Contribution of coal ash used as an additive to concrete to radiation exposure

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Introduction

- Fly Ash (FA) contain higher activity concentration of ^{226}Ra, ^{232}Th and their decay products and ^{40}K, than common aggregates or sand. Thus, its use in concrete will enhance their activity concentration.

2004-2012	^{40}K [Bq/kg]	^{232}Th [Bq/kg]	^{226}Ra [Bq/kg]
FA average	281	138	156
RSD of averages	12%	15%	11%

- This higher activity combined with the mineralogical characteristics of FA may influence on the radiation exposure of the population in buildings.

- The results of a survey of different mixtures of concrete containing FA is presented.

Survey method

- Laboratory measurements
  - Concrete samples (cubes) having 0, 75 and 120 kg/m^3 of FA from different sources were examined
- The FA was produced at different power plants
- Cement, sand and aggregates were from the same source
- The radionuclide content and the Rn emanation were determined according to IS 5098 procedures
- Five samples were sent to NRG (Netherlands)
- In-situ measurements (performed in a new building)
  - In the framework of a specific study
  - Rn and ventilation tests

Exposure calculation

- The calculation of the potential population exposure was based on the SI 5098 principles
- Standard room at normal living conditions
- Calculation of gamma index

$$\frac{C_K}{A_K(\rho d)} + \frac{C_{Ra}}{A_{Ra}(\rho d)} + \frac{C_{Th}}{A_{Th}(\rho d)} \le I_\gamma = 0.4 \equiv 0.44 mSv/y$$

- Calculation of total index (γ+Rn)

$$\frac{C_K}{A_K(\rho d)} + \frac{C_{Ra}}{A_{Ra}(\rho d)}(1-\varepsilon) + \frac{C_{Th}}{A_{Th}(\rho d)} + \frac{\varepsilon \cdot C_{Ra}}{A_{Rn}(\rho d)} \le I = 1 \equiv 1.1 mSv/y$$

- Problem: only one set without FA

Radionuclide activity concentration

Material	FA [kg/m^3]	^{40}K [Bq/kg]	^{232}Th [Bq/kg]	^{226}Ra [Bq/kg]
Cement		110.7	22.9	70.8
Sand		74.8	7.8	9.2
Aggregate		33.6	1.5	40.6
Concrete	0	**43.3** (56.7±8.2)	**5.4** (5.1±1.5)	**37.2** (26.7±2.4)
Concrete	75	**59.8** (49-67.2)	**9.7** (7.2-14.5)	**33.3** (30.9-37.5)
Concrete	120	**65.8** (48.4-85.6)	**11.2** (7.5-19.5)	**37.7** (33.6-42.4)

Radon emanation

Material	FA [kg/m^3]	^{222}Rn [%]
Concrete	0	**7.8** (17.3±3.3)
Concrete	75	**9.2** (8.2-10.8)
Concrete	120	**8.4** (6.6-11.5)

Radon emanation coefficient

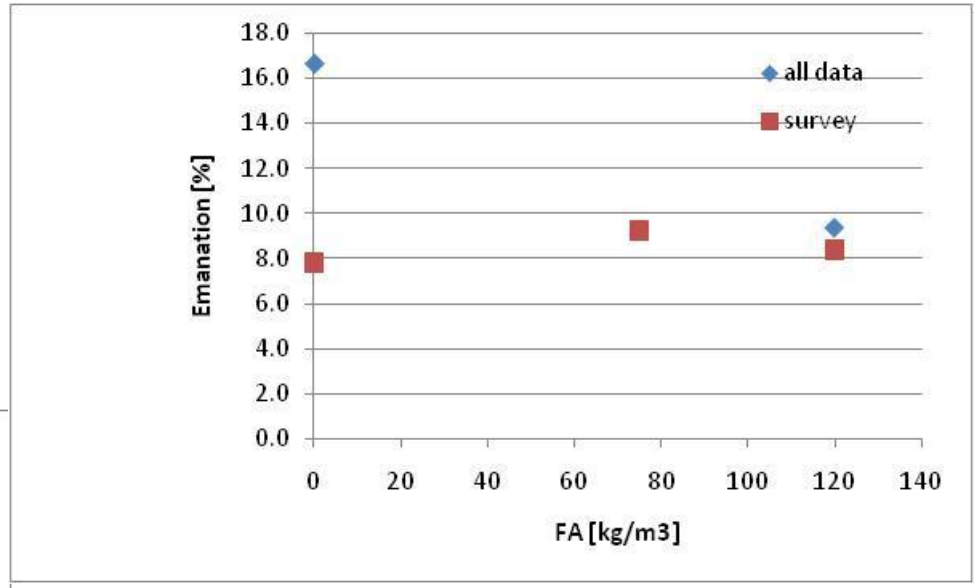
FA type	FA [kg/m^3]	^{222}Rn [%]	75/0	120/75	120/0
	0	7.8			
Kpc	75	9.8	26%		
	120	8.3		-15%	6%
Glencore	75	9.8	26%		
	120	9.2		-6%	18%
Billiton	75	9.2	18%		
	120	8.4		-9%	8%
Drummond	75	10.8	38%		
	120	8.6		-20%	10%
MIM	75	8.2	5%		
	120	7.0		-15%	10%-

