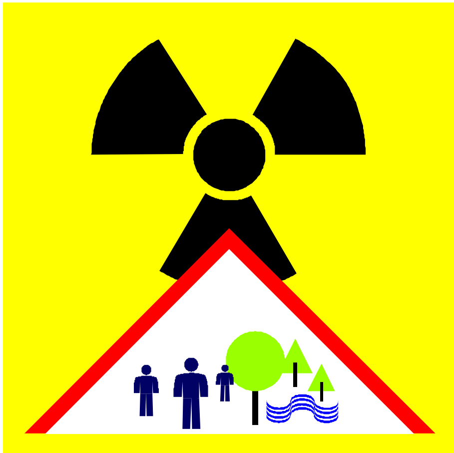
Radiation Protection 88



Recommendations for the implementation of Title VII of the European Basic Safety Standards Directive (BSS) concerning significant increase in exposure due to natural radiation sources

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Directorate-General
Environment, Nuclear Safety and Civil Protection

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FOREWORD

The Basic Safety Standards for the Health Protection of the General Public and Workers against the Dangers of Ionizing Radiation are laid down in a new Council Directive (96/29 EURATOM of 13 May 1996, replacing Directive 80/836 as amended by Directive 84/467). The new Directive differs from the earlier versions in that special provisions have been laid down concerning exposure to natural radiation sources (Title VII of the Directive). Such exposures were not explicitly dealt with before, even though they were implicitly within the scope of the Standards, hence the introduction of the new provisions may bring a significant change in national legislation.

In order to assist the Member States in transposing the Directive, guidance will be provided in a Commission Communication. This communication will explain the overall framework of the implementation of Title VII. The flexible approach adopted in the Directive and highlighted in the Communication however requires more detailed technical guidance and recommendations on the identification of work activities and related workplaces that might be of concern, and on related protection measures.

The present document offers such technical guidance. It was established by a working party of the Group of Experts established under the terms of Article 31 of the Euratom Treaty, and was endorsed by this Group of Experts at its meeting on 14 November 1996. The Commission acknowledges the efforts of all those that were involved in this process, and in particular the members of the Working Party (see Annex 1).

This document is intended to offer guidance to national authorities and the Commission hopes that it will serve this purpose. It does not infringe by any means on the responsibility of Member States to ensure compliance with the Basic Safety Standards.

Contents

SECTION 1 - INTRODUCTION

1 Title VII of the revised European Union Basic Safety Standard Directive has for the first time set down a framework for controlling exposures to natural radiation sources arising from work activities. The regime in Title VII is necessarily flexible to encompass the difficulties posed and variations exhibited by natural radiation. This document is intended to offer guidance to National Authorities on how they might approach their responsibilities, recognising that many undertakings will not have appreciated the extent of possible exposures. In particular it suggests ways of identifying the types of work activities that should be made subject to control, and the nature of the controls that may then be appropriate.

Title VII of the European Union BSS consists of three Articles:

Article 40 - Application

Article 41 - Protection against exposures from terrestrial natural radiation sources

Article 42 - Protection of air crew

This document follows the same general framework as the BSS. The articles are given in italics followed by commentary on them.

Article 40 - Application

1 This Title shall apply to work activities not covered by Article 2.1 within which the presence of natural radiation sources leads to a significant increase in the exposure of workers or of members of the public which cannot be disregarded from the radiation protection point of view.

2 Each Member State shall ensure the identification, by means of surveys or by any other appropriate means, of work activities which may be of concern. These include, in particular:

a) 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;

b) work activities involving operations with, and storage of materials, not usually regarded as radioactive but which contain naturally occurring radionuclides, causing a significant increase in the exposure of workers and, where appropriate, members of the public;

c) work activities which lead to the production of residues not usually regarded as radioactive but which contain naturally occurring radionuclides, causing a significant increase in the exposure of members of the public and, where appropriate, workers.

d) aircraft operation.

3 Articles 41 and 42 shall apply to the extent that the Member States have declared that exposure to natural radiation sources due to work activities identified in accordance with paragraph 2 of this Article needed attention and had to be subject to control.

2 Article 40 lays down that Title VII does not apply to exposures from practices as defined in Article 2, paragraph 1. These are covered under Titles III to VI and VIII. Article 2 applies largely to artificial radiation sources but some work with natural radioactive materials (eg, where the intention is to make use of their radioactive or fissile properties) falls within this definition of a practice.

3 The European Basic Safety Standards Directive (BSS) follows the recommendation of ICRP (Publication 60, paragraph 134 et seq) that the concept of occupational exposure to ionising radiation should be limited to exposures which can reasonably be regarded as amenable to control. Potassium 40 in the body, cosmic rays at ground level and above ground exposure to radionuclides in the undisturbed earth's crust are explicitly excluded. [BSS Paragraph 2.4] The term undisturbed earth's crust means the earth's crust where no quarrying, underground or open cast mining is carried out. Ploughing, excavation or refill as part of farm or construction work is not considered to «disturb» the earth's crust, except where such works are carried out as part of interventions for restoration of contaminated earth. The surface of a uranium field which was never exploited is undisturbed earth's crust; if the uranium field was, but it is no longer exploited, then Section II of Title IX, intervention in cases of lasting exposures, may apply. The BSS also excludes radon exposure in dwellings. In line with the Commission recommendation 90/143/Euratom on the protection of the public against indoor exposure to radon, Member States may decide to implement a programme of control of domestic exposures. If so, the domestic and occupational programmes are likely to be related.

4 Elevated levels of radon in workplaces and occupational exposure to materials or residues containing natural radionuclides can be regarded as amenable to control. However, since such exposures are ubiquitous it is necessary to have a general system for applying controls selectively. The BSS are consistent with ICRP recommendations that these exposures should be excluded from the scheme of occupational exposure for practices and considered separately unless the relevant national authority has determined otherwise.

