UNITED KINGDOM QUALITY ASH ASSOCIATION

Technical Datasheet

Radiation and Fly Ash

Introduction

Many substances, including naturally occurring materials, emit some radiation. Radioactivity is the disintegration of atomic nuclei by the emission of subatomic particles called alpha particles and beta particles or by the emission of X-rays and/or gamma rays. This was discovered in 1896 by the French physicist Antoine Henri Becquerel when he discovered that the element uranium can blacken a photographic plate, although separated from it by glass or black paper.

All building materials contain various amounts of natural radioactive nuclides. Materials derived from rock and soil contain mainly natural radionuclides of uranium (^{238}U), thorium (^{232}Th) series and the radioactive isotope of potassium (^{40}K). The radioactive elements that originate in coal are no different and also include uranium (U), thorium (Th), and their numerous decay products, including radium (Ra) and radon (Rn). These elements are concentrated in the fly ash (Pulverised Fuel Ash – PFA) after combustion within the power station. The vast majority of coals and fly ash do not contain significantly different levels of radioactive elements than naturally occurring materials such as granite rock, clay bricks, etc.

Radiation is measured by the number of spontaneous transformations that occur in a material each second and expressed in a unit called the Becquerel (Bq). For example a 1kg sample of ^{239}Pu has an activity of ~2,000,000,000,000 Bq that is it emits 2,000 billion or 2 Tera alpha particles per second (2TBq). However, not all the radiation will be absorbed into a person, as this radiation is scattered in all directions. Some forms of radiation pass through the body virtually harmlessly, where others are a significant risk. The harmful dosage received is measured in Sieverts (Sv), which attempts to reflect the biological effects of radiation as opposed to the physical aspects. For example a Chest X-ray will result in a dose of 0.02mSv, a flight to New York 0.042mSv. The annual UK exposure is quoted as being ~2.6mSv. Approximately 0.05% of the radiation we are exposed to results from products, with the majority being naturally occurring radon, food and drink, cosmic and gamma rays and medical procedures.

Getting radiation into perspective

Some of the potential sources of radiation may be surprising. As much of the food we eat contains ^{40}Potassium, a source of radiation, this leads to typical radiation levels[i];

Substance	***Brazil nuts***	***Bran flakes***	***Tea***	***Molasses***	***Coffee***
Radioactivity (Bq/kg)	460	600	640	900	1000

However, before worrying about this the body self-regulates the proportion of potassium it carries to around 70 Bq/kg, so it doesn't really matter how much of these foods we consume. ^{40}Potassium emits beta particles of around 1 MeV, incapable of penetrating typical cardboard packaging, so we have no worries about browsing in a coffee shop either. While some radioactive materials are not recognised by the body at all, and are hence fairly quickly got rid of, the ones to worry most about include things like the fission products ^{90}Strontium (confused by mammalian biochemistry with calcium and thus deposited in bones) and radioactive isotopes of basic body-building blocks, like ^{119}Iodine.

Some granites such as those found in Cornwall contain 10 to 20 parts per million of uranium, resulting in significant levels of radiation of 1,200Bq/kg. However, to put this in perspective natural uranium would emit 10,000,000 Bq/kg – which would be somewhat more hazardous.

Regulating radiation

The EU Commission has proposed[ii] that Member States shall establish national reference levels not exceeding (as an annual average):

- 200 Bq/m^3 for new buildings;
- 400 Bq/m^3 for existing dwellings
- 400 Bq/m^3 for buildings with a high occupancy of the public;
- 1000 Bq/m^3 for existing workplaces and other public buildings.

The Radioactive Substances Act 1993 (RSA93), which is primarily designed to limit naturally occurring radioactive substances, gives limits for which all PFA falls substantially lower than and therefore not subject to this regulation. The Ionising Radiations Regulations 1999 (IRR99) is designed to protect those working with naturally occurring radionuclides. Studies indicate that the doses to workers working with ash and members of the public in structures built using ash based building materials are exposed to significantly less than prescribed 1mSv/year. As for radon in dwellings the UK limit is an average annual radon gas concentration of 200Bq/m^3.

Typical radioactivity concentrations for various building products are given in RP112, see Table A[iii].

Material & Concentrations	Typical Activity (Bq/kg)			Maximum Activity (Bq/kg)		
	^{226}Ra	^{232}Th	^{40}K	^{226}Ra	^{232}Th	^{40}K
Most common building materials (May include by-products)						
Concrete	40	30	400	240	190	1600
Aerated and lightweight concrete	60	40	430	2600	190	1600
Clay (Red) bricks	50	50	670	200	200	2000
Sand-lime bricks	10	10	330	25	30	700
Natural building stones	60	60	640	500	310	4000
Natural gypsum	10	10	80	70	100	200
Most common industrial by-products used in building materials						
By-product gypsum (Phosphor gypsum)	390	20	60	1100	160	300
Blast furnace slag	270	70	240	2100	340	1000
Coal fly ash	180	100	650	1100	300	1500

Table A- Typical and maximum activity concentrations in common building materials

In a project carried out by the Health Protection Agency, T D Gooding et al[iv] reported for PFA that the ^{226}Radium values ranged from 70 to 150Bq/kg, ^{232}Thorium from 70 to 150Bq/kg and ^{40}Potassium levels from 540 to 1100Bq/kg. The radium values are all well below the 180Bq/kg typical EU limit value[v] and the others within the expected ranges.

