Radon Protection of Buildings in Europe
'Reliability-Based', 'Person-Centred' Design & Construction

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Keywords : European Union (E.U.), Built Environment, Radon Protection, Human Health, Safety, Risk, 'Real' Construction Performance, 'Reliability-Based' Design, 'Person-Centredness', Harmonized Action Programme, Legislation, Technical Control, Performance Indicators.

1. Introduction to the Issues

Launching the newly reviewed Irish Building Regulations in 1997, the national authority having jurisdiction decided that special emphasis should be placed on the requirement relating to **radon protection of buildings**. This requirement had already existed in the previous 1991 Building Regulations, but was widely disregarded. Gradually, awareness and experience of this important aspect of building performance increased in the construction industry. In 2002, however, it is becoming increasingly clear that, for building designers and construction organizations alike, the issue of **reliability** is now becoming a challenge.

In a European context, the construction sector operates in a common, and rapidly evolving, legal climate. Regional, environmental, socio-economic, institutional and political constraints ensure that this climate is harsh. The predominating influence of regulatory bodies and scientists in the initial stages of developing a **Harmonized European Policy** on 'radon protection of buildings' has resulted in an absence of direction. Vacuous assumptions continue to be made with regard to human radon exposure limits ; legally established radon action / reference / clearance levels differ not only between one European country and another, but between different building types, e.g. housing and 'workplaces'. The basis for a building design remains, typically, a 'predictive' national radon survey which offers no assurance of certainty to users. And although interesting fragments of data have appeared from disparate sources, there are still no reliable European radon statistics (refer to Article 285 / ex Article 213a in the consolidated text of the European Union's TEC - 97/C 340/03).

Further to a presentation at the Liege European Symposium on Radon Protection, in 2001, which examined the necessary application of the EU's **Precautionary Principle** ..... this paper looks more closely at the relationship between 'health protection' and 'assessment of risk to safety'. Mirroring previous work carried out in the Czech Republic and Sweden on Soil Radon Risk Classification, a proposal is made regarding a **Building Footprint Categorization** which will facilitate more reliable estimation of Indoor Radon Activity. A **Radon Protection Reliability Matrix** is also elaborated as a design guide for the incorporation of radon protection measures in buildings. A practical, construction-oriented approach is now necessary to provide 'real' performance solutions.

Finally ..... based on a 'person-centred' approach, institutional openness, and meaningful consultation between researchers and practitioners, it is advocated that the initial elements of a **Common European Technical Agenda** on 'radon protection of buildings' must be outlined, and agreed as a basis for further positive progress.

2. 'Person-Centredness' as a Core Value in Design & Construction

These are interesting times - the benefits of modern technology have bypassed and long overtaken the stirring thoughts, visions and catchcries of Architects at the beginning of the 20th. Century. However, at this time in Europe, we must now ask ourselves some difficult questions .....

"What should be the Design Agenda for the 'built environment' in this new millennium ? "
"Do we understand the 'real' needs and desires of 'real' people in an inclusive society ? "

Sustainable Human and Social Development is the declared long term goal of the European Union, as re-stated time and time again in its Treaties, policies and actions. It is Sustainable Design - the art and science of the design, supervision of related construction / de-construction, and maintenance of sustainability in the built and virtual environments - which is currently generating a quantum leap in the forward evolution of a more coherent design philosophy ..... one in tune with the spirit of this age.

Principle 1 of the 1992 United Nations Rio Declaration on Environment and Development states .....

'Human beings are at the centre of concerns for sustainable development.
They are entitled to a healthy and productive life in harmony with nature.'

And 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'.

Deeply embedded, therefore, within this philosophy is the concept of 'person-centredness', i.e. that core design value which places real people at the centre of creative concerns, and gives due consideration to their health, safety, and welfare in the built environment - it includes such specific performance criteria as : a sensory rich and accessible (mobility, usability, communications and information) environment ; fire safety ; thermal comfort ; air, light and visual quality ; protection from ionizing and electromagnetic radiation ; nuisance noise abatement ; etc. An important 'person-centred' design aid is the questionnaire survey, which is not only a very valuable source of direct information, but also formalizes meaningful consultation between practitioners and end users.

