Risks from Radon

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The risk coefficient of $8x10^{-10}$ per Bq h m^{-3}, recommended in the ICRP draft report "Radiological Protection against Radon Exposure" (October 2011) appears to lead to the overestimation of risks from radon. It particularly overstates the risk to non-smokers. Without qualification, therefore, the ICRP draft report has the potential to cause unwarranted concern.

The risks from radon that are implied by policies for remediation of dwellings in the US and UK are not realistic.

The radioactive daughters of radon isotopes, emissions and half-lives

- Rn-222 α↓3.82d Rn-219 α↓3.96s Rn-220 α↓55.6s
- Po-218 α↓3.11m Po-215 α↓1.78ms Po-216 α↓0.14s
- Pb-214 β↓26.8m Pb-211 β↓36.1m Pb-212 β↓10.6h
- Bi-214 β↓19.8m Bi-211 α↓2.14m Bi-212 β↓60.5m
- Po-214 α↓164μs Tl-207 β↓4.77m Po-212 α↓0.30μs
- Pb-210 β↓22.3y Pb-207 (stable) Pb-208 (stable)
- Bi-210 β↓5.01d
- Po-210 α↓138d
- Pb-206 (stable)

Radon-222, from the decay chain of uranium-238, is the most important radon isotope

Radioactive "daughters" from the decay of radon (gas) are all solid. When decay occurs in the bronchus or lung, these solid nuclides (polonium, lead and bismuth) tend to deposit on the surface of the mucous membrane

Radon has always been a part of our environment, throughout evolution, and it is a fundamental principle of evolutionary biology that species adapt to their environments

However, human behaviour – particularly smoking, living in buildings and mining underground – has modified our exposure to radon, because radon accumulates in enclosed spaces

Where the risk of lung cancer due to radon is discernible, it is about 25 time higher for smokers than for non-smokers

Recommendations of the ICRP: Draft Report, October 2011

- reference level for radon in dwellings reduced from 600 Bq m^{-3} to 300 Bq m^{-3}
- no specific reference level for workplaces (previously 1000 Bq m^{-3})
- national authorities advised to set reference levels in accordance with ALARA
- a risk coefficient of $8x10^{-10}$ per Bq h m^{-3} for exposure of a population of all ages to radon-222, at all levels, without reference to smoking habits

Risks estimated using the risk coefficient recommended by the ICRP

Place	Concentration of radon, Bq/m^3	Estimated nominal risk rate, per person per year
Workplace with high level of radon (normal working hours)	**900**	**$150x10^{-5}$**
Workplace with a lower level of radon	100	$16x10^{-5}$
Dwelling with high but compliant level of radon (person at home most of the time)	**250**	**~$130x10^{-5}$**
Dwelling with the mean level of radon in Australia	11	~$6 x10^{-5}$
Dwelling with the mean level of radon in 27 countries of the European Union	55	~$30 x10^{-5}$
Dwelling with the mean level of radon in areas targeted for remediation in Britain	64	~$40 x10^{-5}$
Outdoors in the open air with exposure 100% of the time to a typical level of radon	20	$14 x10^{-5}$

Risks to Individuals in Australia

Nature of the Risk	Risk rate, per person per year
Cancer from all causes	$180x10^{-5}$
Lung cancer from all causes	**$37x10^{-5}$**
Smoking 20 cigarettes per day •all health effects •all cancers •lung cancers	 ~$500x10^{-5}$ ~$200x10^{-5}$ ~$100x10^{-5}$
Drinking alcohol (average for regular drinkers) •all health effects •alcoholism and alcoholic cirrhosis	 ~$40x10^{-5}$ ~$10x10^{-5}$
Travelling by motor vehicle	**$8x10^{-5}$**
Accidents at home	$10x10^{-5}$
Drowning	$2x10^{-5}$

Comparison of the figures in these two tables shows that the implications of the ICRP Statement on Radon are:

- The estimated risk of death from exposure to radon at work and at home could be more than ten times greater than the observed risk of travelling by car, which would be surprising
- The estimated risk of lung cancer from radon could be three to four times greater than the observed risk of lung cancer from all causes, which is actually known to be dominated by smoking

