

# Exposure to Background Radiation In Australia

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**SUMMARY** The average effective dose received by the Australian population is estimated to be  $\sim 1.8$  mSv / y. One half of this exposure arises from exposure from terrestrial radiation and cosmic rays, the remainder from radionuclides within the body and from inhalation of radon progeny. This paper reviews a number of research programmes carried out by the Australian Radiation Laboratory to study radiation exposure from natural background, particularly in the workplace. The control and regulation of occupational exposure to elevated levels of background radiation is an emerging issue that needs to be addressed on consistent, Australia-wide basis.

## 1 INTRODUCTION

In Australia the exposure to radiation during the mining and milling of uranium is closely monitored and the relevant State regulations require that the effective dose to each exposed worker is less than 20 mSv per year. The implementation of these radiation protection practices for technologically enhanced sources takes place against a background of *natural* radiation. There is no inherent difference between this *natural* radiation and the radiation associated with the mining activities. In recent years it has been recognized that some sources of *natural* radiation can lead to a significant radiation exposures to small sections of the public or to particular occupational groups. This paper aims to provide a brief review of the main sources of *natural* radiation, in the context of the changing approach to the control of exposure to elevated levels of background radiation. Some specific research programmes carried out by the Australian Radiation Laboratory (ARL) will be described to illustrate approaches to the quantification and management of exposure to *natural* radiation.

## 2 BACKGROUND RADIATION

Background radiation can be categorised into terrestrial sources and cosmogenic sources. Their contributions to background radiation in Australia has been reviewed by Carter (1). Terrestrial sources consist of primordial radionuclides with half lives sufficiently long ( $> 10^8$  y) that they are still present in the environment. Two radionuclides,  $^{232}\text{Th}$  and  $^{238}\text{U}$ , are particularly important, since they are present at ppm levels in most soils and rocks and they are the precursors to a whole series of radioactive decay products. Natural potassium contains 0.012% of the radioactive isotope  $^{40}\text{K}$ .

Cosmic radiation is produced by the interaction between high energetic particles of solar and interstellar origin with matter in the upper atmosphere. These interactions produce both a range of radiation types and a number of short lived radionuclides, chiefly tritium,  $^7\text{Be}$  and  $^{14}\text{C}$ .

There are three principal pathways for exposure to radiation: external irradiation and internal irradiation through inhalation or ingestion. The magnitude of the annual effective doses for the main contributors to the natural background are summarised in Figure 1. For Australia, the total effective dose is 1.8 mSv / y. The cosmic ray portion of the external irradiation is estimated to be  $\sim 0.3$  mSv/y at ground level. The terrestrial component, as determined from an Australia-wide survey of indoor gamma ray levels, is estimated to be 0.6 mSv/y (2). Internal irradiation from  $^{40}\text{K}$  and U/Th series radionuclides in the body gives effective doses of approximately 0.2 mSv/y and 0.17 mSv/y, respectively (1).

### Background Radiation Dose by Source

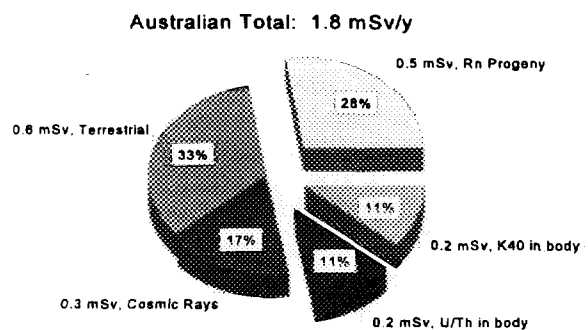


Figure 1. Major components of the annual radiation dose from natural radiation sources in Australia.

The uranium and thorium decay series each produce isotopes of the radioactive gas radon. Historically,  $^{222}\text{Rn}$  and  $^{220}\text{Rn}$  were called *radon* and *thoron*, respectively. Radon gas is very mobile and can diffuse from the site of production into the open air. Inhalation of the radioactive decay products of  $^{222}\text{Rn}$  (*radon progeny*) has been shown to lead to an increase in lung cancer risk. This is assumed to be related to the alpha irradiation of the respiratory tract. The average  $^{222}\text{Rn}$  concentration in Australian homes was measured by ARL in 1990 as  $11 \text{ Bq m}^{-3}$  (2). This compares to a global average indoor value of  $40 \text{ Bq m}^{-3}$  (3). The average radiation dose to the Australian population was estimated to 0.5 mSv per year.

### 3 REGULATORY FRAMEWORK

In its Publication 60 (4), the International Commission on Radiological Protection (ICRP) assessed the lifetime risk for exposure to radiation to be 5% per Sv. The Commission detailed concepts of practices (activities that increase exposure) and interventions (activities designed to reduce exposure) for the control of radiation exposure. Practices and interventions need to be justified (more good than harm) and to provide maximal net benefit. In Publication 65 (4) the ICRP applied this framework to the management of exposure to background radiation, and recommended intervention levels for radon in dwellings and the workplace.

