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Natural radionuclides and Cs-137 in biomass combustion residues: how to solve the puzzle?

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Overview

- Introduction : biomass for energy production
- Biomass measurement campaign: sampling and measurements
- Biomass measurement campaign: results (U-238 decay chain, Th-232 decay chain, K-40, Cs-137)
- Comparison with firewood (logs) measurement campaign
- Incorporation of ashes in building products
- Conclusion

Introduction: biomass for energy production

- 60% of renewable energy¹
- 12% energy consumption in 2020¹
- Issues:
 - Sustainability of resources
 - Treatment of the residues
 - Reuse and recycling should be preferred to landfilling
 - Fly ashes as a valuable resource for the construction industry → radiological characterization
 - Nuclear weapons tests and Chernobyl accident → organic material used as fuel contaminated with Cs-137

¹ SCARLAT, N., FAHL, F., Heat and Power from Biomass Technology Development Report 2020, EUR 30505 EN, European Commission Joint Research Centre, Luxembourg, 2020

2 biomass power stations (BPS):

BPS1

- Large-scale (industrial)
- Electrical power station
- 200 MW

BPS2

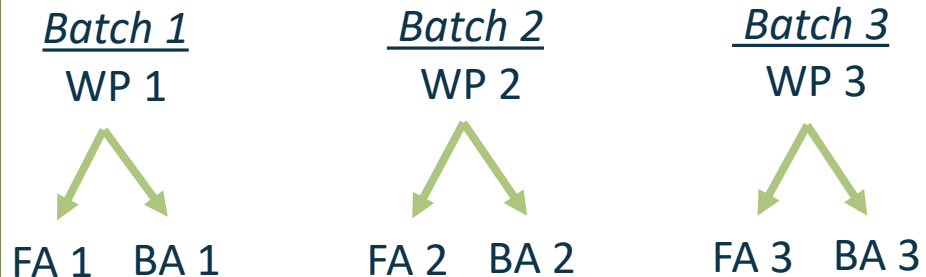
- Small-scale (local)
- Electrical and thermal power station (cogeneration)
- 3 MW electrical power +
7 MW thermal power

Sampling (2/2)

2 biomass power stations (BPS): Wood pellets (WP), fly ashes (FA), bottom ashes (BA)

BPS1

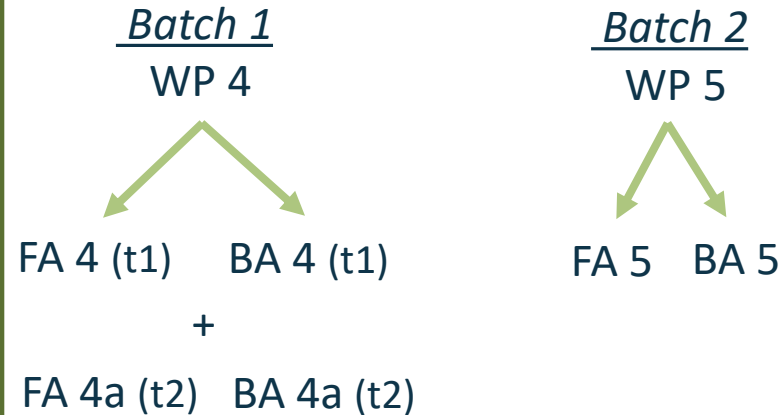
9 samples:



Wood pellets originated from **Russian federation**

BPS2

8 samples:



Wood pellets originated from **Belgium**

Measurements

Alpha spectroscopy



Samples	U-238	Ra-226	Th-228 and/or Ra-228	K-40	Po-210	Pb-210	Cs-137
WP	x	x	x	x		Partially	x
FA	x	X	x	x	x	Partially	x
BA	x	x	x	x	x	Partially	x



Gamma spectroscopy



2 laboratories:

- IRE-Elit
- SCK-CEN

Clearance/exemption levels applied in Belgium (NORM residues)

Use of clearance/exemption levels (CL/EL) of European Commission Report “Radiation Protection 122 Part II”