What does this mean to the user?

Drawing conclusions is best left to the experts in the field, as one has to take into account radiation from all sources to arrive at an annual exposure. Gooding, for example, concluded that;

> *"The annual excess doses* [from PFA] *are the quantities of interest. These were estimated to be 4.5 µSv/year for workers manufacturing building materials, 1.7 µSv/year for construction workers and approximately 200µSv/year for members of the public living in houses built from PFA-containing materials.*
>
> *These doses must be put into context. The average annual radiation dose to a member of the public in the UK is 2.7 mSv, of which 50% is from radon. The inhalation dose of 66 µSv/year quoted above corresponds to an increase in the radon level of 1.3 Bq/m^3, which is less than 10% of the average indoor radon level of 20 Bq/m^3 and less than 1% of the Action Level of 200 Bq/m^3. Although at 20 Bq/m^3 the dose contributions from the building materials and the ground are similar, the contribution from the latter can increase the indoor radon level by several orders or magnitude; radon concentrations of 2000 Bq/m^3 are not unusual in several parts of the UK[vi]. Thus the excess contribution from PFA in the building materials is small."*

Similarly, Puch et al[vii] concluded from a similar extensive study in Germany that;

> *"The exposure of workers handling coal ash within the power station and at the disposal site is only insignificantly increased compared to the natural radiation. There is also no significant additional exposure of the public from ash disposal sites.*
>
> *The use of by-products in building materials contributes a negligible share in the radiation dose obtained on living in dwellings."*

Puch et al also states that measurements at German disposal sites showed the local radiation of 0.14 µG/h, whereby a 2000 hours per annum exposure would equate to an effective dose of 0.28 mSv/y, which should be viewed in comparison with the exposure 0.40 mSv/y resulting from terrestrial radiation sources. This effective dosage from PFA (fly ash) is well within the expected range of the natural radiation results.

These low results are partially due to the low rate at which radon can escape from bound materials, e.g. blocks, concrete, etc and that in the majority of construction materials that are made with PFA usually contain only a small proportion of the material. Even on an ash disposal site, the inherent low permeability of the material results in low radon exhalation rates.

In most cases any radiation may result from other materials, including naturally occurring materials, which may be significantly higher than coal fired power station products. However, even for those regularly working on ash disposal sites, the radiation emanating from such mounds has been shown to be insignificant in comparison with natural radiation sources.

Conclusions

The use of PFA in building products and construction represents no significant increased risk to the producer or building owner or to people working regularly with ash at factories or on disposal sites. The levels of radiation are minimal in comparison with the background radiation emanating from the ground and from other naturally occurring materials.

In general usage the term 'fly ash' is used for pulverized coal ash but it can also cover ash from burning other materials. Such 'fly ash' may have significantly differing properties and might not offer the same advantages as ash from burning pulverized coal. UKQAA datasheets only refer to PFA / fly ash produced from the burning of predominantly coal in power stations.

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[i] Progress in Magnetic Confinement Fusion Research, T N Todd and C G Windsor, UKAEA-Euratom Fusion Association, Culham Science Centre, Abingdon, OX14 3DB, UK, Contemporary Physics, 1998, volume 39, number 4, pages 255-282.

[ii] European Commission Services considerations with regard to natural radiation sources in BSS Directive, 16 January 2009

[iii] Radiation protection 112, Radiological Protection Principles concerning the Natural Radioactivity of Building Materials, 1999, Directorate-General, Environment, Nuclear Safety and Civil Protection, EU Commission.

[iv] A radiological study of pulverised fuel ash (PFA) from UK coal-fired power stations, T D Gooding, K R Smith, L K A Sear, AshTech 2006, UKQAA.

[v] Smith K R, Crockett G M, Oatway W B, Harvey M P, Penfold J S S and Mobbs S F. Radiological impact on the UK population of industries which use or produce materials containing enhanced levels of naturally occurring radionuclides. Part 1: Coal-fired electricity generation. NRPB-R237. Chilton (2001).

[vi] Green B M R, Miles J C H, Bradley E J and Rees D M. Radon Atlas of England and Wales. NRPB-W26 (Chilton, 2002).

[vii] Puch K-H, Bialucha R and Keller G, Natural occurring radioactivity in industrial by-products from coal-fired power plants, from municipal waste incineration and from the iron- and steel industry, Report for the 7th International Symposium „The Natural Radiation Environment ‟ Rhodes, Greece, 20-24. May 2002