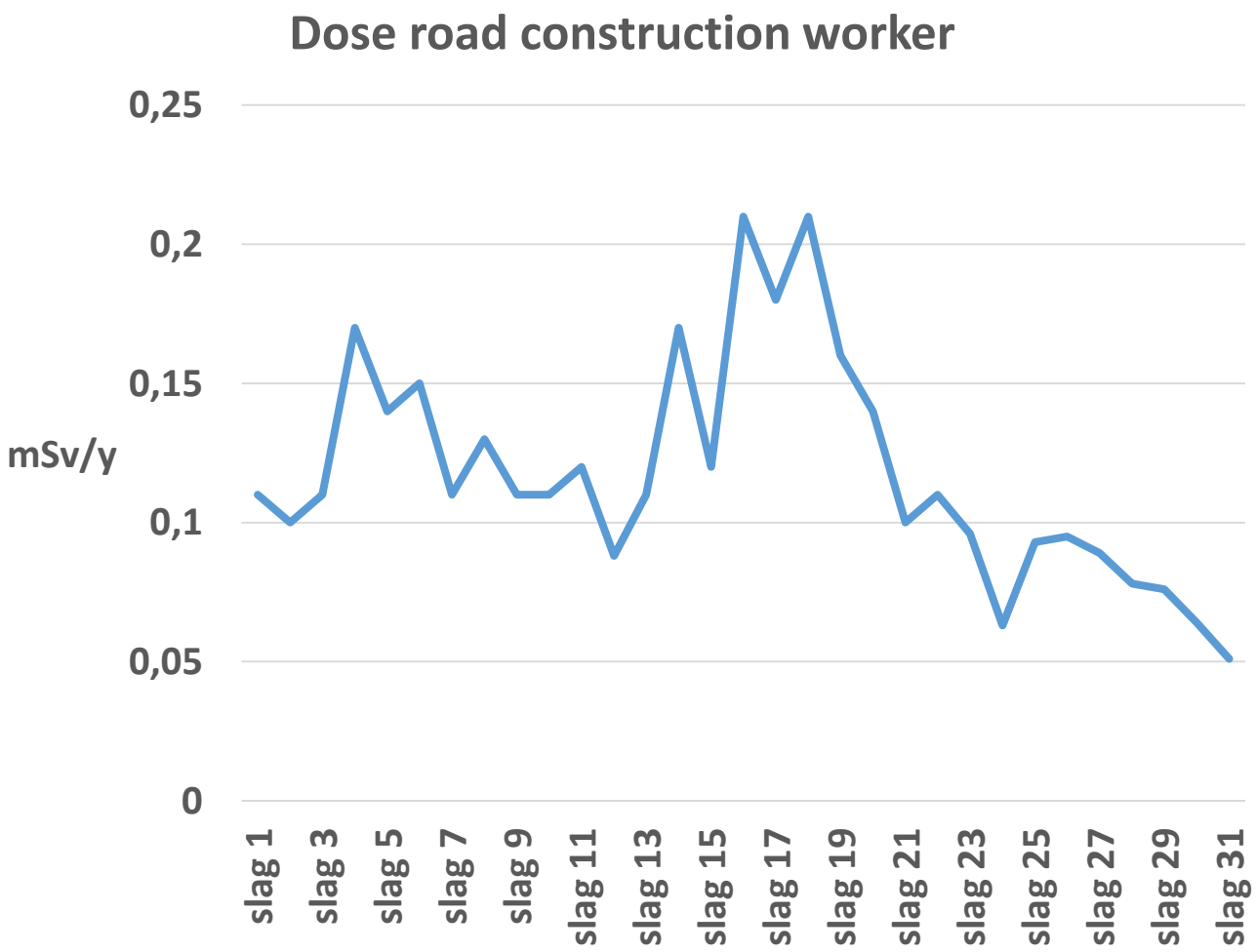
[2] Nuccetelli, C., Pontikes, Y., Leonardi, F., & Trevisi, R. (2015). New perspectives and issues arising from the introduction of (NORM) residues in building materials: A critical assessment on the radiological behaviour. *Construction and Building Materials*, *82*, 323–331.