	U-238sec	Ra-226+	Ra-228+	Th-228+	K-40	Po-210	Pb-210+	Cs-137
CL/EL (Bq/kg)	500	500	1000	500	5000	5000	5000	100
CL/EL – “mono-landfill” (Bq/kg)	100	100	100	100	-	-	-	-

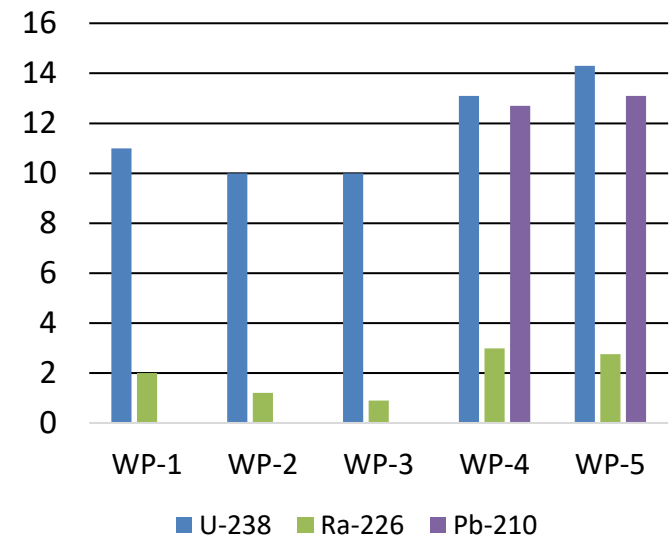
If $AC^1 < CL$: no additional constraints for residue management (exception: mono-landfill) → clearance from further surveillance

If $AC^1 > CL$: follow-up necessary

¹ activity concentration

Results (Bq/kg): U-238 decay chain

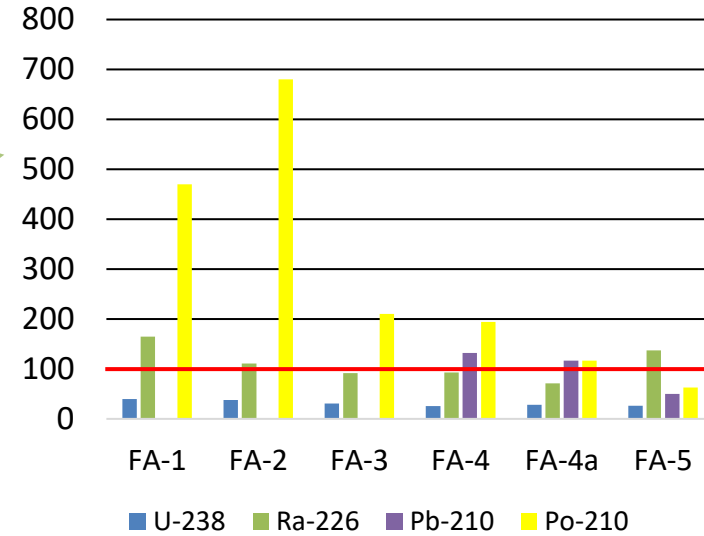
Wood pellets



Concentration factors

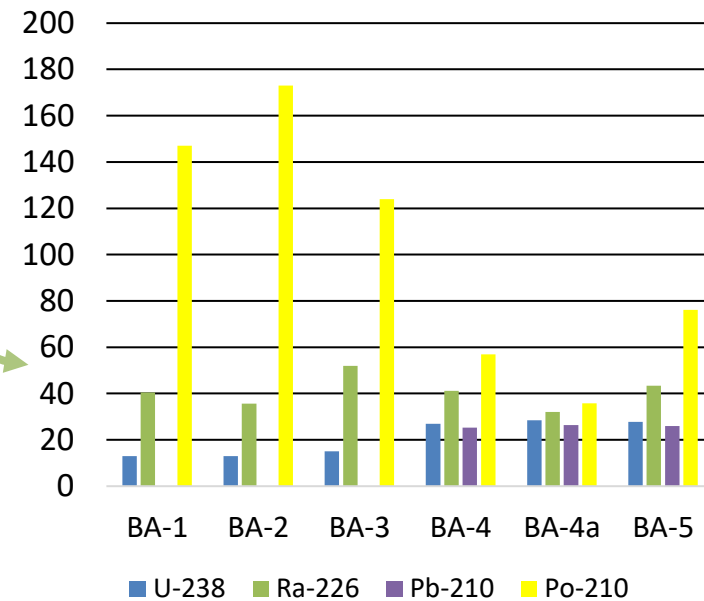
FA-1	83
FA-2	93
FA-3	102
FA-4	31
FA-4a	24
FA-5	50