3. The Sustainable 'Life Cycle' of a Building

The many actors and disciplines involved in the European construction sector each have their traditional views and opinions concerning the different phases, and the duration, of a building's life cycle. Generically, however, we may identify the following ten segments in a complete cycle .....

- Expressed needs / wants / desires / requirements of the client **;**
- Planning brief and performance specification for the building **;**
- Site analysis and evaluation **;**
- Design **;**
- Preparation for construction **;**
- Construction **;**
- 'Early life' of the building in use - including management, maintenance, servicing **;**
- Adaptable 'middle age' of a building in use - including renovation, refurbishment, modification, alteration, and extension **;**
- De-Construction **;**
- Disposal .

With adequate emphasis placed on 'adaptability' throughout the design stage of a building, and quality of construction on site, it must be a requirement - to realize the target of a sustainable 'built environment' - that the minimum duration of that building's life cycle will be in the order of .....

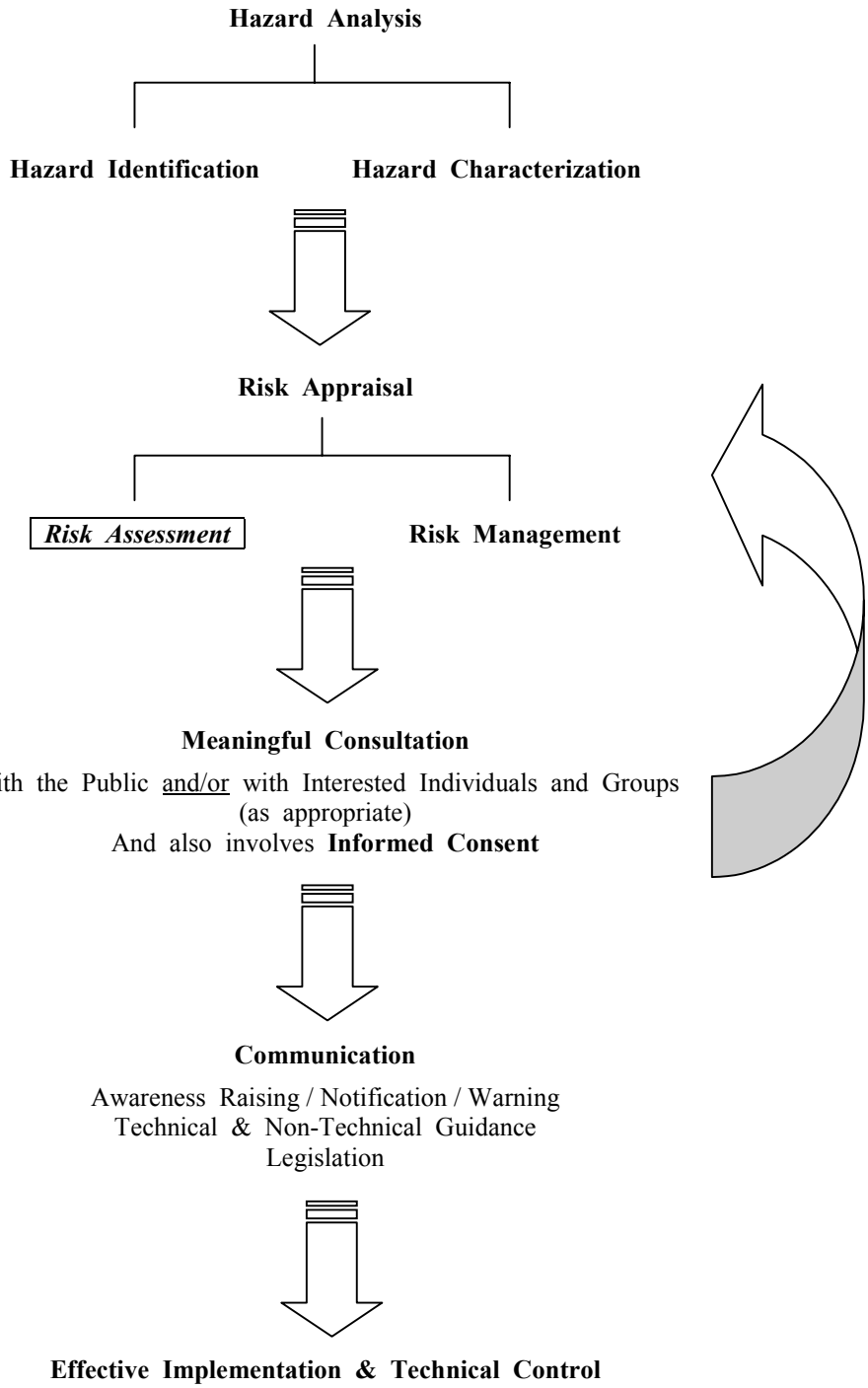
for structure	100 – 200 yrs **;**
for the building fabric	50 – 100 yrs **;**
for services	20 – 30 yrs **;**
for furniture & fittings	10 – 20 yrs .