Dose calculations

- Based on Radiation Protection (RP) 122 (part II)
  - Scenarios are specified
  - Severe dose model
  - Activity concentration of
    - ^{234m}Pa or ^{234}Th (highest of ^{238}U decay chain)
    - ^{228}Ac
    - ^{40}K
- Two scenarios
  - Road construction worker
  - Public space outdoor as sport ground
    - More severe than road use

Picture from: http://1fotonin.com/

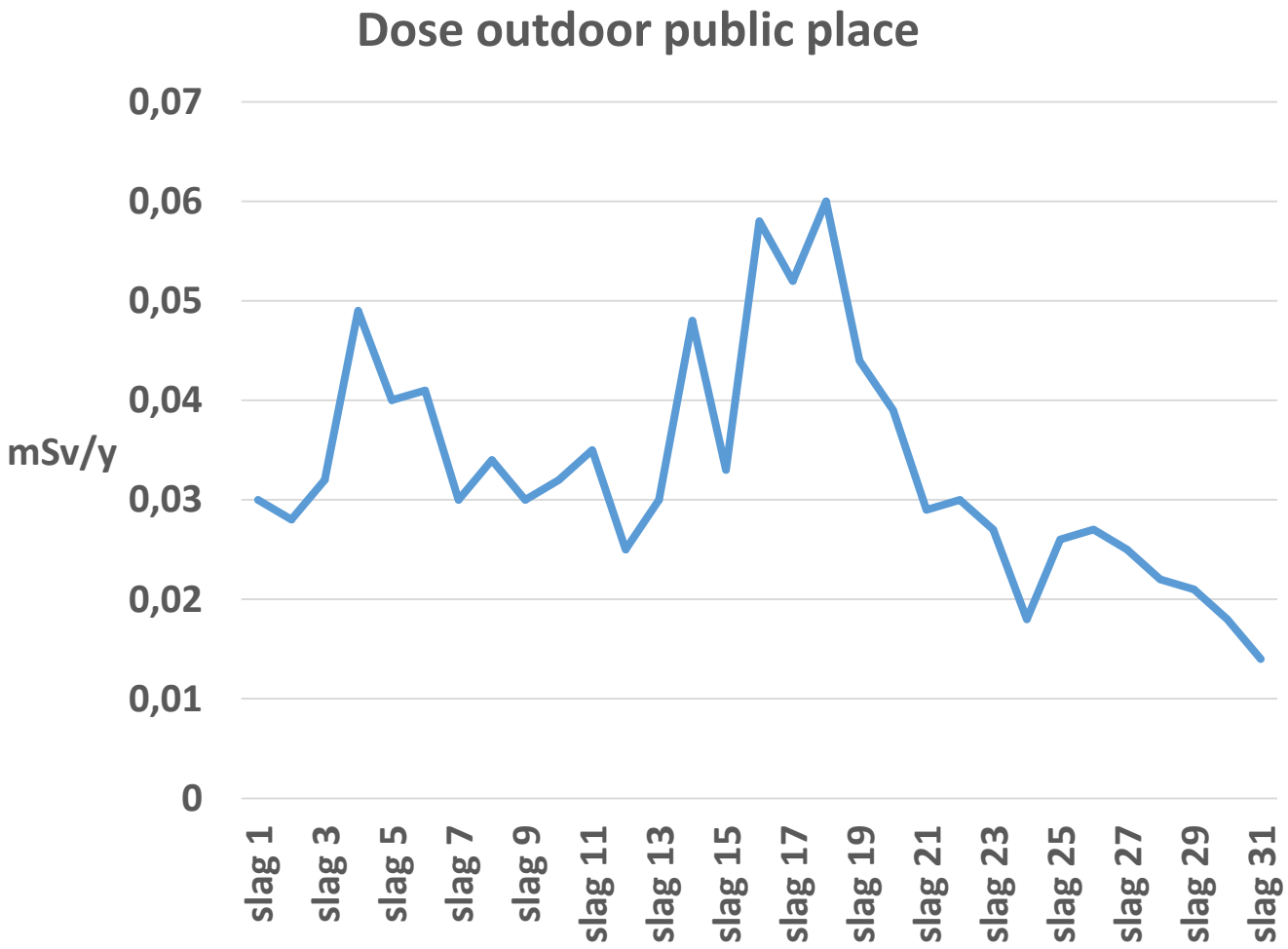
Dose calculations – road construction worker



Dose assessment according to RP122 (part II)

- exposure time: 1800h/a
- plane geometry (length 100 m – width 10 m – thickness 0.4 m)
- Density: 2000 kg/m3
- dilution factor: 1
- breathing rate: 1.2
- annual average dust concentration: 1 mg/m^3 ingestion rate: 10 mg/h

Dose calculations – outdoor public place



Dose assessment according to RP122 (part II)

- Exposure time: 500h/a
- plane geometry (length infinite – width infinite – thickness 0.1 m)
- Density: 2000 kg/m3
- dilution factor: 1
- breathing rate of 0.925 m^3/h
- annual average dust concentration: 0.5 mg/m^3
- ingestion rate: 10 mg/h

Conclusion

- Thorough measurements are usefull
  - Don’t take equilibrium for granted (in industrial) samples
- Variations in output of materials throughout typical NORM-radionuclides
  - Good to monitor production
- Measured slags are safe to use
  - Road construction worker
  - Public outdoor spaces

Questions?

- Tom Croymans
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