BA-1	20
BA-2	30
BA-3	58
BA-4	14
BA-4a	11
BA-5	16



Fly ashes

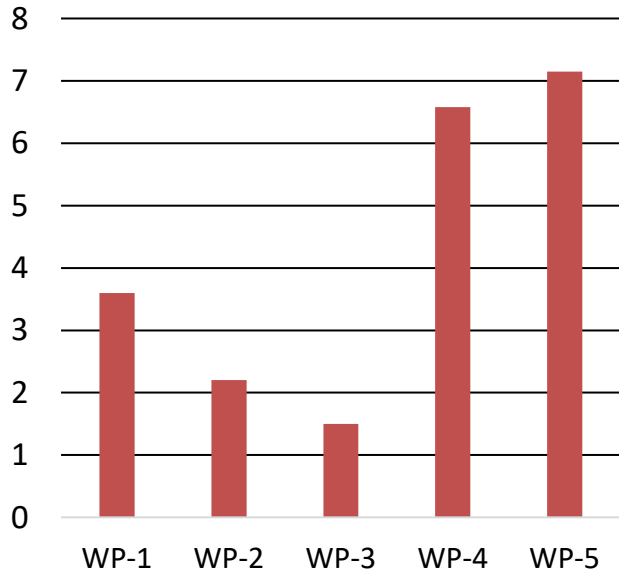
Clearance/exemption level for Ra-226



Bottom ashes

Results (Bq/kg): Th-232 decay chain (Th-228 or Ra-228)