5 National authorities thus need to decide in which parts of their territory and for which activities and working conditions it would be appropriate for doses from natural radioactivity to be regarded as part of occupational exposure or even public exposure. These decisions must be based on a sound review of the patterns and levels of exposure throughout the territory for which the authority is responsible. This will normally require surveys to be conducted, though there are circumstances in which surveys can be complemented by other techniques. For example, geological mapping can help in making maximum use of measurements of radon levels in buildings. This is discussed in more detail below. Knowledge of activity concentrations in building materials and in sources of water may also provide useful general indications of where levels of natural radioactivity are high.

6 Note that 40.2a refers to exposures from the natural radiation environment while 40.2b and 40.2c refer to exposures arising from work involving naturally radioactive materials. Paragraph 40.2d refers to cosmic ray doses incurred during flight. This is, of course, a form of natural

background radiation but control of doses during aircraft operation is sufficiently distinct to justify it being treated separately.

7 While the BSS brings exposures to natural radiation sources within the same general framework as other exposures to radiation this does not mean that identical procedures are to be followed in the case of natural and artificial radiation sources. This is because of the special features of some exposures to natural radiation sources, in particular, that some approaches to control may be regarded as interventions and, as such covered broadly by Title IX, rather than practices, broadly covered by Titles III, IV,V, VI and VIII. The sections which follow discuss exposure to radon, to materials containing natural radionuclides and to cosmic rays. Some similarities in the control schemes for these three classes will be apparent but they are by no means identical. The control scheme for radon is perhaps the most developed.

8 National Authorities may need to consider controlling doses to members of the public as well as those to workers. This applies in particular to work activities giving rise to the release of materials containing natural radionuclides in liquid or gaseous effluents or as solid waste. Public exposure to cosmic radiation is not considered.

SECTION 2 - RADON IN WORKPLACES

Article 40 - Application

1 ...

2 Each Member State shall ensure the identification, by means of surveys or by any other appropriate means, of work activities which may be of concern. These include, in particular:

a) work activities where workers and, where appropriate, members of the public are <u>exposed to thoron or radon daughters or gamma radiation</u> or any other exposure in workplaces such as spas, caves, mines, underground workplaces and aboveground workplaces in identified areas;
b) ....
c) ....
d) ....

3 Articles 41 and 42 shall apply to the extent that the Member States have declared that exposure to natural radiation sources due to work activities identified in accordance with paragraph 2 of this Article needed attention and had to be subject to control.

Article 41 - Protection against exposure from terrestrial natural radiation sources

For each work activity declared by them to be of concern, the Member States shall require the setting-up of appropriate means for monitoring exposure and as necessary:

a) the implementation of corrective measures to reduce exposure pursuant to all or part of Title IX;

b) the application of radiation protection measures pursuant to all or part of Titles III, IV, V, VI and VIII.

Section 2.1 - Introduction

9 As with other natural radionuclides, exposures to radon and its decay products are ubiquitous. The levels are, however, exceptionally variable and high doses can be incurred. A system is required under which attention can be concentrated on the highest exposures and where action is most likely to be effective. National Authorities must arrange for representative surveys to be undertaken to determine the scale and nature of radon exposures in different types of workplace unless they already have this information.

10 There are several isotopes of radon. Attention is normally focused on ^{222}Rn because its relatively long half-life (4 days) facilitates its escape from the matrix which contained its

parent ^{226}Ra. Under certain circumstances ^{220}Rn (thoron, half-life one minute) can be important. The general principles set out in this document can also be adapted to the control of exposures to thoron.

11 The hazard in high radon environments comes from radon decay products rather than radon gas itself. Nevertheless, for practical reasons control measures should generally be expressed in terms of the concentration of radon gas.

12 Actions Levels and Radon Prone Areas are concepts which National Authorities are likely to find useful in controlling radon exposures in the workplace and also in dwellings (houses and flats). Because Action Levels and Radon Prone Areas for occupational and domestic control are interrelated the discussion below necessarily touches on the control of domestic as well as occupational exposures.

Section 2.2 - Surveys

13 Separate investigations should be undertaken of the geographical variation of radon exposures in above ground workplaces (eg, factories, shops, offices and some waterworks) and in below ground workplaces.

14 Below ground workplaces where radon concentrations may require controls include non-uranium mines, tunnels, galleries in radon spas, subways, underground installations, catacombs, show caves and tourist mines, underground water treatment works and stores. Surveys of all types of underground workplace should be carried out; it is not necessarily the case that high levels of radon in below ground workplaces are found only in areas which also have high levels in buildings.

15 The distribution of atmospheric aerosol size distribution has, in principle, the potential to affect doses. Nevertheless, in many circumstances it will be adequate for control purposes to consider just the quantity of alpha energy to be released by the radon daughters. The equilibrium factor is generally used to provide such a measure.

16 In many circumstances the equilibrium factor will be found to be about 0.4 to 0.5 in above ground workplaces and in some below ground workplaces. Investigations can be carried out to indicate any circumstances where this is not the case. Experience to date suggests that equilibrium factors outside the range specified may arise in mines or workplaces with high or low ventilation rates or where aerosol concentrations are usually high or low (and also in buildings in warm climates). Nevertheless, routine direct measurements of equilibrium factors in specific workplaces will not generally be necessary.