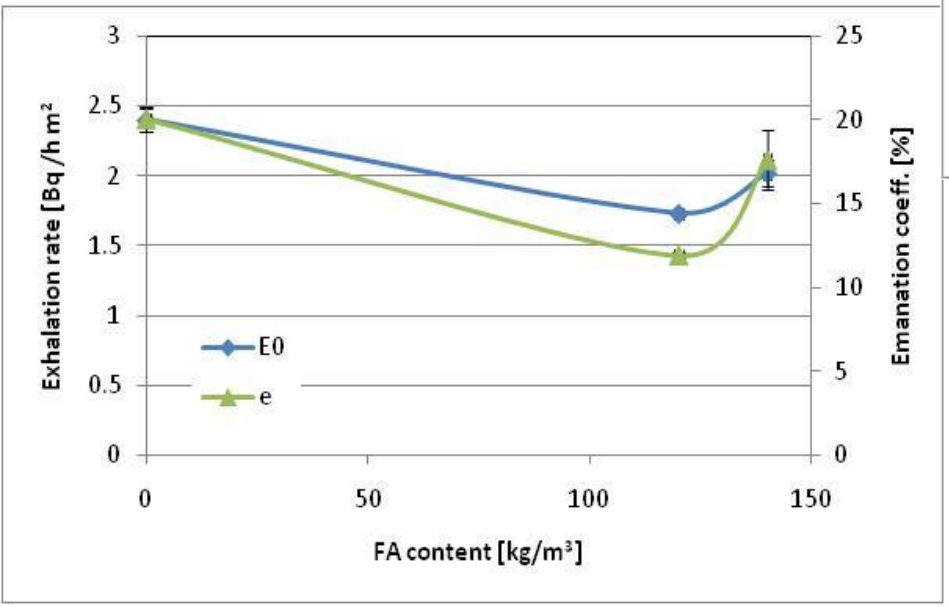
Radon emanation coefficient

FA type	FA [kg/m^3]	^{222}Rn [%]	75/0	120/75	120/0
	0	7.8			
Glencore	75	8.8	13%		
	120	6.6		-25%	-15%
CMC	75	9.1	17%		
	120	9.1		0%	17%
Suek	75	9.1	17%		
	120	7.4		-19%	-5%
Kpc	75	8.5	9%		
	120	7.7		-9%	-1%
Xstrata	75	9.1	17%		
	120	11.5		26%	47%