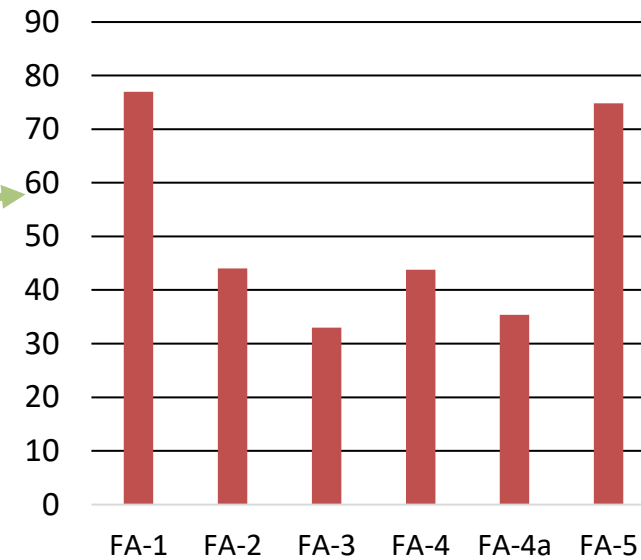
Wood pellets



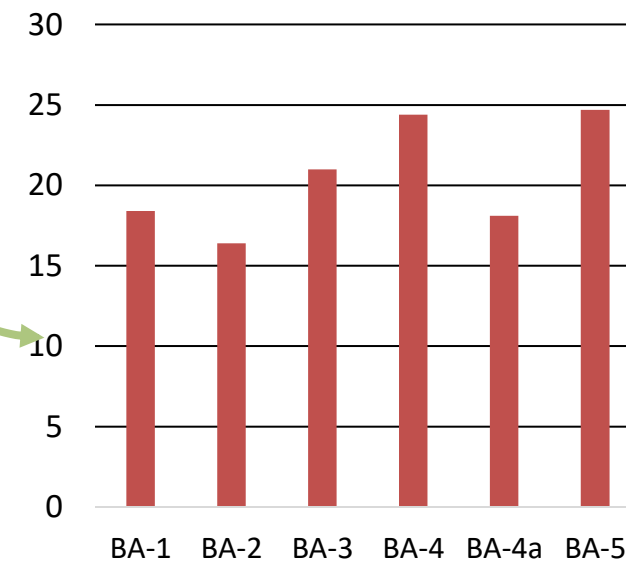
Concentration factors

FA-1	21
FA-2	20
FA-3	22
FA-4	7
FA-4a	5
FA-5	10

BA-1	5
BA-2	7
BA-3	14
BA-4	4
BA-4a	3
BA-5	3



Fly ashes



Bottom ashes

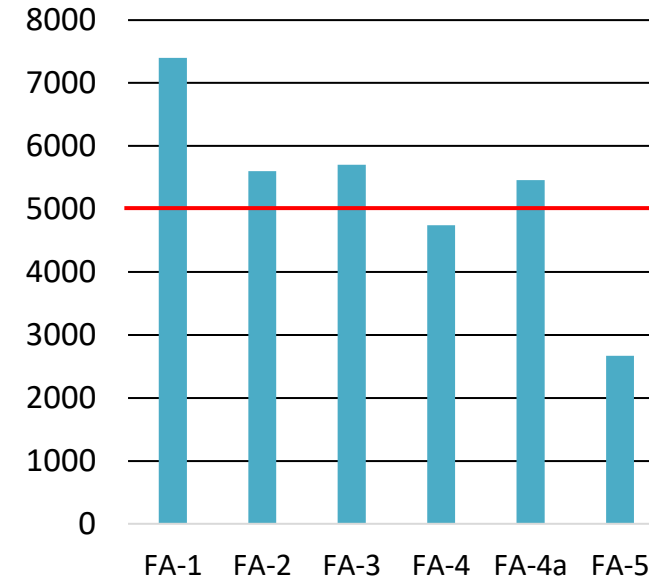
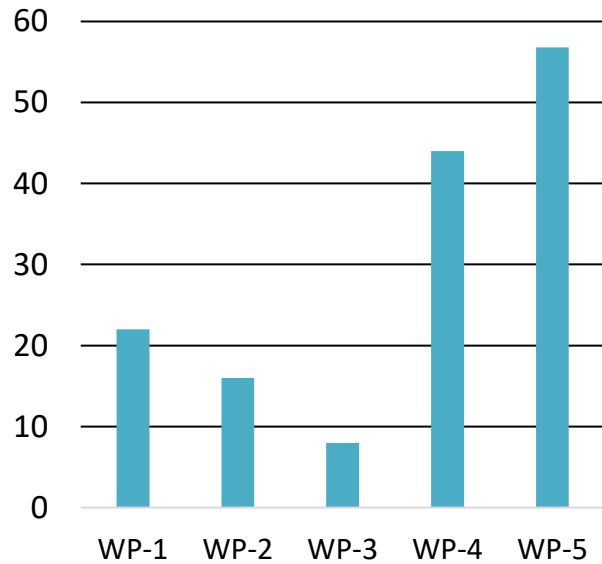
Results (Bq/kg): K-40

Concentration factors

FA-1	336
FA-2	350
FA-3	713
FA-4	108
FA-4a	124
FA-5	47

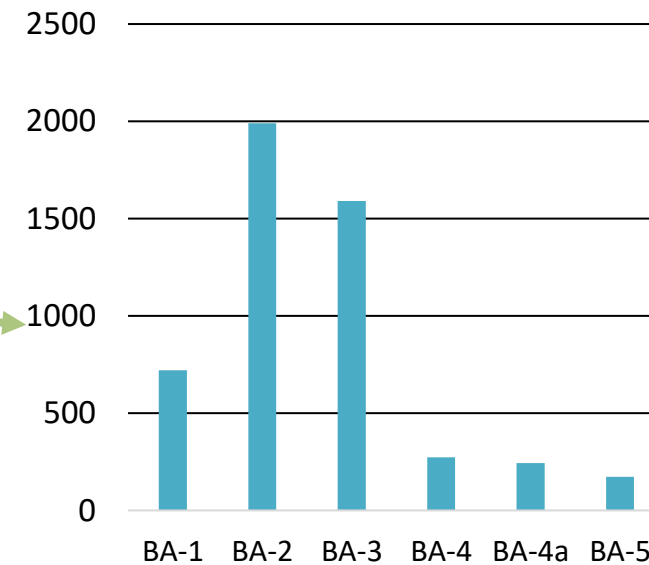
BA-1	33
BA-2	124
BA-3	199
BA-4	6
BA-4a	6
BA-5	3