The circumstances for these implications to apply would be extreme but circumstances could readily be encountered in which the estimated and observed risks would be of the same orders of magnitude

Studies of radon health effects

- Cohort **studies of miners**, who worked in underground uranium mines before the problem of radon was properly recognised, have shown that exposure to high concentrations of radon caused increases in the incidence of lung cancer, the greatest risk being to smokers
- **Geographical studies** in the US have shown a negative correlation between recorded incidences of lung cancer and measured levels of domestic radon up to about 200 Bq m^{-3}. This has given rise to a great deal of controversy
- Adjustments for smoking indicate that there is no effect of radon at levels less than 100 Bq m^{-3}
- Many **case-control studies** of the effects of domestic radon have been carried out in homes around the world. This approach is a classic alternative to cohort studies in epidemiology

Results of case-control studies

- Effects on the incidences of lung cancer are uncertain at radon levels below 100 Bq m^{-3}
- The estimation of risks at levels below 200 Bq m^{-3} depends on extrapolation from risks observed at higher levels, as follows:
- The lifetime risk to smokers is 1.5% per 100 Bq m^{-3} from radon plus 9.7% from smoking by itself
- The lifetime risk to non-smokers from radon is 0.06% per 100 Bq m^{-3} (25 times less than for smokers)
- There is a 0.41% lifetime risk of lung cancer which has nothing to do with radon or tobacco smoke
- Hence, at 100 Bq m^{-3} the estimated risk to non-smokers from radon would be ~7 times less than the risk from other causes. At ~680 Bq m^{-3}, the risk to non-smokers from radon is about the same as the risk from other causes.

Remediation of Dwellings

- Measures include active ventilation in new and existing buildings, and membranes in the foundations of new building
- In Britain, there has been detailed consideration with costing and analysis of cost-effectiveness
- In Britain and the US, remediation of homes is recommended where radon levels are already less than 100 Bq m^{-3}
- Cost-effectiveness is based on numbers of lung cancer deaths attributed to radon. In Britain, 70% of these are **estimated** to occur in homes where the radon levels are below 50 Bq m^{-3}. It appears that this is also likely to be much the same in the US

Comment on Remediation Practices in the US and Britain

- The use of such figures appears to contravene the ICRP recommendation (paragraph 66 of ICRP 103) :
- "… *[because of the] uncertainty on health effects at low doses, the Commission judges that it is not appropriate, for the purposes of public health planning, to calculate the hypothetical number of cases of cancer … that might be associated with very small radiation doses received by large numbers of people over very long periods of time …*"
- Calculating the number of cancers due to radon levels less than 50 Bq m^{-3} is the equivalent of calculating the number from doses less than 2 mSv due to fall-out from Chernobyl
- As already noted, studies of the risks from exposure to domestic radon show that effects on the incidence of lung cancer are uncertain for radon levels less than ~100 Bq m^{-3}

The Situation in Australia

- With proper regulation, there should be no discernible occupational risk from radon in uranium mines. In modern mining practice, ventilation not only reduces radon levels but substantially reduces the equilibrium factor for its decay products
- As far as the author is aware, there is no direct evidence of any risk from inhaling radon in homes
- Concentrations of radon are less than 50 Bq m^{-3} in 99% of randomly selected dwellings, and exceed 200 Bq m^{-3} in less than 0.1%. The average level is 11 Bq m^{-3}
- There would be no significant risk to non-smokers from inhaling domestic radon at these levels
- The lifetime risk to smokers from radon at 200 Bq m^{-3} is about 3%, on top of the 10% from smoking itself

Recommendations for Dwellings

- The design objective for new homes should be the limitation of radon levels to less than 100 to 200 Bq m^{-3}, depending on cost
- Owners of existing homes where radon levels are expected to be greater than 200 Bq m^{-3} should be advised to have the level measured
- Non-smokers with existing homes in which the radon level is found to be greater than 600 Bq m^{-3} should be advised to consider remediation to reduce the level
- Smokers with existing homes in which the radon level is found to be greater than 200 Bq m^{-3} should be advised to consider remediation to reduce the level
- Smokers should also be advised that a more effective and cheaper way of reducing the risk **from radon** is by not smoking