17 Radon surveys should be based on reliable long term measurements (ideally one year and at least several months) in workplaces of various kinds in order to average out short-term variations in radon levels. It may be necessary to apply seasonal correction factors since radon levels in buildings are generally higher in winter than in the summer. Appropriate correction factors should be derived from experimental measurements conducted over a whole year in real situations typical for each country and type of workplace. The surveys should be properly designed and with adequate power to yield the precise information desired. It will be necessary to take into account differences between concentrations averaged over 24 hours (as measured by long-term passive measurements) and those encountered during the working day. The latter will generally be lower by a factor which can be estimated from experience or by special measurements.

There may be a role for short-term screening measurements. However, such measurements will require special protocols and very careful interpretation.

18 Measurements should be made with appropriate detectors and equipment which have undergone approved calibration and quality assurance programmes.

19 Geological information may be a useful general guide to identifying areas where radon levels in buildings are likely to be above average. However, there is a complex relationship between geological parameters such as uranium concentrations in soil and radon levels in buildings. Nevertheless geological maps can be helpful in interpolating the results of surveys of measurements of radon in buildings.

Section 2.3 - Action Levels

20 A radon Action Level is a concentration of radon gas above which National Authorities require (or in the case of domestic exposure, possibly recommend) that action is taken. The choice of action level will, in part, be determined by practical consideration in view of the national circumstances. However, the levels chosen for domestic and occupational circumstances should be compatible from the radiological protection point of view (see ICRP Publication 65, paragraph 85).

21 National authorities should define radon Actions Levels for workplaces as they may do for dwellings (houses and flats). Occupational exposures to radon above the Action Level will be subject to Regulatory Control. However, it is expected that the normal response to finding that radon levels in a workplace are above the Action Level will be to undertake remedial measures so that the Regulations need no longer be applied. This should be decisive action to effect a substantial reduction, not just to edge below the Action Level.

22 ICRP suggests that the best choice of Action Level for dwellings may be that which defines a significant but not unmanageable number of houses requiring remedial work (Publication 60, paragraph 217). ICRP further recommends that the Action Level for dwellings should fall in the range 200-600 Bq m^{-3} (Publication 65, paragraph 73). [The 1990 recommendation of the European Communities was for a reference level of 400 Bq m^{-3} for existing dwellings and a target of 200 Bq m^{-3} for new buildings.]

23 ICRP, in Publication 65, derives a range of Action Levels for workplaces of 500-1500 Bq m^{-3} on the basis of equivalence of doses to the range for dwellings (paragraph 86) and therefore recommends that National Authorities should choose Action Levels for homes and workplaces which are similarly placed within the two ranges (paragraph 86). It is likely that this will also result in a significant but not unmanageable number of workplaces requiring remedial work. This ICRP range of Action Levels is intended as a world wide recommendation.

24 ICRP recognises that an action level can have two distinct purposes:

a) to define workplaces either in which intervention should be undertaken, or

b) to identify where the system of protection for practices should be applied.

It concludes that there are clear advantages in the adoption of the same action level for both purposes. In the context of the BSS Directive, it is the regulatory purpose which is of primary interest.

25 For this regulatory purpose, it is very desirable for the action level not to exceed the dose level at which special actions are required to protect workers involved in practices - ie, the criterion for classifying category A workers. It is therefore recommended that, within the European Union, the Action Level for places of work should be set in the range 500-1000 Bq m^{-3} time averaged radon gas concentration. This is based on occupational exposure of 2000 hours per year and an equilibrium factor of about 0.4; if there are circumstances where these factors are significantly different then a modified Action Level might be appropriate. National Authorities may also select an Action Level below the specified range if they judge that this is desirable and will not lead to an impractical radon programme. It may be noted that the International BSS specify an Action Level of 1000 Bq m^{-3}.

26 For workplaces with high occupancy (eg, residential homes, residential schools, some hospitals) it may be appropriate to adjust the Action Level to reflect the increased occupancy.

The undertaking may also have a duty to control the exposures of members of the public who spend significant periods in the workplace (again residential homes, schools and some hospitals provide examples).

Section 2.4 - Radon Prone Areas

27 National Authorities may find it useful to define radon prone areas. It is suggested by ICRP (Publication 65, paragraph 76, 102) that radon prone areas might be those parts of the country where at least 1% of dwellings have radon levels more than ten times the national average as determined by appropriate statistical sampling. It is recognised, however, that some National Authorities may adopt an alternative, but also appropriate approach to the definition of a «manageable number». Both the geographical variation of radon concentrations and the choice of action level will influence the definition of radon prone areas [paragraph 76]. It should not be overlooked, however, that high radon concentrations may occur also outside the defined radon prone areas. The same geographical definition of radon prone areas should be used for homes and for workplaces (paragraph 85).

28 The definition of radon prone areas is not relevant to the control of radon exposures in below ground workplaces. These should be treated on their merits regardless of whether the workplace falls within a radon prone area or not (ICRP 65, paragraph 85).

Section 2.5 - Testing and Remedying Existing Workplaces

29 National Authorities must decide where employers need to measure radon levels in workplaces. It would be prudent to take action most urgently where radon levels are highest and National Authorities may wish to set priorities for action within radon prone areas. These might be in terms of radon level (ICRP 65, paragraph 76) or the types of workplace. It is likely that measurements will be needed in all underground workplaces of most kinds or at least in a large enough sample for a clear and statistically significant picture to be reached.

30 Within the specified areas employers should arrange for radon levels to be measured in above ground workplaces. If the measurement time is less than one year and the (seasonal corrected) result approaches the action level it may be appropriate for the result to be verified with repeated measurements in different season. Where the first seasonally corrected results show radon levels well in excess of the Action Level, then action should be taken without awaiting

further results.

If radon concentrations are found to be below the Action Level then there is no requirement for further action other than re-testing if the concentrations are marginal or substantial changes are made in the construction or use of the building. Employers may, however, consider undertaking remedial measures if radon concentrations approach the Action Level. ALARA will often indicate that this is appropriate even though it is not within the regulatory requirements of the Member States.