Wood pellets



Clearance/exemption level

Fly ashes



Bottom ashes

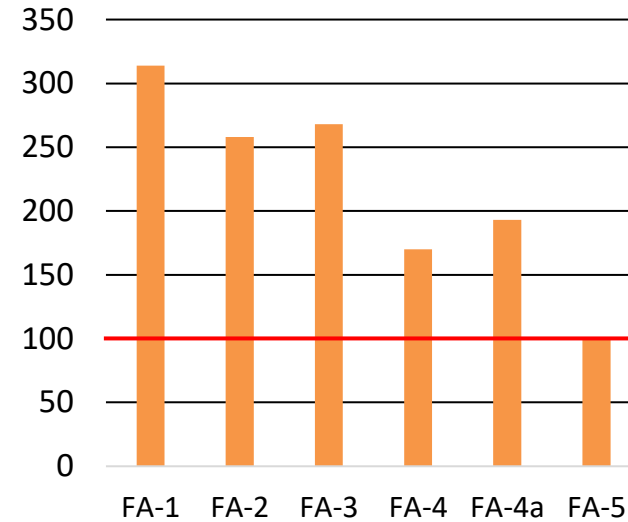
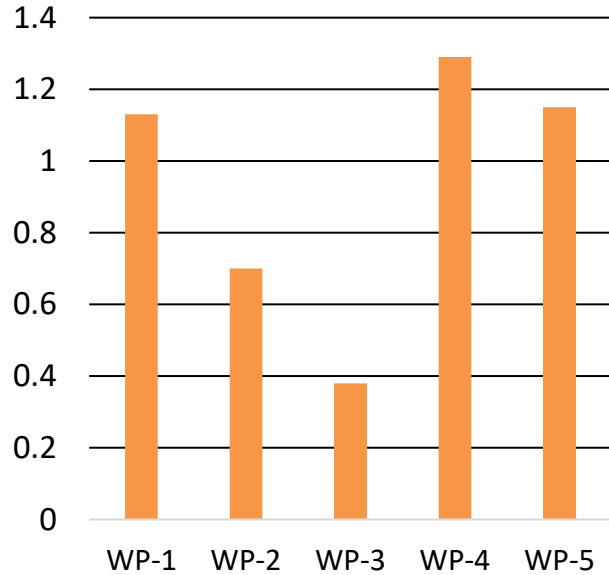
Results (Bq/kg): Cs-137

Concentration factors

FA-1	278
FA-2	369
FA-3	705
FA-4	132
FA-4a	150
FA-5	86

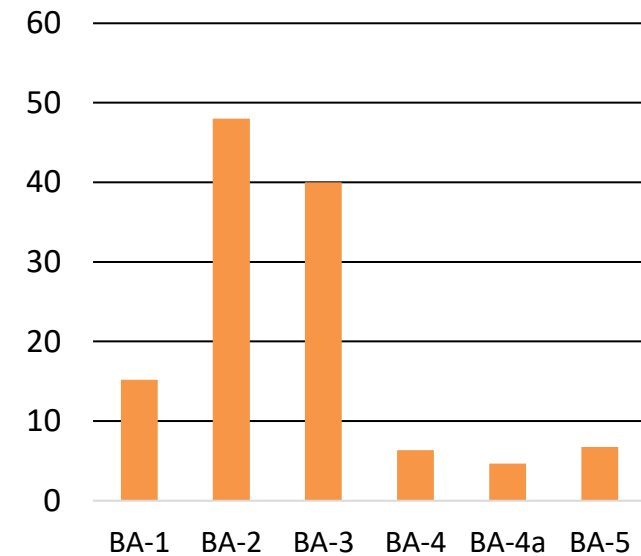
BA-1	13
BA-2	69
BA-3	105
BA-4	5
BA-4a	4
BA-5	6

