INTERNATIONAL ADVICE AND NATIONAL IMPLEMENTATION OF CONTROLS ON OCCUPATIONAL EXPOSURE TO RADON

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1 ABSTRACT

Natural radiation sources were not included in the early schemes for controlling occupational exposure to radiation. However, significant steps towards harmonising our approach to natural and to artificial radiation sources were made in 1990/91 with the appearance of ICRP Publication 60. This was followed up by Publication 65 in 1994 with more detailed and specific advice on the control of radon exposures.

This attention to natural radiation sources was arguably not overdue. UNSCEAR 2000 estimates that, in the early 1990s, about 6.5M workers received almost 12,000 man Sv pa from natural radiation sources (excluding uranium mining and milling). Most of this exposure came from radon. These figures for natural radiation sources contrast with 0.8M workers in the nuclear industry receiving 1,400 man Sv pa. Even a decade before (1980-84), when doses in the nuclear industry were higher, the annual collective dose was “only” 3,000 man Sv.

The European Union included natural radiation sources in its Basic Safety Standard Directive of 1996. This was followed up by more detailed and practical, but non-binding, advice in a publication “Radiation Protection 88” of 1997. Member states were obliged to implement the Directive by May 2000. This paper gives more background on natural radiation exposures, international advice on controlling them, and some specific detail on what certain countries have done.

2 INTRODUCTION

Since life first appeared on earth, all living things have been exposed to radiation from natural sources. These natural radiation exposures are conveniently divided into those from:

- Radon (including the short lived decay products)
- Naturally occurring materials containing uranium and thorium
- Cosmic rays

UNSCEAR (1) has included these natural sources in its review of occupational exposures. This paper concerns itself with radon, but Table 1 reproduces the UNSCEAR summary for all three types of natural exposure and contrasts these with data for the civilian nuclear fuel cycle. Doses to the most highly exposed groups are broadly comparable, but many more workers are exposed to natural radiation sources.

Looking at Table 1 in more detail we can see that doses to miners and doses from radon in above ground workplaces account for 90% of the total collective dose. This is largely from radon, though one should note that a small component of the miner doses is due to gamma rays rather than radon (estimated by UNSCEAR to amount to about 0.8 mSv pa). A correction has also been made in this table for radon doses which would have been incurred even if the individuals concerned had not gone down the mine (0.5 mSv pa). Data on radiation exposure of miners are available from a number of countries (Table 2). They are probably much less well established than the doses incurred by workers in the nuclear industry, but it is clear that they are variable and often not insubstantial. Despite the uncertainties in doses to miners, they are far more firmly established than the details of the largest component of collective dose in Table 1, that from radon in above ground workplaces. These have been obtained by extrapolating data for a single country on the basis of national Gross Domestic Products. UNSCEAR frankly describe this procedure as crude.

No matter what the precise levels of dose may be, it is clear that radon, in a number of circumstances, can lead to significant occupational exposure to radiation. The conventional system of radiation protection has traditionally been restricted to the control of exposures from artificial radiation sources. Of course, it had been recognised from the early years that natural radiation sources also lead to exposures of human beings. Indeed, exposures received by underground miners from radon were large enough to have resulted in clearly elevated death rates, a situation unparalleled in radiation protection since the early radiologists and luminisers. However, natural radiation sources are generally accepted and very often overlooked because the radiation plays no important part in the process considered. To take countermeasures would be disruptive and possibly economically harmful, how can action be justified when the status quo has been accepted for years? On the other hand, it seems quite illogical to impose stringent controls on a process which involved, say, part of the nuclear fuel cycle while ignoring another, where doses might be similar, and possibly even from the same radionuclide, just because the latter involved "natural" material. Steps towards tackling this dilemma are described below.

3 GUIDANCE FROM ICRP

It was against this background that ICRP decided, in Publication 60 (2) to move towards including natural radiation sources within the general system of radiation protection. For the reasons outlined above, ICRP did not recommend that the existing systems of control for artificial radiation sources should simply be transferred to natural exposures. Indeed, they noted that since radiation is ubiquitous, one might reach a situation in which all workers were subject to a regime of radiological protection. To tackle this particular problem, advice from ICRP is that measures to control occupational exposures from natural sources should be considered only in circumstances where they might reasonably be regarded as the responsibility of the operating management. This would exclude radon in the outdoor air, uranium and thorium in the undisturbed earth's crust and cosmic rays at ground level. ICRP also recognised that it was desirable to allow national authorities discretion in the scope of the controls which should be applied.

ICRP identified four types of exposure to natural radiation sources which should be considered as a part of occupational exposure. These correspond to the three categories listed above with the last, cosmic rays, far-sightedly divided into those incurred in aircraft and those incurred in spaceflight. The focus of this paper is on radon and we should note the formulation chosen by ICRP for its recommendation on occupational exposure to radon:

> "Operations in workplaces where the regulatory agency has declared that radon needs attention and has identified the relevant workplaces"

Radon levels vary greatly from country to country and it would not be reasonable to expect that control measures would be introduced at the same radon concentrations. There should be national autonomy in deciding where action should be taken. This point was amplified in ICRP Publication 65 (3) where ICRP suggest a range of radon concentrations of 500-1500 Bq m^{-3} within which an occupational Action Level might usually be set.

