Radon Protection of Buildings

Critical Issues of Design & Construction in the E.U.

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1. Introduction to Issues

The predominating influence of physicists, geologists, and regulatory authorities in the initial phases of developing a European Union strategy on the ***radon protection of buildings*** has resulted in an uncertain climate for building designers, construction organizations and product manufacturers ..... legally established action / reference / clearance levels differ not only between one E.U. Member State and another, but between one building type and another within a single Member State, typically dwellings (200 Bq/m^3) and workplaces (400 Bq/m^3) ..... the concept of 'risk assessment' is confused with that of 'health protection' ..... if the existence of a radon health problem is actually acknowledged by national authorities, the recommended basis for a building design is typically a 'predictive' radon survey which gives no reliable information about a specific locality or an individual construction site ..... independent, properly accredited testing laboratories are not available to establish the ***fitness for intended use*** of radon-related products and building systems ..... and finally, nationally disseminated guidance on radon is typically removed from the practical, socio-economic and legal constraints within which the construction sector must now operate in the E.U.

Once the European Commission eventually produces a proposal for a Services Liability Directive, the ***health objective*** for building designers will become very clear - a sufficiently low level of radon, or radon associated, ionization activity must be achieved in the spaces and cavities of all buildings, such that a significant hazard to human health will not be posed. Refer to the ***1997 Amsterdam Treaty***, which states that ' a high level of human health protection shall be ensured in the definition and implementation of all Community policies and activities '.

This paper examines some critical issues of design and construction in the development of a ***harmonized*** European radon protection strategy for buildings. To be effective, this strategy must be based on a multi-disciplinary approach, institutional openness, political accountability, and 'meaningful' consultation between researchers, practitioners and building users. It is also clear that, given the current uncertainty and lack of reliable scientific data in the European Union, the ***precautionary principle*** must be invoked.

2. Radon Soil Gas - A Natural Phenomenon

Radon is a colourless, odourless and tasteless radioactive gas. It is a natural phenomenon in soils ; it is not an artificial, or manmade, 'contaminant'.

Formed from the decay of naturally occurring radium, it moves through cracks and fissures in the soil, and then into the atmosphere, or into cavities and spaces under and in buildings. It is also present within well water and building materials, but concentrations released from these sources are usually, though not always, small compared with soil emissions.

It is a known human carcinogen, and in the U.S.A. has been identified as one of the most serious cancer risks (Group A) under investigation by the Environmental Protection Agency. [1] It is a major cause, second only to cigarette smoking, of lung cancer deaths. Radon has also been classified as a Group 1 carcinogen by the World Health Organization (WHO/IARC 1988) .

3. Natural Radon (incl. Rn-222, Rn-220, RnD) & Harm to Human Health [2, 3]

Natural radon consists of three isotopes, one from each of the three natural radioactive disintegration series (uranium, thorium, and actinium). The longest lived isotope, **radon-222** (alpha emitter of 3.823 day half-life), discovered in 1900 by the German chemist Friedrich E. Dorn, arises in the uranium series. The name radon is sometimes reserved for this isotope in order to distinguish it from the other two natural isotopes, called 'thoron' and 'actinon' because they originate in the thorium and actinium series, respectively.

The gas thoron, **radon-220** (alpha emitter of 55.6 second half-life), was first observed in 1899 by the English scientists R. B. Owens and Ernest Rutherford, who noticed that some of the radioactivity of thorium compounds could be blown away. The gas actinon, **radon-219** (alpha and gamma emitter of 3.92 second half-life), was found in 1904, independently by Friedrich O. Giesel and Andre-Louis Debierne, to be associated with actinium.

See Table B, Annex I on Page 23 of **E.U. Council Directive 96/29/Euratom** [4] for a listing of the radioactive decay product groupings of U-238, Th-232 and Ra-223.

The isotopes of natural radon decay progressively to a series of 'decay products' (RnD). It is these products, and not the radon gas itself because it is inert, which first attach themselves to minute particles suspended in the air, i.e. aerosols, depending on ventilation in a building space, and on aerosol size and concentration. A small proportion of decay products remain in unattached form.