31 If radon levels are found to be above the Action Level in a workplace or part of a workplace but occupancy is very low then it may be sufficient to monitor and control access to the area. It is emphasised that this is not intended as a substitute for remedial measures when occupancy is a significant fraction of a normal working year. It might, for example, apply to a store room visited for an hour or two per week or a pumping station visited for half a day a month.

32 If radon concentrations are above the Action Level and occupancy is not very low then remedial action to reduce the radon level should be required. This should be decisive action aiming at a substantial reduction in radon concentrations (ICRP 65, paragraph 71, 105). Experience indicates that relatively simple and inexpensive remedial measures are successful in significantly reducing elevated radon levels in the majority of above ground workplaces.

33 Member States should ensure that advice and assistance is available to employers on how to obtain appropriate radon measurements and, if necessary, on remedial measures appropriate to places of work.

34 If remedial measures are successful in reducing radon concentrations below the Action Level then no further action is needed other than re-testing if substantial changes are made in the construction or use of the building. Where the reduced radon level relies on active measures, such as a fan, then its efficient operation needs to be checked occasionally. The National Authority may also require periodic re-testing, particularly if radon concentrations approach the Action Level.

Section 2.6 - Applying the Radiation Protection System

35 If, despite all reasonable efforts, radon concentrations remain above the Action Level, then a scheme of radiological protection should be introduced which follows the principles set out in Titles III, IV, V, VI and VIII where these are appropriate. Application of these principles to protection against radon may vary in some instances from their application to artificial sources. The most important elements are monitoring exposures, defining controlled and supervised areas and dose limits. These are discussed in more detail below. (See also ICRP Publication 65, paragraph 98.)

Monitoring Exposures

36 Where radon concentrations remain above the Action Level after attempts at remedying then monitoring should be undertaken. Monitoring may be of individuals (for example, with etched track dosemeters worn on the clothing) or of the areas in which they work (for example, with continuously recording electronic equipment). In most circumstances, workers should be categorised in the same way as they are for other work with radiation. If radon levels are just above the Action Level then area monitoring may be adequate. If exposures might approach

the dose limit then personal monitoring will normally be preferred (see ICRP Publication 65, paragraph 99). In cases where radon levels are high in areas which are normally unoccupied, area monitoring together with individual control of occupancy times may be appropriate.

Records of Exposures and Calculation of Doses

37 Records of monitoring radon exposures of workers shall be kept. Such records may be in terms of Bq m^{-3} h or in mJh m^{-3} (see below). Nevertheless, despite the use of special units for radon exposures, there will be a need to calculate and record effective doses, for example where the workplace is part of a practice involving artificial radiation sources and so it is necessary to combine estimates of dose from other natural or artificial radiation and from radon for comparison with dose limits and for record keeping.

The conversion convention recommended by ICRP in Publication 65 should be used for this purpose on a provisional basis. In the case of workers, paragraph C of Annex III of the BSS shows that 1 mJh m^{-3} of radon decay products is equivalent to 1.4 mSv; with equilibrium factor 0.4, 3.2×10^5 Bq m^{-3} h radon gas is equivalent to 1 mSv[*]. For members of the public, 1 mJh m^{-3} is equivalent to 1.1 mSv and 4×10^5 Bq m^{-3} h radon gas is equivalent to 1 mSv. The conversion convention is based on the epidemiological data discussed in ICRP Publication 65. Nevertheless, it is recognised that there is, at present, a discrepancy of a factor of about two to three between risk estimates from dosimetry and from epidemiology and conversion conventions may change.

38 For thoron decay products the presently recommended conversion factor is 0.5 mSv per mJ h m^3, about one third of the value for radon (BSS, paragraph C of Annex III). This figure is based on the ICRP Publication 50 dosimetric model and, as in the case of radon decay product conversion conventions, may be subject to change with increase of scientific knowledge.

39 It is emphasised that estimates of doses from radon should be made only if these exposures are important in their own right. There is no requirement to assess radon doses purely because other radiation doses are being assessed and recorded.

40 If radon and other exposures are combined, personal dose records should contain separate estimates of dose from radon as well as the sum of doses from radon and from other occupational exposures. Time integrated gas exposures (Bq m^{-3} h) with the equilibrium factor or time integrated radon daughter exposure (Bq m^{-3} h, mJh m^{-3} or WLM) should be retained for personal monitoring. If area monitoring is used to control exposures, then similar information should also be kept.

41 As with exposures from practices, personal dose records and area monitoring results should be kept as specified in Title VI.

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[*] The historical unit the Working Level Month is still encountered though its use is deprecated. For workers, 1 WLM is equivalent to 5 mSv. Under standard assumptions 1 WLM would be incurred by working for a year in a time averaged radon concentration of about 750 Bq m^{-3}. [1 WL = 3700 Bq m^{-3} EEC; divide by F = 0.4 and 12 months yields 771 Bq m^{-3}, rounded downwards.]

Controlled and Supervised Areas

42 When making decisions on the boundaries of supervised and controlled areas employers should bear in mind that this should not be purely on the basis of whether individual doses can be confidently predicted to be below 3/10 of the dose limit (ICRP 60, paragraph 252). Rather the distinction should be a matter of judgement involving not just the level of dose but also its variability and the potential for unpredictable exposures. A key point will be whether special operating procedures are required.

Dose and Exposure Limits

43 The primary dose limits are defined in Article 9 of the Directive. These are 100 mSv in a consecutive five year period with a maximum of 50 mSv in any one year. In practice a number of quantities and units have been used for controlling radon exposures - in particular the Working Level Month. It is recommended that these historical units should no longer be used.