The Australian National Health and Medical Research Council (NH&MRC) and the National Occupational

Health and Safety Commission (NOH&SC) have prepared jointly recommendations and standards based on the ICRP 65 recommendations, for application in the Australian context (5,6). These documents recommend an occupational dose limit of 20 mSv/y and a member of the public limit of 1 mSv/y. For exposure to environmental radon, two intervention or *action levels* are recommended. An *action level* of  $200 \text{ Bq m}^{-3}$  was recommended for radon in dwellings. Houses in excess of this level require remedial action to reduce the radon levels to below the *action level*.

Of greater significance, is the recommendation for an *action level* for  $^{222}\text{Rn}$  in the workplace of  $1000 \text{ Bq m}^{-3}$ . For workplaces with radon levels in excess of this *action level*, the preferred option is to modify the workplace conditions in order to reduce the radon levels to below  $1000 \text{ Bq m}^{-3}$ . If this reduction is not possible, it may be necessary to implement radiation monitoring programmes to ensure compliance with regulatory radiation limits. In practice, this would mean that some employees working in locations with conditions exceeding the *action level* would be treated as radiation workers and individual radiation records would need to be maintained to ensure that no employee received more than 20 mSv per year. The regulation of occupational exposure to radiation is the responsibility of the appropriate State authority. There are State or Territory regulations covering workplace exposure to radiation during the mining and milling of radioactive ores. There are presently no regulations covering workplace exposure to natural radiation.

TABLE 1: SUMMARY OF RADON IN HOMES SURVEY RESULTS BY STATE

State	Monitors Sent	Monitors Returned	Mean Rn (Bq m <sup>-3</sup> )	Rn SD (Bq m <sup>-3</sup> )	Mean γ (mSv)	Mean γ (mSv)	SD γ (mSv)
ACT	279	244	15.5	9.8	0.78	1.08	0.25
NSW	1010	905	9.0	12.1	0.45	0.90	0.28
NT	238	189	13.9	27.7	0.70	0.80	0.27
QLD	463	408	6.3	4.4	0.62	0.74	0.26
SA	361	328	14.1	11.8	0.70	0.96	0.25
TAS	308	278	9.6	8.9	0.48	0.73	0.22
VIC	857	706	10.0	7.8	0.50	0.88	0.27
WA	34	309	12.4	9.1	0.62	1.19	0.39
Australia	3862	3367	10.5	11.8	0.52	0.90	0.31