A significant danger to human health arises from the inhalation of these continuously decaying products, which are carried by radon gas and aerosols into a person's lungs. The radiation dose to lung tissue is dominated by alpha particle emissions from the decay products, which then become attached to the lung linings ; damage to sensitive cells is caused, and the probability of cancer developing increases. When radon is permitted to accumulate in a building, e.g. in an internal Radon Vent Pipe, a source of penetrating gamma particle radiation is created and serious adverse effects on human health may result.

Typically, certain sections of a population are at greater risk of suffering harm to health from radon, e.g. the very young and the elderly, people with activity limitations, and smokers. Exposure to elevated levels of the gas may also be implicated in the occurrence of other cancers, such as leukaemia in children. With prolonged exposure to the radiation from any form of ionization activity, genetic and human fertility damage will also occur, thus impacting adversely on future generations.

Unfortunately, reliable E.U. radon-related scientific data is either scarce, contradictory, or withheld.

4. E.U. Legislation - A High Level of Health Protection is Mandated

Extracts from Article 174 of the Treaty Establishing the European Community (TEC) [5] state .....

1. Community policy on the environment shall contribute to pursuit of the following objectives :

- ***preserving, protecting and improving the quality of the environment ;***
- ***protecting human health ;***

2. Community policy on the environment shall aim at a high level of protection taking into account the diversity of situations in the various regions of the Community. It shall be based on the precautionary principle and on the principles that preventive action should be taken, that environmental damage should as a priority be rectified at source and that the polluter should pay.

Article 6 of the TEC states .....

Environmental protection requirements must be integrated into the definition and implementation of the Community policies and activities referred to in Article 3, in particular with a view to promoting sustainable development.

An extract from Article 95 of the Treaty Establishing the European Community states .....

3. The Commission, in its proposals envisaged in paragraph 1 concerning health, safety, environmental protection and consumer protection, will take as a base a high level of protection, taking account in particular of any new development based on scientific facts. Within their respective powers, the European Parliament and the Council will also seek to achieve this objective.

An extract from Article 152 of the Treaty Establishing the European Community states .....
1. A high level of human health protection shall be ensured in the definition and implementation of all Community policies and activities.

A Services Liability Directive is in course of preparation by the European Commission, and will complement ***E. U. Council Directive 85/374/EEC, of 25th July 1985, on the approximation of the laws, regulations and administrative provisions of the Member States concerning liability for defective products*** .

5. What is the Precautionary Principle ?

On 2nd February 2000, the European Commission issued an important Communication [6] on the Precautionary Principle - which establishes guidelines for its use, and the avoidance of misuse.

The precautionary principle is not defined in E.U. Treaties, which prescribe it only once (see Article 174(2) of the TEC above). However, in practice its scope is much wider - especially where preliminary, objective scientific evaluation indicates that there are reasonable grounds for concern that potentially adverse effects on human health may be inconsistent with the high level of protection specified in legislation (see Articles 95(3), 152(1) and 174(2) of the TEC above). The time dimension of the precautionary principle goes beyond potential injury in the short and medium terms. It also extends to the long-term, and the wellbeing of future generations (note the reference to 'sustainable development' in Article 6 of the TEC above).

The E.U. Court of Justice has already reviewed the application of the precautionary principle. In its judgement on the validity of the Commission's decision to ban the export of beef from Great Britain in order to prevent BSE transmission (Judgements of 1998-05-05, Cases C-157/96 and C-180/96), the Court held .....
" Where there is uncertainty as to the existence or extent of risks to human health, the Institutions may take protective measures without having to wait until the reality and seriousness of those risks become fully apparent.' (Ground 63 of Case C-157/96, and Ground 99 of Case C-180/96).

A distinction must always be made between 'assessing risk to safety' and 'the protection of human health'. On 23rd March 2001 at an IABSE Conference in Malta, two controlled benchmark studies [7] were presented on the subject of risk assessment. So wide was the scatter of results, that they were of no use to anybody.

