A risk assessment of the potential impacts of radon, terrestrial gamma and cosmic rays on childhood leukaemia in France

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Abstract

Natural radioactivity (NR) is an ubiquitous phenomenon and exhibits large geographic variations. Recommended risk models for radiation-induced leukaemia prediction, which are issued from the Life Span Study (LSS) of Hiroshima and Nagasaki A-bomb survivors, suggest that NR could induce some leukaemia cases. This work estimates the percentage of childhood leukaemia that might be related to 3 sources of NR (radon, cosmic and terrestrial gamma rays) in France. National rates of childhood leukaemia over period 1990-2004 were provided by the French registry of childhood malignancies. Risk models proposed by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and the US National Research Council (BEIR VII) to predict radiation-induced leukaemia cases were used. Estimated annual red bone marrow doses for the average French child due to radon, terrestrial gamma and cosmic rays are 0.27, 0.49 and 0.28 mSv respectively. The percent of leukaemia cases that might be attributed to these combined exposures varies from 4 to 18 % according to UNSCEAR models, depending on whether the additive or multiplicative version is used. It is about 11% according to BEIR VII models, whatever the version. These preliminary point estimates results suggest that a sizeable percentage of childhood leukaemia cases might be attributable to NR. However, the adopted risk assessment approach entails important uncertainties. Some are related to the transposition of risk models from acute (LSS) to chronic (NR) exposures and from external to less accurately known internal doses. Uncertainties related to risk estimates issued from the LSS are also important and will be considered at further steps. Beside, a planned INSERM-IRSN epidemiological study of the relation between NR and childhood leukemia in France as part of the Geocap project will aim at reducing uncertainties by providing direct observations.

Keywords: children; leukaemia; natural sources; radon; risk assessment; France

1. Introduction

Natural radioactivity (NR) is an ubiquitous phenomenon and exhibits large geographic variations. Applying recommended models for the prediction of radiation-induced leukaemia [1, 2] to low dose and low dose rate exposures resulting from NR may yield a non-negligible estimated burden of cases [3]. This would especially be pronounced in children, which are known to be more radiosensitive than adults [4]

This work estimated, as a first approach, point estimates of the percentage of childhood leukemia that might be related to NR in France. The present paper focuses on the potential impacts of three major components of NR: radon, terrestrial gamma and cosmic rays.

2. Material and Methods

National rates of childhood acute leukaemia over period 1990-2004 were provided by the French registry of childhood malignancies [5, 6].

Mean doses to the red bone marrow that children would receive from radon, terrestrial gamma and cosmic rays in France were estimated using national averages [7] of:

- radon concentration in buildings, computed out of 12,261 indoor radon measurements results corrected for season and duration of measurement [8]
- dose rates from terrestrial gamma rays computed out of 14,661 measurements results [7]
- dose rates from cosmic rays estimated on the basis of altitude of each municipality [9]

The rough equivalence of adult whole body and child red bone marrow dose was assumed for cosmic and terrestrial gamma rays [10] while red bone marrow doses to children from radon were estimated using specific conversion coefficients proposed by Kendall and colleagues [11].

Models proposed in 2006 by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) [1] and by the US National Research Council Biological Effects of Ionizing Radiation (BEIR VII) committee [2] to predict radiation-induced leukaemia cases were used. These models were developed from the Hiroshima and Nagasaki A-bomb survivors Life Span Study (LSS) dataset. As UNSCEAR and BEIR VII committees employed additive and multiplicative models to describe patterns of radiation related risk in the LSS, we explored the use of both kinds of models (i.e., additive and multiplicative) for the purpose of the present risk assessment.

In this paper, only point estimates of the percent of leukaemia cases that could be attributed to NR will be reported. Such estimates are directly derived from the maximum likelihood estimates of the risk models coefficients obtained, when the models above (UNSCEAR and BEIR VII) were fitted to the LSS cohort data.