4. 'Protection of Health' & 'Assessment of Risk to Safety' ?

The many Accession Countries in central and eastern Europe are now completing their implementation of the **acquis communautaire**, i.e. the body of existing European Union legislation. Such is the range of languages, cultures and traditions involved, that the first order of business in any area of technical harmonization related to health protection and safety must be the development of a common understanding in terminology and concepts.

Presented visually ..... what exactly is the relationship between 'health protection' and 'assessment of risk to safety' ?

Figure 1



As previously discussed in Liege last year, the level of uncertainty with regard to the hazard of radon in buildings and its serious and irreversible adverse impacts on human health requires that, as mandated by European Union legislation, the 'precautionary principle' be applied .....

'Where there is uncertainty as to the existence or extent of risks of serious or irreversible damage to the environment, or injury to human health, adequate protective measures must be taken without having to wait until the reality and seriousness of those risks become fully apparent.'

The 1994 E.U. Energy Charter Treaty, augmented by the 1972 United Nations Stockholm Declaration on the Human Environment, provides us with a definition of 'environmental impact' which binds together protection of the environment and human health .....

'Any effect caused by a given activity on the environment, including human health and safety (and welfare), flora, fauna, soil, air, water, (and especially representative samples of natural ecosystems), climate, landscape and historical monuments or other physical structures or the interactions among these factors ; it also includes effects on cultural heritage or socio-economic conditions resulting from alterations to those factors.'

In any particular endeavour, therefore, the following Question must be asked .....

"Is there a potential for serious or irreversible damage to the environment or health ? "

Concerning radon protection of buildings, the Design Objective must then be .....

Protection of Human Health.

'Assessing risk to safety' is but one element in the middle of an elaborate process ; it is an exercise which is performed prior to 'meaningful consultation' with interested individuals, groups, or society as a whole - whichever is appropriate. And unless there is sufficient reliable data available, this exercise is of little value. 'Protection of health', on the other hand, is the target end condition demanded by European Union legislation.

Points to note with regard to Figure 1 :

(a) The process illustrated must be transparent ;
(b) Clear statements on reliability must be made with regard to supporting statistical databases and methods of risk assessment ;
(c) Statements of uncertainty must accompany calculations ;
(d) **'Informed Consent'** must be interpreted as 'consent freely obtained - without threats or improper inducements - after appropriate disclosure to a person (or persons) of relevant, adequate and easily assimilated information in a form, e.g. oral, written, braille, and language understood by that person (those persons) '.

5. Radon Protection of Buildings - An Emphasis on 'Reliability'

The initial response of many European countries to the problem of radon in buildings has been to develop 'predictive' National Radon Risk Maps. These are useful design aids in the case of small construction projects ; unfortunately, they are not reliable and the average values shown may actually conceal a considerable degree of variability in the radon concentrations found in completed buildings. Since the Liege European Symposium on Radon Protection, we have been working on mirroring previous efforts in the Czech Republic and Sweden to classify soils according to radon risk. By filling in some pieces on the construction side of the equation, however, a more reliable estimate of Indoor Radon Activity will be facilitated. The Irish Agrément Board partnered this work.

During the autumn of 2001, drafting of Irish Agrément Board Certificate No. 01/0130 was nearing completion. One of the final technical issues to be resolved was that of prescribing the 'effective pressure field' of a radon collection sump. We were aware that the quality of workmanship across building sites in Ireland differed greatly, and we were also aware that installation monitoring in the USA had thrown up widely varying results.