44 There are uncertainties in the conversion of time integrated radon exposure data to mSv and there may be advantages in working in terms of the former when controlling radon exposures. Under standard assumptions including an equilibrium factor of 0.4 and 2000 hours occupational exposure an annual dose of 20 mSv is equivalent to about 6×10^6 Bq h m^{-3} radon gas and this level of exposure would be reached by working continuously in a radon concentration of about 3000 Bq m^{-3}. Alternatively, National Authorities may work in terms of the time integral of the concentration of radon progeny α energy (see ICRP Publication 65). In SI units 20 mSv is equivalent to 14 mJ h m^{-3}.

Section 2.7 - Construction of New Workplaces

45 Although not explicitly mentioned in Title VII it would be sensible to consider preventing high radon levels arising in new workplaces rather than taking remedial measures after they have been built.

It is simple and cheap to incorporate measures to reduce radon levels at the time that the building is being constructed. It should be noted that radon preventative measures which prevent the entry of soil gas into dwellings have incidental advantages eg, in inhibiting the entry of damp and moulds.

46 National Authorities should delimit localities within radon prone areas or elsewhere within which appropriate radon preventative measures should be included in the construction of new workplaces. These should ensure that radon levels in new workplaces are as low as reasonably achievable and that further remedial measures can easily be introduced if necessary.

47 Building materials are not usually a dominant source of radon. Nevertheless, it may be found that high levels of ^{226}Ra or other natural radionuclides in some materials should be avoided. Certain kinds of lightweight alum shale concrete, tuff or granites may provide examples. It should be noted that other factors, for example γ radiation, may need to be considered in the choice of building materials with high levels of natural radioactivity.

Section 2.8 - Natural Gamma Ray Exposures in Workplaces

48 Cosmic rays have been sufficiently attenuated by the atmosphere that they typically deliver a dose of about 0.3 mSv a year at ground level. Natural gamma rays from the ground and from building materials normally make a comparable addition to this dose. However, circumstances have been reported where this contribution is larger.

49 High gamma doses from the ground or from building materials will only arise if there are high levels of ^{238}U, ^{232}Th or their decay products. Surveys will show where these circumstances may arise. It should be noted that in many circumstances the same concentration of natural radionuclides which results in elevated levels of gamma radiation may lead to doses from radon or thoron which are of greater radiological significance.

SECTION 3 - INDUSTRIAL PROCESSES INVOLVING NATURAL RADIONUCLIDES OTHER THAN RADON

Article 40 - Application

1 *....*

2 *Each Member State shall ensure the identification, by means of surveys or by any other appropriate means, of work activities which may be of concern. These include, in particular:*

a) *....*

b) *work activities involving <u>operations with and storage of materials</u>, not usually regarded as radioactive but which contain naturally occurring radionuclides, causing a significant increase in the exposure of workers and, where appropriate, members of the public;*

c) *work activities which lead to <u>the production of residues</u> not usually regarded as radioactive but which contain naturally occurring radionuclides, causing a significant increase in the exposure of members of the public and, where appropriate, workers.*

d) *....*

3 *Articles 41 and 42 shall apply to the extent that the Member States have declared that exposure to natural radiation sources due to work activities identified in accordance with paragraph 2 of this Article needed attention and had to be subject to control.*

Article 41 - Protection against exposure from terrestrial natural radiation sources

For each work activity declared by them to be of concern the Member States shall require the setting-up of appropriate means for monitoring exposure and as necessary:

a) *the implementation of corrective measures to reduce exposures pursuant to all or part of Title IX;*

b) *the application of radiation protection measures pursuant to all or part of Titles III, IV, V, VI and VIII.*

Section 3.1 - Introduction

50 Surveys may show that there are circumstances in which the use and storage of materials not generally regarded as radioactive nevertheless gives rise to significant doses because the materials contain elevated levels of natural radionuclides. Examples might include monazite sands, rare earth ores and also the scale which can build up in pipes and valves of parts of some oil, coal or other mineral processing and similar plant. In these circumstances the appropriate national authority might declare that exposures due to work activities with these materials should be regarded as falling within the definition of occupational and/or public exposure to radiation (see, eg, ICRP 60).

51 Some industrial processes which may result in significant exposures from natural radionuclides to workers and/or members of the public are listed in Table 1. Whenever materials contain uranium and thorium consideration should be given to the extent to which their decay products are also present. It should be noted that the degree of exposure depends not only on the activity concentration of the material involved but also on any chemical or physical processing which may increase the availability of the material. For example, grinding up raw materials may generate respirable dusts and may also make it easier for radon to escape into the air of the workplace. Processing materials rich in uranium or thorium families at high temperatures (e.g. coal combustion) could enrich airborne dust in some radionuclides of the uranium and thorium series, eg Po-210 and Pb-210. At very high temperatures (about 3000°C or above) other nuclides of the uranium or thorium families may also gasify, eg, Ac-228 may gasify from welding rods doped with Th-232 during welding. Attention must be paid to the possibility that waste streams may be responsible for a more significant hazard than the main process leading to the product.

52 Table 1 should not be taken to be comprehensive but rather as illustrating the kind of process where exposures may occur and where it may therefore be necessary to assess exposures. Conversely, the fact that a process is listed does not imply that it will always lead to significant doses. If details of the process change then a review of exposures may be desirable.

Section 3.2 - Control of Exposure of Workers

53 The important routes of radiation exposure from these processes for workers are normally external gammas and inhalation of dust. The appropriate control measures may include limitation of exposure time, attention to the arrangements for storage of bulk material and dust control. In some cases radon or thoron may present a problem and surface contamination may also need to be considered. It is not necessarily the case that the highest doses arise when the plant is operating normally. In some circumstances, the maximum doses will be incurred during maintenance.