FA influence on Rn exhalation

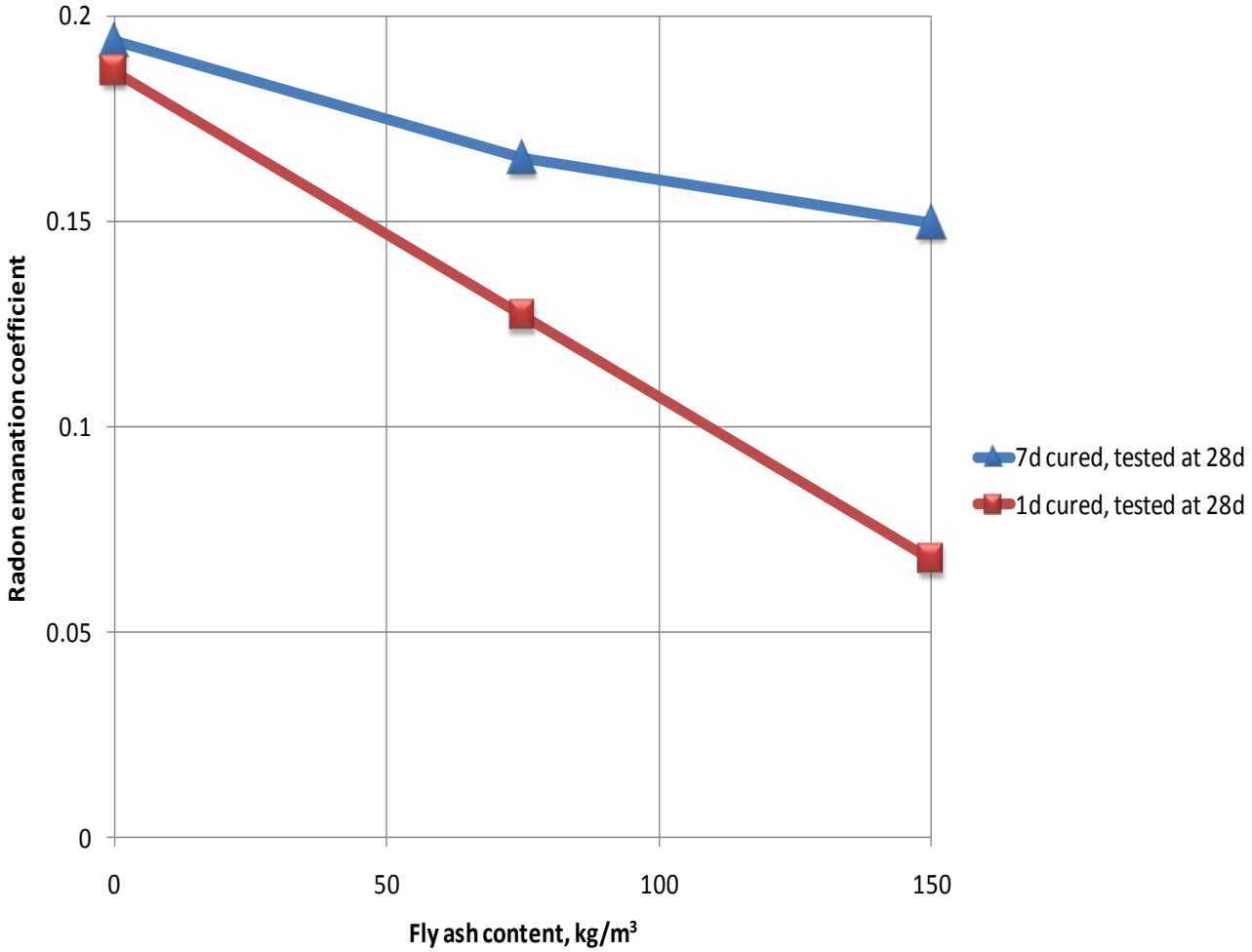
- Survey and previous data





Influence of curing period on Rn

- Laboratory samples measured in the lab



Exposure calculation by SI 5098

FA type	FA [kg/m^3]	E_γ [mSv/y]	E_{tot} [mSv/y
	0	**0.13**	**0.42**
Kpc	75	**0.12**	**0.43**
	120	**0.14**	**0.46**
Glencore	75	**0.17**	**0.54**
	120	**0.20**	**0.59**
Billington	75	**0.13**	**0.42**
	120	**0.15**	**0.48**
Drummond	75	**0.13**	**0.48**
	120	**0.15**	**0.44**
MIM	75	**0.14**	**0.43**
	120	**0.17**	**0.45**

Exposure calculation by SI 5098

FA type	FA [kg/m^3]	E_γ [mSv/y]	E_{tot} [mSv/y]
All data	0	**0.12**	**0.44**
Glencore	75	**0.13**	**0.42**
	120	**0.14**	**0.37**
CMC	75	**0.13**	**0.42**
	120	**0.14**	**0.45**
Suek	75	**0.14**	**0.43**
	120	**0.14**	**0.39**
Kpc	75	**0.17**	**0.46**
	120	**0.19**	**0.51**
Xstrata	75	**0.13**	**0.45**
	120	**0.15**	**0.55**