Three categories of construction execution quality were agreed with the Irish Agrément Board :

Category A

(i) Supervision of the works is exercised by appropriately qualified and experienced personnel from the principal construction organization ;

(ii) Regular inspections, by appropriately qualified and experienced personnel familiar with the design and independent of the construction organization(s), are carried out to verify that the works are being executed in accordance with the design.

Category B

Supervision of the works is exercised by appropriately qualified and experienced personnel from the principal construction organization.

Category C

This level of construction execution is assumed when the requirements for **Category A** or **Category B** are not met.

This, in turn, permitted us to the formulate the following guidance in IAB Certificate No. 01/0130 :

As a general rule .....

- with Category A Construction Execution, allow for one Radon Sump to service an area not greater than **200 m^2** ;
- with Category B Construction Execution, allow for one Radon Sump to service an area not greater than **100 m^2** ;
- with Category C Construction Execution, allow for one Radon Sump to service an area not greater than **50 m^2**.

Recently, we have brought this design guidance to the another level of development :

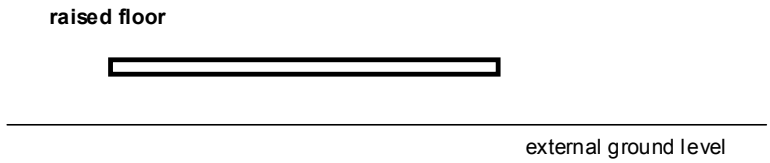
Radon Protection Reliability Matrix - Radon Soil Gas Control System		**Building Footprint Categorization**								
		Ground Floor Profile I			Ground Floor Profile II			Ground Floor Profile III		
		Quality of Construction Execution								
		A	B	C	A	B	C	A	B	C
Soil Radon Risk Classification	**Low**	200 m^2	100 m^2	50 m^2	200 m^2	100 m^2	50 m^2	150 m^2	75 m^2	N/A
	Medium	200 m^2	100 m^2	50 m^2	200 m^2	100 m^2	50 m^2	150 m^2	75 m^2	N/A
	High	200 m^2	100 m^2	50 m^2	150 m^2	75 m^2	N/A	100 m^2	50 m^2	N/A

Table 1 ~ Reliability Matrix for a Radon Soil Gas Control System

Table Key : Areas shown indicate maximum limits to be serviced by one Radon Collection Sump.
The central relationship is highlighted by the heavy box in the middle of the Table.
N/A ..... Not Applicable. Not permitted.

As this work progressed, still another factor had suggested itself - the Building Footprint.

Ground Floor Profile I



Ground Floor Profile II

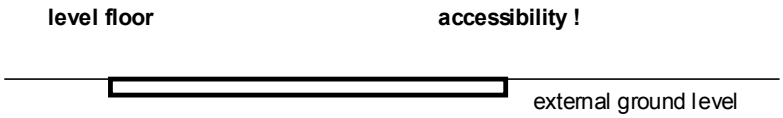
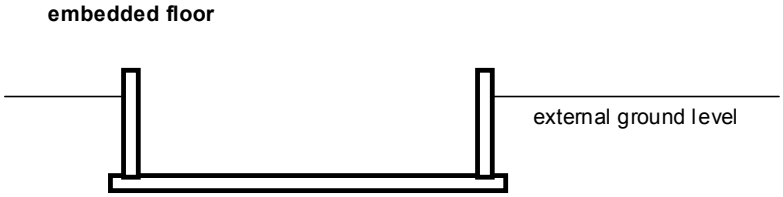


Figure 2

Ground Floor Profile III



Closer examination of Ground Floor Profile III helped to highlight the difference between .....

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' shall not exceed a figure, taking into account measurement uncertainty, of **10×10^{-12} m^2 / s** .

and

Radon Resisting Barrier : A radon resisting membrane, or membrane assembly, which is capable of withstanding hydrostatic pressure.

As shown below, detailing of a ground floor construction which incorporates a Radon Resisting Membrane, can accommodate likely construction settlement over the full life cycle of a building, allows for the installation of very high levels of thermal insulation, and permits independent accessibility for people with disabilities requires more than general design input. Figure 3 illustrates a detail having application in Europe (outside seismic zones) .....