6. Radon in Buildings - Human Health Target

The World Health Organisation, in the preamble to its Constitution, defines 'health' as ..... ***'a state of complete physical, mental and social wellbeing, and not merely the absence of disease or infirmity '.***

Given the high level of scientific uncertainty and the appalling lack of reliable scientific data in the Union, it is a legal imperative that the 'precautionary principle' be applied. Within the E.U. therefore, a policy priority, and the design / construction objective, must be to achieve a sufficiently low level of radon, or radon associated, ionization activity in the spaces and cavities of <u>all</u> buildings - such that a significant hazard to human health is not posed. Referencing the approach taken in U.S. Federal Legislation (Indoor Radon Abatement Act (IRAA) of 1988), an average radon activity level which lies within an ambient range of **10 - 40 Bq/m^3** should be the 'human health' target in the European Union.

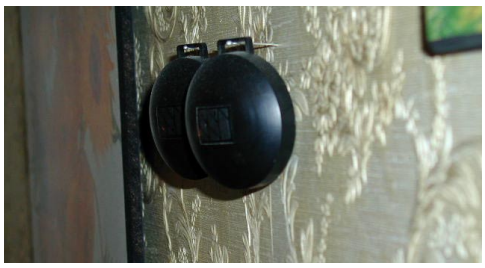
7. Radon Measurement Uncertainty [2] & Results of a 'Real' Building Survey

(i) **Variations With Time & Measurement Duration**
Concentration variations of radon and its decay products (RnD) occur on many time scales, from hourly to annually, and depend on seasonal factors and weather conditions, building characteristics, operation of building heating / refrigeration systems, living habits, source relative strength, etc. Usually, concentrations are higher in the evening and night than in the late morning and early afternoon, higher in the winter than in the summer. However, it is not yet possible to predict these variations with accuracy.

(ii) **Measurement Accuracy**
Measurement detectors / instruments should initially be calibrated, and then regularly checked. Periodic institutional participation in measurement 'round robin' comparison programmes is also recommended.

(iii) **Measurement Precision**

Precision is assessed by repeatable measurements, i.e. exposing many detectors at the same time to the same concentration. This allows an estimate to be made of the coefficient of variation of the detectors at that value of concentration. A periodic check on precision should always be made.



We wished to examine, at first hand, this measurement uncertainty. A detailed **Radon Survey** of a house in Dublin was carried out, using Etched-Track Alpha Particle Detectors (in pairs as shown above) supplied by the Radiological Protection Institute of Ireland (RPII). Four different time durations were chosen .....

Measurement Start Date : 1999-08-11

3 Month Period : ..... 2000-02-11 - 2000-05-11 | **6** Month Period : ..... 1999-08-11 - 2000-02-11

9 Month Period : ..... 1999-08-11 - 2000-05-11 | **12** Month Period : ..... 1999-08-11 - 2000-08-11

Measurement Termination : 2000-08-11

Location of Radon Detectors & Reference		**3 Months** (Feb-April)	**6 Months** (Aug-Jan)	**9 Months** (Aug-April)	**12 Months** (Aug-July)
Main Bedroom - 1st Floor (internal wall - bed)	**A**	-	**10** Bq/m^3	-	-
Main Bedroom - 1st Floor (internal wall - bed)	**C**	-	**12** Bq/m^3	-	-
Main Bedroom - 1st Floor (internal wall - bed)	**K**	**19** Bq/m^3	-	-	-
Main Bedroom - 1st Floor (internal wall - bed)	**M**	**23** Bq/m^3	-	-	-
Main Bedroom - 1st Floor (internal wall - chimney breast)	**H**	-	-	**16** Bq/m^3	-
Main Bedroom - 1st Floor (internal wall - chimney breast)	**J**	-	-	**22** Bq/m^3	-
Main Bedroom - 1st Floor (boxes - horizontal)	**P**	-	-	-	**16** Bq/m^3
Living Room - Upper Gr Floor (external wall - shelf unit)	**D**	-	**53** Bq/m^3	-	-
Living Room - Upper Gr Floor (external wall - shelf unit)	**E**	-	**56** Bq/m^3	-	-
Living Room - Upper Gr Floor (external wall - shelf unit)	**N**	**71** Bq/m^3	-	-	-
Living Room - Upper Gr Floor (external wall - shelf unit)	**O**	**60** Bq/m^3	-	-	-
Living Room - Upper Gr Floor (internal wall - tv)	**F**	-	-	**72** Bq/m^3	-
Living Room - Upper Gr Floor (internal wall - tv)	**G**	-	-	**62** Bq/m^3	-
Living Room - Upper Gr Floor (shelf - horizontal)	**Q**	-	-	-	**58** Bq/m^3
Pantry - Ground Floor (internal wall - near door)	**B**	-	**28** Bq/m^3	-	-
Pantry - Ground Floor (internal wall - near door)	**L**	**24** Bq/m^3	-	-	-
Pantry - Ground Floor (internal wall - near window)	**I**	-	-	**29** Bq/m^3	-