54 Normal commonsense precautions should be taken to avoid all unnecessary exposures to radiation. Beyond this, assessments should be made to estimate the doses to workers from such natural radionuclides. If the doses are less than 1 mSv per year then no special precautions are required. If annual doses exceed 1 mSv then the normal scheme for controlling exposures can usually be applied. The Directive requires that, as necessary, Titles III, IV, V, and VI would apply in whole or in part. If doses exceed 6 mSv then it may, in rare cases, be appropriate to define a controlled area.

55 If doses exceed 1 mSv but are less than 6 mSv it would be appropriate to consider, for

example, whether doses could effectively be reduced and whether there is a possibility that doses increase either over time or as the result of an accident. If doses are low and cannot effectively be reduced and if there is no realistic potential for accidents then few radiation protection measures are likely to be required beyond whatever is necessary to ensure that doses do not increase.

Section 3.3 - Control of Exposures of the Public

56 Exposures of the public may arise from the product of a process (eg, building materials) or from atmospheric or liquid discharges, from re-use of by-product material or from disposal of solid waste. The important routes of radiation exposure of the public are external gamma radiation, inhalation and ingestion.

57 The practical protection of members of the public is dealt with in Title VIII. Article 43 lays down a general duty on Member States to create the conditions for the best possible protection of the public. Article 47 stipulates that the undertaking responsible for a practice shall be responsible for achieving and maintaining an optimal level of protection for the environment and the population. The same general principles should apply to work involving natural radiation even if it falls outside the definition of a practice.

Table 1 Examples of industries where enhanced exposure to natural sources of radiation might occur

Work activity/industry/product	Radionuclides and typical activity concentrations	Occupational exposure above 1 mSv/main pathways/particularities	Public exposure above 1 mSv/ main exposure routes/special features
Phosphate industry (fertilizer production) Phosphoric acid (detergents and food)	Feed material: 1.5 kBq kg^{-1} U By-product gypsum: 1 kBq kg^{-1} Ra-226 But high concentrations of Ra (100 kBq kg^{-1}) may precipitate in the plant	POSSIBLE/Gamma radiation and inhaled dust at production plants/Accumulated radium-rich scales (~ 100 kBq kg^{-1})	POSSIBLE/Liquid discharges, re-use of by product gypsum, atmospheric discharges if thermal processing involved (Pb-210 and Po-210)
Sulphuric acid production	Pyrites: slag containing > 1 kBq kg^{-1}	? Inhalation and external doses	?
Coal mine de-watering plants	Sludges may contain 50-100 kBq kg^{-1}	POSSIBLE/External gamma and internal hazard during maintenance	Disposal will need attention
Coal and fly-ash	Fly-ash: typically 0.2 kBq kg^{-1} U, Th Levels up to 10 kBq kg^{-1} have been reported in special circumstances	NOT LIKELY	POSSIBLE/Re-use of fly-ash as construction material
Metal production: smelters	Tin ore: U, Th $\leq$ 1 kBq kg^{-1} Lead/Bismuth smelting (bismuth may contain 100 kBq kg^{-1} of $^{210}Bi/^{210}Po$) Ilmenite, rutile (titanium) Bauxite, red mud (aluminium): U, Th; < 1 kBq kg^{-1} Pyrochlore or columbite (for ferro-niobium): 50 kBq kg^{-1} Th Activity may concentrate in slags and furnace dusts	POSSIBLE/Gamma radiation and inhalation of dust at production plant/Dust scales: (~ 100 kBq kg^{-1})	POSSIBLE/Atmospheric discharges (particularly of volatile materials such as Pb-210 and Po-210), Re-use of waste

Table 1 (Continued)

Magnesium/Thorium alloys	Up to 4% Th in final alloys Typically 20% Th in the master alloy	POSSIBLE/Dusts and fumes	POSSIBLE/Disposal may need attention
Rare earths: processing of monazite sands, etc	Rare earth ores for cerium, lanthanium, etc: up to 10 kBq kg^{-1} U, up to 1000 kBq kg^{-1} Th But activities in waste streams and dusts may be very high	POSSIBLE/Gamma radiation, inhalation	POSSIBLE/Re-use of waste
Foundry sands	Zircon sands (1-5 kBq kg^{-1}) Monazite sands (up to 1000 kBq kg^{-1})	POSSIBLE/inhalation of dusts, possible enrichment of Po, Pb	
Refractories, abrasives and ceramics	Zirconium minerals: 5 kBq kg^{-1} U, 1 kBq kg^{-1} Th	POSSIBLE/Gamma radiation and specially inhalation of dust at production plant	POSSIBLE/Re-use of waste
Oil/gas industry	Radium in scales (normally 1-100 kBq kg^{-1}, but up to 4000 kBq kg^{-1}) Possibly also Th and daughters (up to 50%) For example, in phase separation vessels on oil platforms	POSSIBLE/Gamma radiation/Radium rich scales; also inhalation in the case of (accidental) dispersion or during maintenance	LIKELY/if disposal of scales are not appropriately arranged
TiO_2 pigment industry	Feed material: ilmenite and rutile ores: 1 kBq kg^{-1} U, Th Waste streams up to 5 kBq kg^{-1}	POSSIBLE/Gamma radiation and inhalation of dust at production plant	POSSIBLE/Re-use of waste
Thoriated welding rods and gas mantels	Thoriated welding rods: up to 500 kBq kg^{-1} Th Gas mantels: thorium oxide 95%	POSSIBLE/Inhalation of welding fumes, gamma radiation from stores/ Inhalation during grinding of rods	POSSIBLE/disposal of grinding waste or gas mantels may need attention