Wood pellets



Fly ashes

Clearance/exemption level

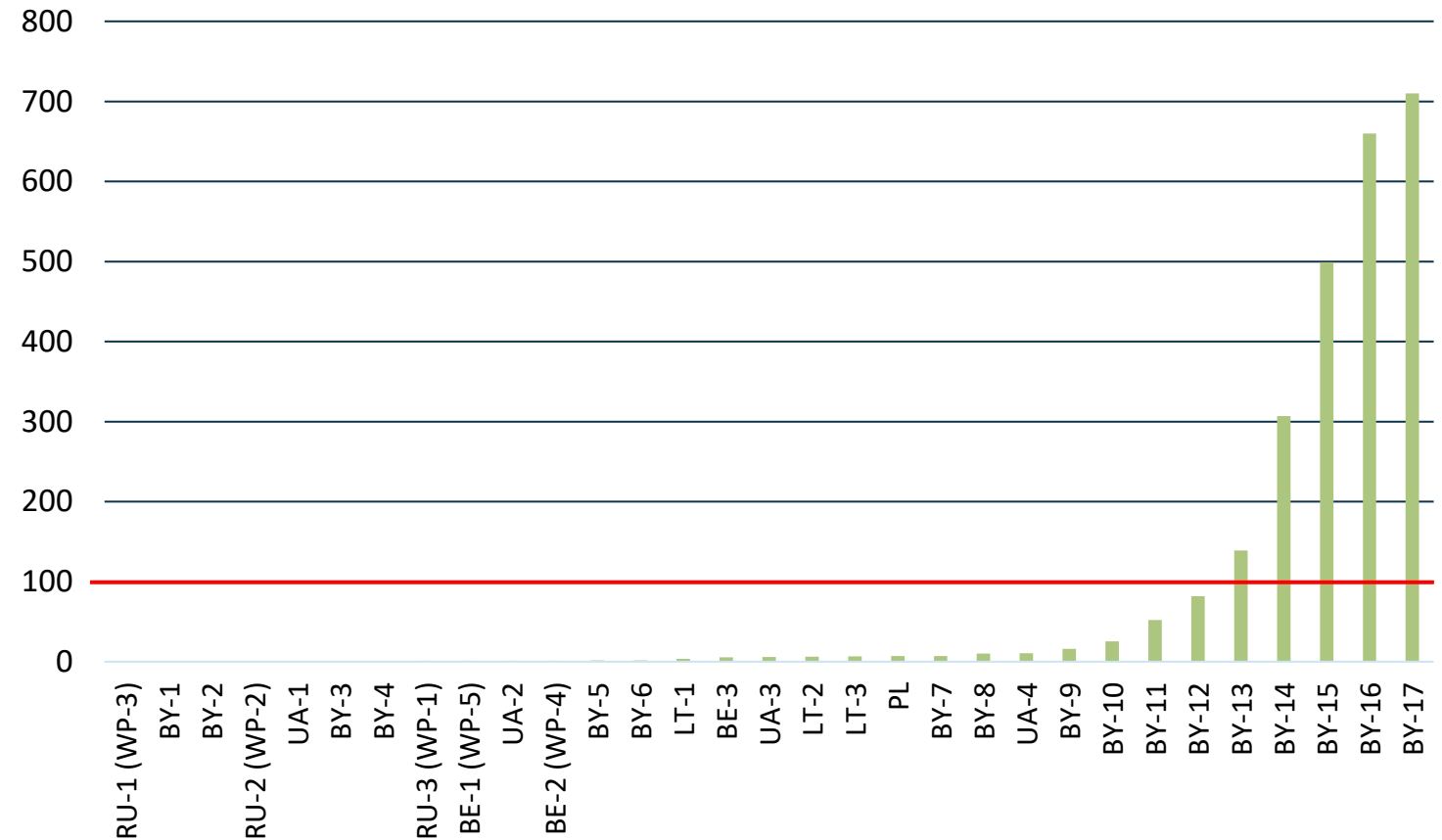


Bottom ashes

Comparison with other firewood samples (1/2)

Results in Bq/kg

- 2020: measurement and inspection campaign on firewood (logs) for domestic use
- 26 logs samples + 5 wood pellets samples
- Maximal AC¹ of Cs-137: **710 Bq/kg**
- All samples with AC > 100 Bq/kg originate from **Belarus**
- All samples originating from Belarus don't present elevated Cs-137 concentration