4 THE INTERNATIONAL BASIC SAFETY STANDARDS

The International Atomic Energy Agency, together with the other joint sponsors, recently updated the International Basic Safety Standards for Protection against Ionising Radiation and for the safety of radiation sources (4). These are broadly compatible with the recommendations of ICRP. For example, paragraph 2.1 of the Principle Requirements states that the (International Basic Safety) Standards shall apply to

> "Practices involving exposure to natural sources specified by the Regulatory Authority as requiring control".

Earlier, in paragraph 1.4 it had been noted that exposures which are essentially unamenable to control are deemed to be excluded from the Standards. Cosmic rays at the earth's surface and "unmodified concentrations of radionuclides in most raw materials" are given as examples of such exclusions. Paragraph 2.5 deals explicitly with exposure to natural radiation sources. These are normally to be regarded as chronic exposure situations, handled if necessary by intervention. Exceptions, to be handled as practices, are where exposure to radon exceeds the specified Action Level (1000 Bq m^{-3}, see Schedule VI) or where the Regulatory Authority has so specified.

5 THE EUROPEAN DIRECTIVE

ICRP Publication 60 provided the impetus for a revision of the European Basic Safety Standards Directive which was published in 1996 (5). This, in Title VII, covered natural radiation exposures. Title VII contains three articles which build on the advice of ICRP.

- Article 40 defines the scope of the application of this part of the directive, listing four areas (unlike ICRP, spaceflight is ignored, but activities producing residues with high levels of uranium and thorium are considered separately from other work with such materials)

- Article 41 defines the action to be taken to control terrestrial natural radiation sources

- Article 42 deals with protection of aircrew

One of the areas defined in Article 40 is

> Work activities where workers and, where appropriate, members of the public are exposed to thoron or radon daughters or gamma radiation or any other exposure in workplaces such as spas, caves, mines, underground workplaces and aboveground workplaces in identified areas;

The European Directive is formulated in careful and well-considered terms, but it is not necessarily in a form which is easy for practitioners to implement. A working party of the Article 31 Expert Group developed a document "Radiation Protection 88" (6) to provide guidance on practical implementation of Title VII of the Basic Safety Standard. The BSS considers natural radiation sources under the same three headings as ICRP: radon, minerals containing natural radioactivity and cosmic rays in aircraft; we will consider only the first of these.

6 GENERAL POINTS ON THE EUROPEAN GUIDANCE

Although the main emphasis is on protection of workers, Title VII also concerns itself with members of the public. There is a fairly direct instruction to Member States to carry out surveys, or other investigations, to establish the scale of exposures to natural radiation sources. However, the Directive emphasises that selection of those exposures to which controls should apply is very much a matter for each Member State.

The phrase in Article 40.1 ".. (exposures) which cannot be disregarded from the radiation protection point of view" suggests that there is a level of dose above which action would be expected. There is some guidance in Radiation Protection 88 on where this level might be for the different types of exposure.

Nevertheless, there was no expectation of completely uniform standards across Europe.

7 EUROPEAN GUIDANCE ON RADON

Although radon in ordinary workplaces and homes was not generally recognised as a radiological hazard until the 1980s, knowledge of radon is now widespread. The advice of Radiation Protection 88 is consistent with that of the ICRP, both in Publication 60 and in Publication 65, though with a European flavour. Advice is given on the way in which measurements of radon gas may be used to assess the risk from radon decay products. There is an undogmatic suggestion that radon prone areas may prove a useful concept in introducing controls.

Radiation Protection 88 recommends that national Action Levels for radon in workplaces should be set in the range 500-1000 Bq m^{-3}. This may be contrasted with the ICRP (3) range of 500-1500 Bq m^{-3} and the IAEA (4) single value of 1000 Bq m^{-3} . This should probably be taken as an expectation that safety standards in Europe may be a little higher than the world-wide average. It is not because radon levels in Europe are conspicuously low!

Where radon concentrations in a workplace exceed the Action Level, the recommendation is to try to reduce them. If concentrations remain above the Action Level then advice is offered on appropriate monitoring and control. It is generally felt that these must be considered on their merits: there is an explicit warning against the automatic declaration of controlled and supervised areas based solely on dose criteria. Much more important questions will be the variability and unpredictability of doses.