Table 1 (Continued)

Porcelain teeth	Up to 0.03% U	POSSIBLE/Fitting and shaping work can cause inhalation dose	?
Optical industry and glassware	Rare earth compounds (eg, cerium) in some polishing powders: Th, U. Some glassware up to 10% of U or Th. Ophthalmic glass for eyeglasses and eyepieces: added U or Th for tinting. Some optical lenses: up to 30% of Th Some lens coating materials	POSSIBLE/Polishing, fitting and shaping work can cause inhalation dose	POSSIBLE/Gamma radiation and alpha radiation (to eye)/the dose limit of 15 mSv for the lens of the eye can be exceeded if U or Th are used for lenses in optical instruments, eyeglasses or eyepieces
Natural stone Fuel peat ash	Some granites up to about 1 kBq kg^{-1} of U or Th. Black shale (alum shale, other shales). Some shales up to 5 kBq kg^{-1} of U Up to 2 kBq kg^{-1} in Tuff Note: ^{40}K may also be at ~ 1 kBq kg^{-1} but is unlikely to be a hazard Usually about 100 Bq kg^{-1} U, but some rare cases with up to few % of U has been observed. (Cs-137 from Chernobyl can be important but is outside the scope of this report.)	POSSIBLE/Gamma radiation	POSSIBLE/Use as building material (gamma and radon)

SECTION 4 - AIR CREW

Article 42 - Protection of air crew

Each Member State shall make arrangements for undertakings operating aircraft to take account of exposure to cosmic radiation of air crew who are liable to be subject to exposure to more than 1 mSv per year. The undertakings shall take appropriate measures, in particular;

- *to assess the exposure of the crew concerned,*
- *to take into account the assessed exposure when organising working schedules with a view to reducing the doses of highly exposed air crew,*
- *to inform the workers concerned of the health risks their work involves,*
- *to apply Article 10 to female air crew.*

Section 4.1 - Introduction

58 National Authorities should ensure that studies are carried out so as to assess the likely magnitude of the exposure to cosmic radiation of air crew of companies for whom they are responsible. These studies should cover all rostering arrangements. By air crew is meant both flight deck and cabin crew. The task of assessing likely exposures is greatly facilitated by the substantial body of knowledge which has been built up about dose rates from cosmic radiation.

59 Doses from cosmic radiation vary strongly with altitude and also with latitude and with the phase of the solar cycle. Table 2 gives a moderately conservative estimate of the number of flying hours at various heights in which a dose of 1 mSv would be accumulated for flights at 60 °N and at the equator. The calculations are towards the minimum of the solar cycle. Slightly higher doses would be incurred at solar minimum itself, but these values are moderately conservative over the whole cycle. Cosmic radiation dose rates change reasonably slowly with time at altitudes used by conventional jet aircraft (ie, up to about 15 km).

60 No further controls are necessary for air crew whose annual dose can be shown to be less than 1 mSv. Table 2 can be used to identify circumstances in which it is unlikely that this level of dose would be exceeded. Thus, for example, if flights are limited to heights of less than 8 km, it is unlikely that doses will exceed 1 mSv.

Table 2 Hours exposure for effective dose of 1 millisievert
Computer based estimates* made at heliocentric potential of 500 MV (towards the minimum of the solar cycle). The uncertainty on these estimates is about ± 20%

Altitude (feet)	Kilometre equivalent	Hours at latitude 60 °N	Hours at equator
27,000	8.23	630	1330
30,000	9.14	440	980
33,000	10.06	320	750
36,000	10.97	250	600
39,000	11.89	200	490
42,000	12.80	160	420
45,000	13.72	140	380
48,000	14.63	120	350

*using the program CARI - 3; a conservative conversion factor of 0.8 has been used to convert ambient dose equivalent to effective dose.

61 It should be noted that Table 2 is in terms of flying hours at a given altitude. Airlines generally work in terms of «block hours». These start when the aircraft is pushed back from its stand and finish when the engines are switched off after landing.

Apart from the time spent on the ground, the aircraft will take an hour in climbing to cruising altitude and descending again. Cruising altitude may vary during a flight. Block hours will exceed flying time at altitude in a way that depends on the details of the flight - in particular on its duration.

62 Tables 3 and 4 give estimates of dose for a variety of typical short and long haul flights together with the corresponding dose from 1000 hours flying on these routes. These figures are illustrative for the specific circumstances cited. Air crew may, in practice, fly on a variety of routes. These calculations are for solar minimum, doses would be reduced elsewhere in the solar cycle. These tables may also be used to identify particular circumstances in which air crew are unlikely to exceed 1 mSv per year. Tables 3 and 4 have been obtained using one available computer program. Other programs may also be appropriate, but any program should be validated by experimental measurements.

Table 3 Effective doses for selected routes at solar min, short haul routes

Route	Flight duration (minutes)	Route dose (effective)	Effective dose/ 1000 hours
		(microsievert)	(millisievert)
Dublin - Paris	95	4.5	2.8
London - Rome	135	6.7	3.0
Frankfurt - Helsinki	160	10.0	3.7
Brussels - Athens	195	9.8	3.0
Luxembourg - Madrid	130	5.5	2.6
Stockholm - Vienna	140	8.2	3.5
Lisbon - Munich	180	9.1	3.0
Copenhagen - Dublin	120	7.1	3.5
Amsterdam - Manchester	70	3.0	2.6
Dublin - Rome	180	10.0	3.3

Short haul routes assume a single cruise altitude of 36,000 ft: 20 mins climb to cruise altitude and 20 mins descent to landing. Flight durations are taken from published timetables and details may change. The uncertainty on the dose estimates is about ± 20%