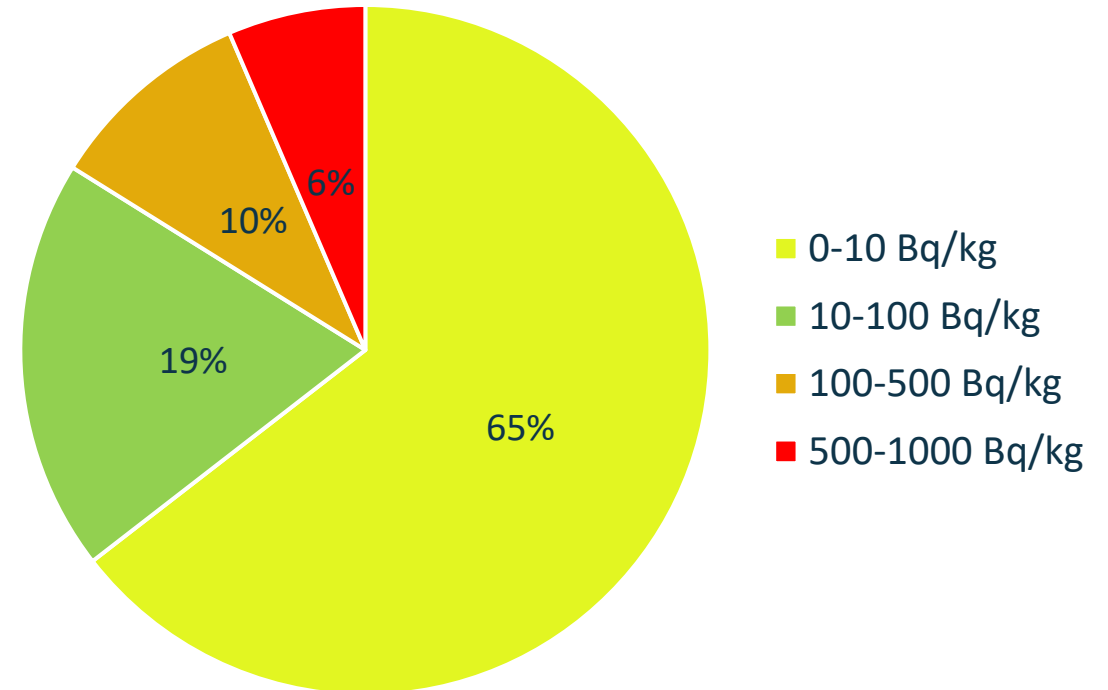
RU=Russia; BY=Belarus; UA=Ukraine; BE=Belgium; LT=Lithuania; PL=Poland

— Clearance/exemption level defined in the EU BSS (100 Bq/kg)

¹ activity concentration

Comparison with other firewood samples (2/2)

- 2020: measurement and inspection campaign on firewood (logs) for domestic use
- 26 logs samples + 5 wood pellets samples
- Maximal AC¹ of Cs-137: **710 Bq/kg**
- All samples with AC > 100 Bq/kg originate from **Belarus**
- All samples originating from Belarus don't present elevated Cs-137 concentration



84% of the samples present an AC < 100 Bq/kg
16% of the samples present an AC > 100 Bq/kg