Wall average exhalation rate

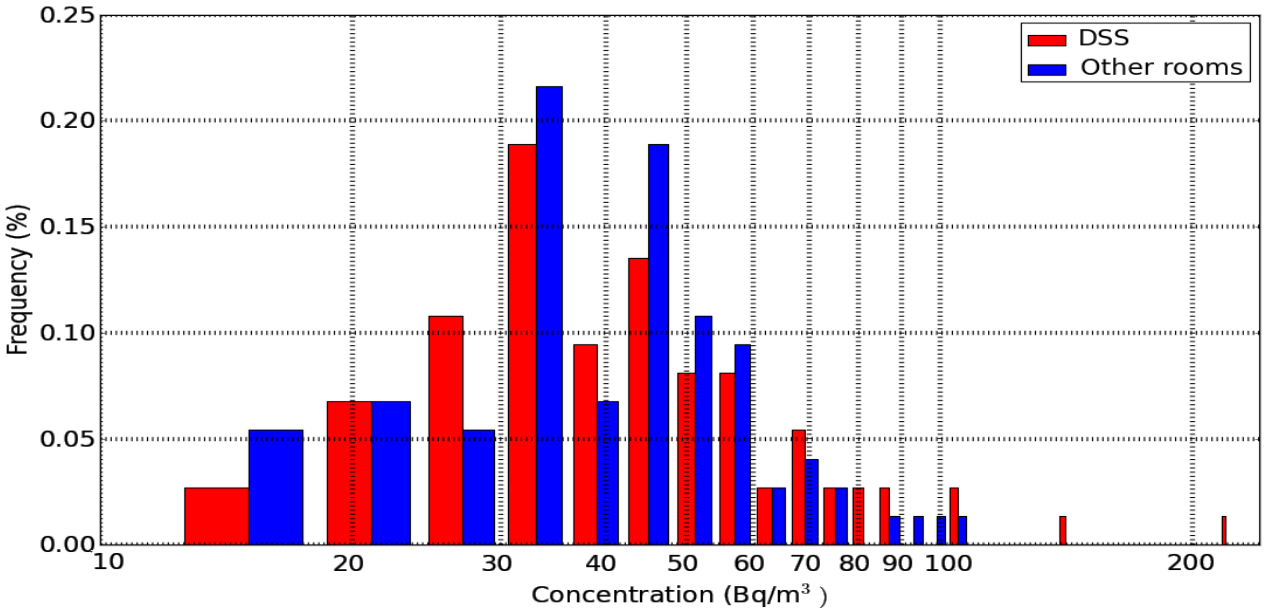
FA content [kg/m^3]	$E_{0wall,av}$ [Bq/m^{2}h]	Standard Deviation	Range [Bq/m^{2}h]
0	7.16	27.4%	3.6-9.4
120	8.30	10.6%	6.3-10.3
140	7.54	23.6%	4.9-11.7

Comparison SNRC - NRG

Material	FA [kg/m^3]	^{226}Ra [%]	^{222}Rn [%]	E_γ [mSv/y]	E_{tot} [mSv/y]
	0	-7%	11%	52%	87%
Kpc	120	-7%	-1%	61%	71%
Billington	120	-8%	11%	56%	78%
mim	120	-4%	0%	58%	77%
Glencore	120	17%	4%	75%	114%

Other exposure calculations

- Under conservative living conditions (ACR~0.1 hr^{-1}) the annual average Rn concentration (no FA in the concrete) was 60 Bq/m^3.
- Under normal living conditions (ACR~ 0.25 hr^{-1}) the annual average Rn was 35 Bq/m^3
- The average Rn under living conditions in RPR survey is 43 Bq/m^3.



Thank you

Questions?

FA activity concentration

Year	^{226}Ra			^{232}Th			^{40}K		
	Ave	Ran ge		Ave	Range		Ave	Range	
2004	174	84.7	223.8	170	63.5	230.1	224	153.8	558.1
2005	164	97.4	233.5	141	55.8	218.3	253	144.1	404.3
2006	181	97.3	251.2	157	59.5	238.9	305	153.8	628.1
2007	173	104	206	152	77.4	188.9	251	105.3	535.6
2008	158	76.3	221.3	152	61	233.3	260	141.7	542.4
2009	135	55.1	220	115	49.4	198.1	299	132.5	463.2
2010	133	58.2	202.6	115	46.9	199.4	315	138.7	516.2
2011	141	57.6	215.6	114	46.4	207.3	321	116.7	513.3
2012	148	75.7	232.2	124	47	217.1	299	122.6	457.1

FA source in concrete samples

Quarry	Country	Power Plant
Blend	Indonesia	Ashkelon
BB Prime	South Africa	Hadera
Newlands	Australia	Hadera
Cal	Colombia	Ashkelon
Rus	Russia	Hadera
La Loma LS	Colombia	Hadera
CerD	Colombia	Ashkelon
SKH	Russia	Hadera
Melawan	Indonesia	
GGV	South Africa