Table 4 Effective doses for selected routes at solar minimum, long haul routes

Route	Flight duration (minutes)	Route dose (E)	Effective dose/ 1000 hours
		(microsievert)	(millisievert)
Stockholm - Tokyo	605	51	5.0
Dublin - New York	450	46	6.1
Paris - Rio	675	26	2.3
Frankfurt - Bangkok	630	30	2.9
London - Toronto	490	50	6.2
Amsterdam - Vancouver	645	70	6.6
Los Angeles - Auckland	760	30	2.3
London - Johannesburg	655	25	2.3
Perth - Harare	665	39	3.5
Brussels - Singapore	675	30	2.7

Long haul routes assume that 50% of the time at cruise altitude is spent at 37,000 ft and 50% at 41,000 ft. Time to reach cruise altitude taken to be 30 minutes and descent time to landing assumed to be 30 minutes. Flight durations are taken from ublished timetables and thus include some time on the ground. These doses will tend to be conservative, ie, somewhat overestimating the true doses. The uncertainty on the dose estimates is about ± 20%

Section 4.2 - Control of Occupational Exposure: General Considerations

63 Employers should explain the risks of occupational exposure to radiation to their staff (see Article 22). Female staff should know of the need to control doses during pregnancy and that their employer must be notified so that any necessary dose control measures can be introduced.

64 Elsewhere in the Directive (Article 21) a distinction is drawn for monitoring and surveillance purposes between those exposed workers who are liable to receive a dose greater than 6 mSv in a year and other exposed workers. It therefore seems appropriate to adopt the same level of dose to identify highly exposed air crew in the sense of Article 42 (second indent). It may be noted that, given the current working patterns of air crew, it seems highly unlikely that a dose of 10 mSv per year would be exceeded. The question of dose limits thus does not arise.

65 For air crew whose annual dose falls in the range 1-6 mSv there should be individual estimates of dose. These estimates of dose should be made available to the individual concerned. For flights below 15 km these may be carried out using an appropriate computer program and internationally agreed information on radiation levels for various routes and altitudes flown. These computer derived dose estimates will generally be moderately cautious overestimates of long-term mean doses. That this is the case should be confirmed by occasional measurements using either active instruments on specific flights or passive measuring devices for a number of flights on an individual route. More realistic assessments of dose would result from a procedure involving such active or passive monitoring. The use of such procedures should be encouraged by National Authorities as appropriate.

66 If full validated experimental measurements are not available National Authorities should ensure that computer derived dose estimates are quality assured and that they reproduce the doses of Table 2 without major inconsistencies. It is highly desirable for different employers to use the same software and that both calculations and instrument measurement protocols produce compatible results.

67 It will normally be possible to adjust rostering so that no individual exceeds 6 mSv per year. However, for air crew whose annual dose is likely to exceed 6 mSv, record keeping in the sense of the Directive is recommended with appropriate medical surveillance.

68 It would be unnecessary and unhelpful to declare supervised or controlled areas in aircraft.

69 Although air couriers and other exceptionally frequent flyers are not mentioned in Article 42, it is recommended that employers of such individuals should make arrangements for determining doses similar to those made by airlines for their staff.

Section 4.3 - Control of Occupational Exposure in High Flying Aircraft

70 Aircraft capable of operating at altitudes greater than 15 km should carry an in-flight active monitor to detect any significant short-term variation in radiation levels. Such variations may arise as a result of solar flares which can cause a sharp increase in the solar component of primary cosmic radiation especially at very high altitudes. Potential exposure resulting from such a flare can be greatly reduced by a controlled descent if active monitoring is used. The

galactic component of cosmic radiation, which is more important at lower altitudes, is not subject to such sudden changes.

Air crew in such aircraft should be subject to the same general monitoring regime as for aircraft operating between 8 and 15 km but account should be taken of the potential variability of doses. Active monitoring may be used to assess the doses to which air crew are exposed or simply to provide a warning of high dose rates. In the latter case, doses should be assessed using a technique which takes account of the variability of doses above 15 km.

In principle, the need to detect high dose rates could be achieved by some means other than an on-board monitor - eg, satellite or ground based solar monitoring systems.

Section 4.4 - Control of Occupational Exposures of Pregnant Women

71 It should be noted that the provisions of Article 10 apply to pregnant air crew and, once pregnancy is declared, the protection of the child to be born should be comparable with that provided for members of the public. This means that, once the pregnancy is declared, the employer must plan future exposures to control the dose to the fetus to within 1 mSv, either for the remainder of the pregnancy or for the whole pregnancy according to how Article 10 is implemented in national legislation.

In many circumstances in radiation protection, it can be assumed that the dose to the fetus will be below 1 mSv if the dose to the surface of the mother's abdomen is kept below 2 mSv. This is not the case when the dose is due to the penetrating cosmic radiation which delivers the dose during flying and the dose to the fetus will be effectively the same as that to the surface of the mothers abdomen. The provision of Article 10.2 in the BSS relating to nursing mothers is not relevant to external exposure from cosmic rays.

SECTION 5 - BIBLIOGRAPHY

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The revised European Union Basic Safety Standards Directive (96/29/Euratom of 13 May 1996) has for the first time set down a framework for controlling exposures to natural radiation sources arising from work activities (Title VII of the Directive). Such exposures were not explicitly dealt with before, hence the introduction of the new provisions may bring a significant change in national legislation.

This document offers detailed technical guidance and recommendations to national authorities on how they might approach their responsibilities. In particular it suggests ways of identifying the types of work activities that should be made subject to control, and the nature of the controls that may then be appropriate.

This document was established by a working party of the group of experts established under the terms of Article 31 of the Euratom Treaty, and was endorsed by this group of experts at its meeting on 14 November 1996.