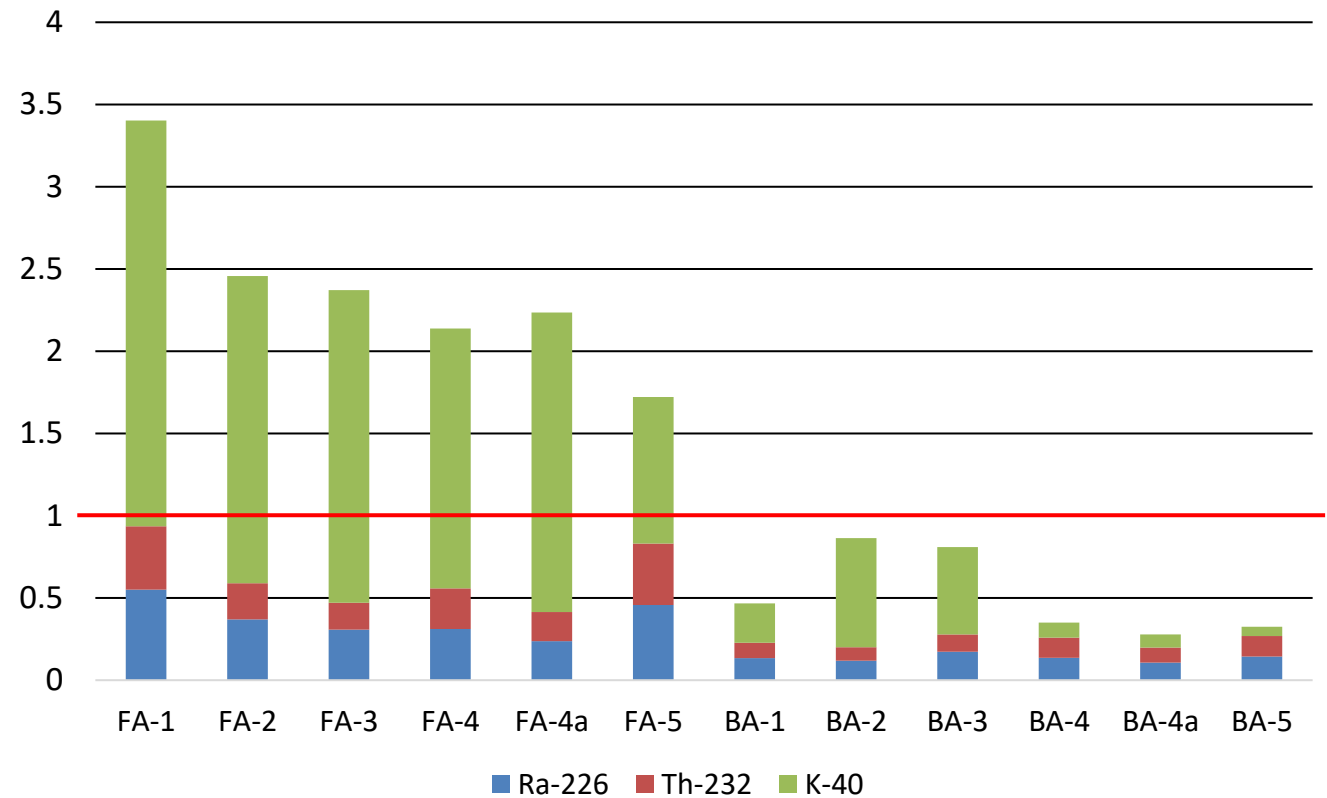
¹ activity concentration

Incorporation of ashes in building products

$$I = C_{\text{Ra-226}}/300 + C_{\text{Th-232}}/200 + C_{\text{K-40}}/3000$$

(C in Bq/kg)

- All **fly ashes** exceed $I = 1$
- Maximal $I = 3.4$
- **K-40** contributes the most
- **!** Building product never composed of 100% of ashes → activity concentration and mass fraction of each component
- **Cs-137**: additional screening method required
- Clarification of dose-criteria:
 - Building material and natural radionuclides: 1 mSv/yr
 - Artificial radionuclides (Cs-137): 0.01 mSv/yr



Conclusions

Biomass measurement campaign:

- Significant concentration factor for Cs-137 and natural radionuclides (K-40) in fly ashes from biomass combustion
- Clearance/exemption level for Cs-137 (100 Bq/kg) exceeded in almost all fly ashes
- Cs-137 activity in wood pellets trivial (around 1 Bq/kg)
- Index I largely exceeded for all fly ashes (max. 3.4)

Firewood (logs) campaign:

- Logs imported in Belgium from countries more impacted by Chernobyl accident (Belarus and Ukraine)
- Cs-137 activity concentration may in some cases exceed trivial values (max. 710 Bq/kg)

Challenges:

- Clarification of applicable regulations concerning Cs-137 contamination in wood and biomass combustion raw material and residue
- Understanding of the concentration process during combustion



Thank you!