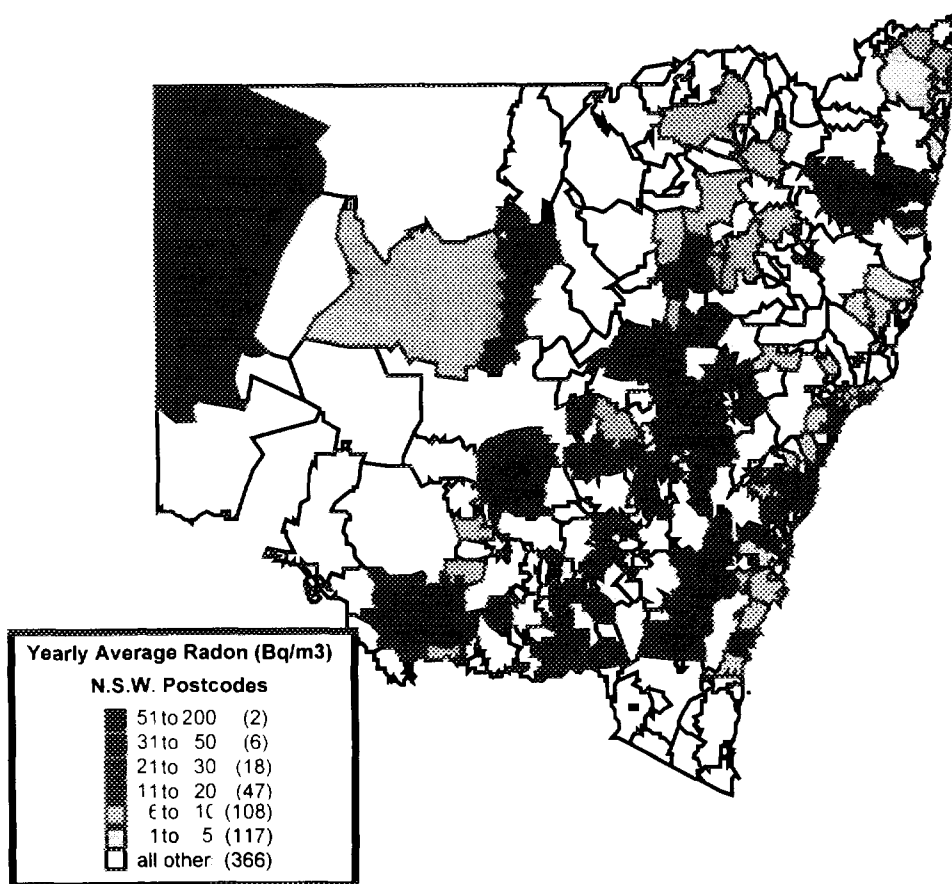


Figure 2. Distribution of average annual radon concentrations for NSW

#### 4 ARL RESEARCH ON EXPOSURE TO BACKGROUND RADIATION

Since the early 1980's ARL has carried out a number of research programmes dealing with exposure to natural background radiation. These programmes were directed to establishing average values (radon-in-homes survey) or to investigate occupational exposure to elevated levels of background radiation (air crew survey and radon in caves survey). These studies provide a basis for interpreting the new recommendations.

##### Radon in Homes

In 1990, ARL conducted a nationwide survey of Australian homes to determine the average annual radiation dose to the Australian population from exposure to <sup>222</sup>Rn and external radiation, terrestrial and cosmic ray (2). Dosimeters were sent to 3862 randomly distributed homes for a period of 12 months. Each dosimeter contained a CR-39 solid state nuclear track detector for the radon measurement and a CaSO<sub>4</sub>(Dy) thermoluminescent detector (TLD) for the measurement of external gamma ray exposure. A total of 3367 monitors were returned for analysis.

The results of the survey for each state show that the average annual radon concentration ranged from 6 Bq m<sup>-3</sup> in Queensland to 16 Bq m<sup>-3</sup> in the ACT. These differences reflect differences in local geology, climate and house construction. Figure 2 shows the distribution of radon concentration for postcode areas in New South Wales.

##### Cosmic Ray Exposure to Air Crews

In response to concerns expressed in the aviation industry, surveys of the cosmic radiation doses received by Australian commercial flight crews were carried out in 1982-1983 and in 1991 (8). Dose rate measurements were made by use of TLD personal monitors, CR-39 disks and portable monitoring equipment. The results, summarised in Table 1, indicate that the average annual doses to domestic crew members were in the range 1.0 and 1.8 mSv. The results further indicate that an increase in annual doses has occurred since 1983. A method of estimating doses from flight records was developed and the results compared favourably with the measurements from both surveys. By use of this method, annual doses up to 3.8 mSv were estimated for international crew members. This represented a significant increase since 1983.

**TABLE 2: ANNUAL RADIATION DOSES TO AIRCREWS FOR DOMESTIC ROUTES**

Group	Date	Annual Dose (mSv)
All	1982-1983	1.0
Attendants	1991	1.5
Engineers	1991	1.1
Pilots	1991	1.8

Prior to the introduction of ICRP Publication 60, the dose limits which were generally acceptable for flight crews were those appropriate for public exposure. Flight crews were not considered to be radiation workers because they were neither employed nor trained to have any direct involvement with radiation sources. Dose estimates for some crew members who fly for many hours a year at high altitudes and high latitudes could exceed the limit for public exposure. It would have been difficult to ignore these doses on the grounds that they occurred due to exposure to natural background radiation. The NH&MRC and NOHSC recommendations potentially place flight crews into the occupational exposure group and the 20 mSv annual dose limit would apply.

**Occupational Exposure to Radon in Caves**

A collaborative study between the Australian Radiation Laboratory (ARL), the University of Sydney and the University of Auckland, was carried out with the support of a research grant from Worksafe Australia. Radon monitors were placed in representative sampling sites in 52 cave systems at 24 locations around Australia. The geographical location of these sites is shown in Figure 3.

The measurements were restricted to established show caves and a total of 286 sites were monitored. A pair of passive, integrating radon monitors based on CR-39 detectors were used to measure both 3-monthly, seasonal, as well as 12-monthly, annual radon levels at each site. The exposure period for the monitors was May 1994 to June 1995. Information was obtained from all locations on the sequence and duration of each cave tour. This allowed for the radon levels to be weighted for the time spent at each sampling site during a tour in order to determine the time-weighted radon level for each show cave tour.

The values for the radon concentration at each monitoring site ranged from ambient (< 20 Bq m<sup>-3</sup>), to over 9000 Bq m<sup>-3</sup>. There was marked seasonal

variability at most measurement sites. The highest value was measured during summer but, in the following season, the same site recorded a radon level close to 1000 Bq m<sup>-3</sup>. Similar trends were found for spatial variations between sampling sites in some cave systems, with variations of more than a factor of 10 between some sites in the same cave system. This spatial variability tended to smooth out the range of values for the time-weighted radon levels for each cave tour. Of the 67 cave tours in this study, 14 tours had time-weighted yearly average radon levels in excess of 1000 Bq m<sup>-3</sup>. Most of these caves were in New South Wales, Victoria and Tasmania. For this study, no show caves in South Australia, Queensland, Western Australia or the Northern Territory were in excess of the intervention level.