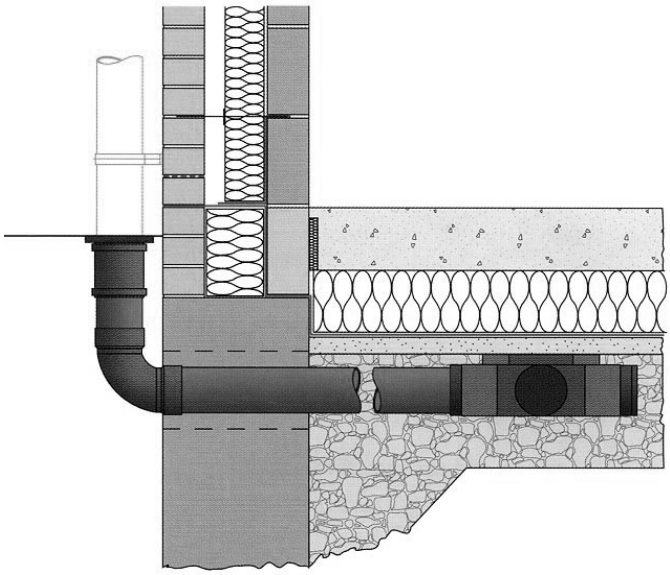


Figure 3

Accordingly, three categories of suitable design and construction execution quality were developed :

Category A

(i) Design of the works is exercised by an independent, appropriately qualified and experienced architect, with design competence relating to radon protection of buildings ;
(ii) Installation / fitting of radon-related construction products / systems is exercised by appropriately qualified and experienced personnel, with construction competence relating to radon protection of buildings ;
(iii) Supervision of the works is exercised by appropriately qualified and experienced personnel from the principal construction organization ;
(iv) Regular inspections, by appropriately qualified and experienced personnel familiar with the design, and independent of the construction organization(s), are carried out to verify that the works are being executed in accordance with the design.

Category B

(i) Design of the works is exercised by an independent, appropriately qualified and experienced architect ;
(ii) Installation / fitting of radon-related construction products / systems is exercised by appropriately qualified and experienced personnel ;
(iii) Supervision of the works is exercised by appropriately qualified and experienced personnel from the principal construction organization.

Category C

This level of design and construction execution is assumed when the requirements for **Category A** or **Category B** are not met.

Radon Protection Reliability Matrix - Radon Resisting Membrane		**Building Footprint Categorization**								
		Ground Floor Profile I			Ground Floor Profile II			Ground Floor Profile III		
		Quality of Design & Construction Execution								
		A	B	C	A	B	C	A	B	C
Soil Radon Risk Classification	**Low**	Lp RM	Lp RM	Lp RM	Lp RDM	Lp RDM	RDM	RDB	RDB	N/A
	Medium	Lp RM	Lp RM	RM	RDM	RDM	N/A	Hp RDB	Hp RDB	N/A
	High	RM	RM	RM	Hp RDM	Hp RDM	N/A	Hp RDB	Hp RDB	N/A

Table 2 ~ Reliability Matrix for a Radon Resisting Membrane

Table Key :	RM	Radon Resisting Membrane
	RDM	Radon & Damp Resisting Membrane
	RDB	Radon & Damp Resisting Barrier
	Lp	Low Performance (robustness)
	Hp	High Performance (radon - with aluminium foil)
	N/A	Not Applicable. Not permitted.

Some further practical issues relating to **reliability** and 'real' construction performance :

(a) Above small construction projects, the level(s) of radon activity in a site's soil(s) - and foundation hardcore - should be established by means of site investigation and testing ;
(b) An on-site membrane integrity test, involving the use of an environmentally-friendly tracer gas, should be carried out after membrane installation is completed ;
(c) Because a viable membrane integrity test can only be carried out between the inside faces of the external walls, hybrid membrane installation should always be considered. A more robust and durable radon resisting membrane should be installed within the depth of wall construction.