8 IMPLEMENTATION OF THE PROVISIONS OF TITLE VII IN THE UK

Exposures to radon at work were already covered under the Ionising Radiation Regulations 1985 (7). This specified that controls were needed if the mean radon daughter concentration over an eight hour working day exceeded the equivalent of 220 Bq m^{-3}. In practice, if this threshold was exceeded in above ground workplaces, it almost always proved possible to undertake remedial measures which reduced the radon concentration to below the Action Level. The new Ionising Radiation Regulations 1999 (8) introduce one small but useful technical simplification: action is required if the mean radon gas concentration over 24 hours exceeds 400 Bq m^{-3}. This is, in practical terms generally the same as 220 Bq m^{-3} over the working day, but permits the use of simple and cheap long term measurements with track etch detectors.

Responsibility for enforcing controls on radon levels in workplaces are divided between the Health and Safety Executive (HSE) and the Local Authorities. The former, broadly have responsibilities for larger workplaces and the latter for service industries (e.g. shops and offices).

9 CONTROLS ON RADON EXPOSURES IN OTHER COUNTRIES

Akerblom (9) has reviewed both domestic and occupational radon Action Levels in a variety of states within Europe and elsewhere. He reported a wide range of occupational Action Levels, 200-3,000 Bq m^{-3}, however, it should be noted that the highest level, 3,000 Bq m^{-3}, is the enforcement level for a country where action is advised at 400 Bq m^{-3}. The next highest Action level was 1500 Bq m^{-3}, and no other example exceeded 1000 Bq m^{-3}. Akerblom also summarises arrangements for implementing and supervising occupational controls on radon exposure. This paper cannot begin a comprehensive review, but a few examples from the literature will be given.

Germany (10) has a long tradition of controlling radon exposures in mines and (since 1994) waterworks and most other below-ground workplaces. It was noted that the number of monitored workers was almost constant at around 25,000 from the mid 1970s to the end of the 1980s. The number then fell sharply, reflecting a reduction in mining activities. Attention has recently turned to above-ground workplaces. A survey of 8,000 such workplaces has suggested that 5-10% (corresponding to 20,000-60,000 employees) may have levels above 1000 Bq m^{-3}. It must be emphasized that these radon measurements are cautious, being made under “closed house” conditions. Nor do they take account of occupancy.

Finland (12) also has a long history attention to radon in workplaces with measurements in mines going back to the 1970s and extension to above-ground workplaces being introduced in legislation of 1992. Exposures in mines have fallen greatly in recent years, largely due to better ventilation in modern mines. Areas where attention should be given to radon in above-ground workplaces are being identified using data on radon in dwellings. A variable Action Level is defined to take account of occupancy.

The dominant contribution to the data on mining in Table 2 is from gold mining in South Africa. A fascinating account is given by Wymer and van der Linde (12). A quarter of a million miners extract 100 million t of ore per year, which yield 600 t of gold. The mines extend to a depth of 3500m, where heating is considerable and rock bursts present a more immediate threat than radiation. Nevertheless, uranium associated with the gold deposits does give rise to radiation exposures by the usual routes of radon, inhalation of dust and external radiation. The first of these is the most important, giving over 70% of the collective dose. Wymer and van der Linde note that doses have been falling with time, largely as a result of improvements in ventilation. The mean annual effective dose is estimated to be about 2.5 mSv and the authors suggest that the industry can operate within dose limits of 20 mSv pa and 50 mSv in any year.

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Table 1

Worldwide occupational exposures to natural radiation (excluding uranium mining) and in the civilian nuclear fuel cycle 1990-94

Occupation or practice	*Number of workers (thousands)*	*Worldwide annual collective effective dose (man Sv)*	*Average annual effective dose (mSv)*
Natural			
Coal mining	3910	2600	0.7
Other mining	760	2000	2.7
Exposure above ground(radon)	1250	6000	4.8
Mineral processing, etc.	300	300	1.0
Aircrew	250	800	3.0
Total	6500	11700	1.8
Fuel Cycle			
Mining and Milling	75	330	4.5
Enrichment & Fuel Fabrication	34	23	0.7
Reactor Operation	530	900	1.4
Reprocessing	45	67	1.5
Research	120	90	0.8
Total	800	1400	1.8

After UNSCEAR 2000

Table 2

Collective dose to miners from radon and its decay products from underground mining (excluding uranium) in the years 1990-1994

Country	*Workers (thousands)*	*Annual collective effective dose (man Sv)*	*Average annual effective dose (mSv)*
Coal Mines			
Germany	105	53	0.50
India	669	67	0.10
Poland	251	380	1.50
USSR	840	170	0.20
United Kingdom	46	23	0.50
United States	51	26	0.50
Other	1940	690	0.36
Total	3910	1410	0.36
Other Mines (excl. uranium)			
Germany	4	28	7.0
India	10	40	4.0
Poland	10	5	0.5
South Africa	340	610	1.8
USSR	40	170	4.3
United States	48	210	4.4
Other	308	755	2.4
Total	760	1820	2.4

After UNSCEAR 2000

Note: to obtain total doses to these miners UNSCEAR add 0.8 mSv pa for naturally occurring external radiation and subtract 0.5 mSv pa to account for dose received irrespective of work.