Note on Average Radon Activity Values [9]

Average values may conceal a considerable degree of variability. Radon concentrations can differ appreciably from one locality to the next, perhaps by a factor of ten - and dramatically from one building to another, perhaps by a factor of one hundred.

8. Developing a Harmonized European Radon Protection Strategy

In the absence of reliable scientific data and research, a ***harmonized*** 'person-centred' radon protection strategy for the European Union must comprise more than one layer of protection - 'defence-in-depth' .....

(i) Phase 1 - Pre-Construction Soil Testing for Radon [10, 11]

In the initial stages of design, the designer / building contractor should have a reasonably precise understanding of the actual radon activity in the soil/soils of the particular site. This allows basic decisions to be made with regard to suitable construction types and materials, methods of detailing, level of construction control required, etc.

SOIL CLASSIFICATION	SOIL RADON ACTIVITY (Bq/m^3)		
(RADON RISK)	SOIL PERMEABILITY LOW	SOIL PERMEABILITY MEDIUM	SOIL PERMEABILITY HIGH
LOW	< 30,000	< 20,000	< 10,000
MEDIUM	30,000 - 100,000	20,000 - 70,000	10,000 - 40,000
HIGH	> 100,000	> 70,000	> 40,000

(ii) Phase 2 of the Protection Strategy

An essential component, in every location, is a durable **radon resisting membrane**, which has been shown to be ***fit for its intended use*** over a full building life cycle - to comply with E.U. and national legislations. Membrane integrity should be tested immediately after installation in a building.

Radon Resisting Membrane : A continuous membrane, properly installed on site, the function of which is to resist the passage of radon soil gas (incl. Rn-222, Rn-220, RnD) into a building.

The radon permeability of a 'radon resisting membrane' should not exceed a figure, taking into account measurement uncertainty, of **10×10^{-12} m^2 / s** .

(iii) Phase 3

A next layer of protection is a suitable **radon control system** at building foundation level.

Radon Control System : A measure designed to control the natural movement of radon soil gas (incl. Rn-222, Rn-220, RnD) in the vicinity of a building at foundation level.

Once the ground floor construction of a building (new or existing) has separation integrity, its sub-floor construction may be pressurized (a buffer of clean air is introduced, maintained and monitored), or de-pressurized (radon is extracted to a position externally where it will no longer cause harm).

(iv) Phase 4

Adequate **fresh, clean air ventilation** should be assured in all buildings. Depending on the severity of the radon problem, however, additional protection may be provided by **positive input ventilation** , which introduces a positive overpressure into habitable spaces. This is particularly useful in existing buildings, where a membrane cannot be installed and the ground floor lacks separation integrity.

(v) Phase 5

Reduce / minimize / eliminate emissions of radon from building materials, and from a building's water supply if sourced from a deep well.

(vi) Phase 6

Mitigate whole building radon activity levels near overhead, high-voltage electrical power lines [12] .

(vii) Final Essential Phase - Post-Construction Building Test for Radon Activity

'Real' radon activity levels should always be measured once construction works have been completed. Additional protection may still be required to reduce radon activity to the 'health level' target.

9. Conclusions

Sufficient objective scientific data is available to show that exposure to radon activity, above ambient levels, is harmful to human health. Such is the level of uncertainty and the lack of additional reliable information,

however, that little else can be stated with confidence. In the current legal climate of the European Union, this places the construction sector in a precarious position.

The 'precautionary principle' is prescribed in E. U. legislation, its scope is very wide, and guidelines on its application have been issued by the Commission. Judgements of the European Court have reinforced and strengthened the principle. It is clear that for decision-makers, building designers, construction organizations and product manufacturers, the principle must be invoked to deal with radon protection in 'real' buildings.

Immediately, a comprehensive **Research Agenda** must be activated, and Eurostat must gather reliable statistics.

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