6. A Common European Technical Agenda

To ensure there is an adequate support framework in place for the construction sector, therefore, it is advocated that the following initial elements of a **Common European Technical Agenda** on 'radon protection of buildings' be outlined, and agreed as a basis for further positive progress :

(i) A coherent, **Harmonized European Action Programme** - covering the short term up to the year 2010 ;
(ii) A multi-lingual, **Harmonized European Vocabulary** ;
(iii) A reliable, **Harmonized European Database** of radon-related statistics ;
(iv) **'Person-Centred' Research and Demonstration** which answers the health needs of 'real' people exposed, over prolonged periods of time, to low levels of ionizing radiation, and the practical demands of those who plan, design, construct and manage for protection of that health in the European 'built' environment ;
(v) A comprehensive array of radon-related **Performance Indicators** - this includes Benchmarking ;
(vi) An effective E.U. regime of **Performance Monitoring and Technical Control**.

7. Conclusions

Once again, it must be stressed that there is sufficient objective scientific data available to show that exposure to radon activity, above ambient levels, is harmful to human health. Such is the lack of **reliable information** in Europe, 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' must be invoked to deal with protection of health from radon in buildings.

Since the launch of the 1997 Irish Building Regulations, awareness and experience of this important aspect of building performance has increased throughout the construction industry in Ireland. For building designers and construction organizations alike, the issue of 'real' construction performance **reliability** is also the important challenge ; and a 'reliability-based' and 'person-centred' approach is now necessary to provide the practical solutions.

8. References

[1] **Irish Agrément Board Certificate No. 01/0130**
Easi-Sump & Easi-Sump Cap-Link Radon Soil Gas Control System. 3rd Print - July 2002.

[2] **Irish Agrément Board Certificate No. 98/0075**
Monarflex Radon Resisting Membranes. 3rd Print - November 1999.

[3] **Technical Guidance Note No. 98/101 (b)**
Proper Evidence of a Test Result within the European Economic Area (EEA). Walsh, C.J. Sustainable Design International Ltd. Last updated - February 2002.
Download from the Internet : http://www.sustainable-design.com/arch/tgn.htm .

[4] **Radon Protection of Buildings - Critical Issues of Design & Construction in the E.U.**
Paper presented at the Third European Symposium on Protection against Radon, which was held in Liege, Belgium. 10th & 11th May 2001. Walsh, C.J. Sustainable Design International Ltd. Download from the Internet : http://www.sustainable-design.com/arch/radon.htm .

[5] **BRE Report - Modelling & Measurement of Soil Gas Flow**
Cripps, A.J. A publication of Building Research Establishment Ltd. London, England. 1998.

[6] **Radon Risk Mapping and Geological Aspects**
Barnet, I. Czech Geological Survey, 11821 Prague 1, Klarov 3, Czech Republic.

[7] **Ground Radon - Monitoring Procedures in Sweden**
Akerblom, G. Swedish Radiation Protection Institute, S-171 16 Stockholm, Sweden. 1993.
Paper published in Geoscientist Magazine, Volume 4, No. 4, Pages 21-27.

[8] **CIB Publication 204 - Protection of Buildings Against Soil Gas Entry**
International Council for Research and Innovation in Building and Construction (CIB). Report. CIB Working Commission 97 : Building on Contaminated Land. The Netherlands. September, 1997.

[9] **Consolidated Version of the Treaty Establishing the European Community (97/C 340/03)**
The Amsterdam Treaty amending the Treaty on European Union, the Treaties establishing the European Communities and certain related acts, signed at Amsterdam, 2nd. October 1997.
Official Journal of the European Communities, Series C, No. 340, 1997-11-10. Office for Official Publications of the European Communities. Luxembourg.

[10] **Communication from the Commission on the Precautionary Principle**
Commission of the European Union. COM(2000) 1 final. Brussels, 2000-02-02.
Download from the Internet : http://europa.eu.int/eur-lex/en/index.html .

[11] **Biological Effects of Ionizing Radiation (BEIR) VI Report : 'Health Effects of Exposure to Radon'**
U. S. National Academy of Sciences (NAS) Committee on Health Risks of Exposure to Radon (BEIR VI). National Academy Press. 1999.

[12] **EUR 14470 - Radiation Atlas - Natural Sources of Ionizing Radiation in Europe**
Green, B.M.R., Hughes, J.S. and Lomas, P.R. Office for Official Publications of the European Communities. Luxembourg. 1993.