3. Results

Over the 1990-2004 study period, 6,784 childhood leukaemia cases were registered in France. Estimated annual red bone marrow doses for the average French child due to radon, terrestrial gamma and cosmic rays were 0.27, 0.49 and 0.28 mSv respectively. Point estimates of the percent of leukaemia cases that could be attributed to these combined exposures vary from 4 to 18 % according to the UNSCEAR models, depending on whether the additive or multiplicative version is used. It is about 11% according to the BEIR VII models, whatever the version (again, additive VS multiplicative) (see table 1).

Table 1. Percent of childhood leukemia cases potentially attributable to radon, cosmic and terrestrial gamma rays in France, period 1990-2004

Model		UNSCEAR		NRC BEIR VII	
Transfer mode		Multiplicative	Additive	Multiplicative	Additive
	Attained age				
	0	0	0	0	0
	1	17.7	0.3	3	2.6
	2	22.7	0.6	4.7	4.2
	3	22.1	1	7.2	5.7
	4	20.9	1.5	10.6	7.6
	5	19.6	2.4	14.2	10.4
% attributable cases by attained age	6	18.5	3.5	17.3	13.1
	7	17.5	4.5	18.4	15.1
	8	16.6	6	19.9	17.9
	9	15.8	7.5	20.9	20.3
	10	15.1	8.5	19.2	21
	11	14.5	8.5	18.4	19.3
	12	13.9	9.4	17.4	19.4
	13	13.4	9.5	16.1	18.2
	14	13	11	15	19.6
% attributable cases over ages 0-14		**17.6**	**3.6**	**11.5**	**10.5**

4. Conclusions

These preliminary results suggest that a sizeable percentage of childhood leukaemia cases might be attributable to NR in France, according to point estimates derived from recommended UNSCEAR and BEIR VII risk prediction models. This is in accordance with other assessments conducted in the UK [3]. However, the adopted risk assessment approach entails several important uncertainties:

- While estimated children red bone marrow doses from terrestrial gamma and cosmic rays are certainly not greatly in error despite approximation by adult whole-body dose, uncertainty is

much more important for estimates of red bone marrow doses resulting from inhalation of radon [11]

- Transposition of risk models from a mid-20th century Japanese to contemporary French population may not be fully adequate, and it is unclear which of additive or multiplicative, UNSCEAR or BEIR VII, models are the most relevant for such a transposition.

- Although the LSS includes individuals who received doses ranging from low (near background) to high (several Sieverts) levels, observations of cases exposed at middle to high levels are influential in LSS risk coefficients estimates. Whether such coefficients may directly be extrapolated to low-dose exposure, implicitly assuming a linear non-threshold (LNT) relation between exposure to ionizing radiation and cancer risks, is still a subject of intense scientific debate.

- LSS members were acutely exposed to ionizing radiation from the atomic bombings, whereas French children are permanently (thus, chronically) exposed to NR. Whether such a difference in dose rates may be important for the induction of childhood leukemia is still unclear.

- There are specific uncertainties in the LSS for the magnitude of the effects at the youngest ages and shortest time since exposure periods (<5 y), since adequate follow up begun in 1950, 5 years after the bombings [1, 2]

Uncertainties related to risk models issued from the LSS were not considered at this stage, due to a lack of readily available and usable data for that purpose. However, work is underway, under the Bayesian paradigm, to characterize the full posterior distribution of leukemia risk model coefficients by fitting such models to the publicly available LSS data (http://www.rerf.jp/library/dl_e/ds02.html) and then, to propagate related uncertainties throughout the above risk assessment process. The posterior predictive distributions of the percentage of childhood leukaemia cases that might be attributable to NR in France, considering LSS model uncertainties, will therefore be produced. Point predictive values of such a percentage as well as uncertainty intervals will be extracted from these predictive distributions.

In parallel, a planned INSERM-IRSN epidemiological study conducted as part of the Geocap project [12](see abstract 2357799) will aim at providing direct observation of the relation between NR and childhood leukemia in France.

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