These integrated radon exposures were converted to radon progeny exposures assuming a single value of 0.4 for the radon equilibrium factor. The yearly radiation dose (annual effective dose) was calculated for 116 tour guides using the conversion convention recommended by the International Commission on Radiological Protection (ICRP). The distribution of the estimated effective doses for these tour guides is shown in Figure 4. The estimated yearly radiation dose for 82 of these guides was less than 1 mSv, between 1 and 5 mSv for 30 guides, and between 5 and 10 mSv for the remaining 4 guides. The highest estimated radiation dose was 9 mSv per year.

There are presently no State regulations covering this type of occupational radiation exposure. If the recommendations in the NH&MRC and NOH&SC document are implemented in State regulations then at least 16 cave tours will have radon levels exceeding the proposed intervention level. It is normally expected that in workplaces with radon levels above

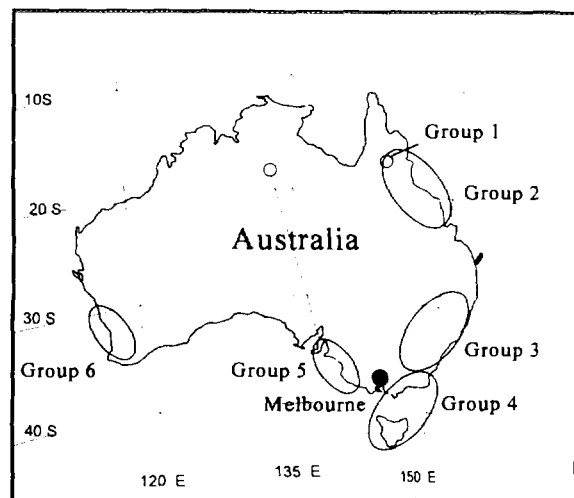


Figure 3 The distribution of the major show caves within Australia, grouped by geographical location.

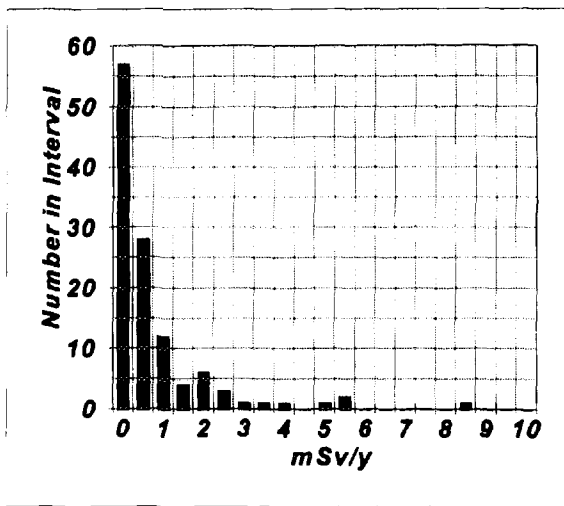


Figure 4. Frequency distribution of annual effective doses received by tour guides in Australian show caves, as determined from radon survey data.

1000 Bq m<sup>-3</sup>, active measures be taken to reduce the radon concentration, such as, improving the ventilation using forced air. The alternative is to designate the workers in such areas as occupationally exposed individuals and to maintain detailed radiation exposure records in order to demonstrate compliance with occupational dose limits. Increasing the ventilation in these show caves is not possible, and it is likely that some form of radiation monitoring, either personal or area, will be required for tour guides working in these cave systems.

## 5 DISCUSSION

The average radiation doses to the Australian population from *natural* background are relatively low, and Australia does not appear to have a problem with elevated radon level in homes, as is the case in Europe and North America. This is not to say that there are no homes in Australia requiring remedial action. On the basis of the ARL survey about 0.1% of Australian homes may have radon levels exceeding the 200 Bq m<sup>-3</sup> action level. This translates to about 2000 to 3000 homes across Australia. ARL has plans for a research programme to identify potential high radon areas.

Of more importance is the emerging issue of exposure to elevated background radiation in the workplace. Radiation exposure to air crews and to show cave tour guides are just two situations that have been studied; other occupational exposure situations are yet to be identified. The control of radiation exposure is a State responsibility. The new Worksafe Standard and the normal Duty of Care requirements imply that some

immediate response is required by both employers and the regulators. There is a need for a consistent, Australia-wide framework for regulating the occupational exposure to background radiation.

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