RadoNorm

Managing risks from radon and NORM

Deliverable 4.3

Joint analysis on association of radon and childhood leukemia and brain cancer

Work Package 4

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Executive Summary

Task 4.3 of RadoNorm combined case-control data from five European countries, using harmonized exposure assessment methods developed to estimate organ doses from both indoor radon and background gamma radiation. Median radon levels ranged from 49 to 139 Bq/m³ and gamma dose rates from 50 to 93 nSv/h depending on the country.

Preliminary pooled analyses show significant dose–response relationships for leukemia with both indoor radon and background gamma radiation, and for brain tumors with gamma radiation. Risk estimates per unit dose were higher than those from the Life Span Study or medical imaging cohorts, even after accounting for age at exposure, possibly reflecting the chronic nature of environmental radiation exposure. Final analyses are underway, with publication expected in autumn 2025.

Table of content

List of Tables

1. Introduction

Residential radon is the most important source of exposure to ionizing radiation in the general population. Radon exposure has been shown to increase the risk of lung cancer in both very high exposure levels in underminers and low-exposure residential settings. No increased risk of other cancers has been shown and organ doses outside the airways are clearly lower than the dose to the lung.

Several studies have evaluated the association between residential radon and risk of childhood leukemia and brain tumors (Lubin 1998, Steinbuch 1999, Kaletsch 1999, UKCCS 2002, Raaschou 2008, Hauri 2013, Kendall 2013, Kollerud 2014). The results have been inconsistent, with meta-analyses suggesting positive correlations, but differences between study types (Moon 2021, Lu 2020, Tong 2012)

2. Results

The work in Task 4.3 included development of a joint protocol for pooled analyses of data on risk of childhood cancer from natural radiation from case-control studies carried out in five countries. The goal was to obtain more precise risk estimates by virtue of a large, pooled dataset with harmonized methods to reduce measurement error and refined dose calculation methods developed in Task 3.3

We explored the possibility to utilize external dose rate data compiled from different European countries in the SafeCast project. It turned out to have limitations and various national surveys of indoor and outdoor dose rates were used instead in estimating the dose rates from background gamma in the places of residence for the study participants. Radon concentrations were estimated using national prediction models using maps of previous measurements, as well as geological and building data.

For data analysis, possibilities for securely pooling original data and for federated analyses while maintaining standards compatible with privacy regulation in all the participating countries were explored. The existing options turned out not to fill the most stringent criteria and therefore separate site-specific analyses were performed, using standardized datasets and shared scripts for running the analyses.

Collaboration with Task 3.3 was essential for the successful completion of Task 4.3, as the dose conversion coefficients allowed estimation of organ doses from radon, which has not been possible previously. This was established by joint meetings of the teams including a workshop at BfS and it enabled us to analyze the impact of radiation exposure from both radon and background gamma using organ doses from both exposure routes.

The Danish data in the analysis comprised of case-control studies with 1134 childhood leukemia cases and 2279 controls, as well as 903 central nervous system (CNS) tumor cases with 2733 controls diagnosed in 1968-1994. Radiation exposure in Denmark was relatively low with a median radon concentration of 49 Bq/m^3 and dose rate for background gamma 65.5 nSv/h.

Case-control studies from Finland (FRECCLE and RiFaTuB studies) included 1359 childhood leukemia cases diagnosed in 1990-2019 with 4077 controls and 1138 pediatric CNS tumor cases diagnosed in 1990-2016 with 3413 controls. Finland had the highest median radon at 139 Bq/m3, with a median background gamma dose rate 71.6 nSv/h.

French data were derived from two studies, Escale and Estelle. A total of 1450 pediatric leukemia cases and 496 CNS tumors diagnosed in 2003-2004 and 2010-2011 were included together 2966 controls. In France, the median radon concentration was 70 Bq/m^3, and the median background gamma dose rate higher than in the other countries at 93 nSv/h.

A Norwegian case-control study was conducted within RadoNorm with 923 childhood leukemia cases and 503 pediatric CNS tumors diagnosed in 1990-2020 with 3124 controls. The median radon for different subgroups ranged 67-70 Bq/m^3, and background gamma median 88 nSv/h.

A Swiss case-control study covered 1063 childhood leukemia cases, 780 pediatric CNS tumors diagnosed in 1990-2016, and a large group of 17,8400 controls. The median radon concentration in the Swiss study was 77 Bq/m^3, and dose rate from background gamma 50 nSv/h.

The mean cumulative doses to the red bone marrow and brain were around 4–6 mSv in all countries (highest in Norway) with a substantially higher contribution from gamma than radon.

Harmonized analysis with shared scripts has been carried out separately by each participant to obtain pooled risk estimates for childhood leukemia and brain tumors in relation to exposure to indoor radon and natural background gamma. Unconditional logistic regression with stratification by matching factors was employed. Confounders available in each study will be included. The pooled analysis is still on-going, but the preliminary results show reasonably consistent findings across the studies.

The preliminary pooled analysis of leukemia that did not yet include all studies showed a significant dose-response for indoor radon, background gamma radiation and total combined with little heterogeneity in data from four countries. For brain tumors, again with data from four countries, a significant dose-response was found for the brain dose from background gamma and total combined dose, while the estimate for dose from radon was non-significant, though the risk estimate per was higher than for gamma. Heterogeneity was also more marked in the brain tumor analysis compared with that of leukemia.

Country	Leukemia cases	CNS tumor cases	Radon (Bq/m3)	Gamma (nSv/h)
Denmark	1134	903	49	66
Finland	1359	1138	139	72
France	1450	496	70	93
Norway	923	503	68	88
Switzerland	1063	780	77	50

Table 1. – Characteristics of material used for WP4.3 by country.

3. Conclusions

This RadoNorm WP was able to generate substantially larger material than in previous case-control studies using harmonized exposures and benefiting from the dosimetry methods generated in in WP3 that allowed accurate estimation of doses from both background gamma and radon to red bone marrow and brain. This allowed the project to produce robust risk estimates for the most common childhood cancers from major sources of natural radiation.

The risk estimates per unit dose are substantially higher than those reported from the Life Span Study of atomic bomb survivors or patients with exposure from medical imaging. This difference remains also after considering age at exposure. A key difference is the chronic nature of exposure to natural radiation compared with medical imaging or atomic bombs in Hiroshima and Nagasaki. However, protracted exposures have generally been linked with lower risk per unit dose.

The final analysis is on-going and a manuscript presenting the results is in preparation. Submission is anticipated during the autumn of 2025.

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