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Quantification of ^{210}Pb in human toenails as an indicator of long-term radon exposure

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As of 2025, radioactive radon (222Rn) gas is estimated to be responsible for >4,000 new lung cancer diagnoses in Canada, and is the leading cause of lung cancer among people who do not smoke tobacco. As a colourless, odourless radioactive gas that emanates from soil and rock, radon can be retained at high levels in built environments such as homes and workplaces. Repetitive exposure to high radon increases lung cancer risk and is directly proportional to cumulative lifetime alpha particle radiation dose. However, there is currently no reliable method to retrospectively quantify long-term radon exposure at the level of a single person.

In this pilot study, we evaluated the feasibility of using lead-210 (^{210}Pb), a long-lived radioactive decay product of radon, to indicate cumulative, long-term radon exposure. Because ^{210}Pb accumulates over time due to the slow rate of lead metabolism by the body, we hypothesized that its concentration in keratinized tissues could reflect lifetime radon exposure. Two consecutive toenail clippings were collected from 67 individuals with well-characterized residential radon histories and environmental time-activity patterns, as determined by the Evict Radon National Study. Radiation doses (in mSv/year) were calculated from long-term residential radon measurements and detailed individual activity patterns. Isotope dilution mass spectrometry using a Neptune multi-collector ICP-MS was employed to quantify trace levels of ^{210}Pb and total lead (Pb), allowing normalization of ^{210}Pb to total Pb content.

Pilot project findings demonstrate a positive correlation between the normalized ^{210}Pb concentrations in toenails and estimated multi-decade alpha radiation dose from residential radon exposure. Participants residing in high-radon environments exhibited a mean ^{210}Pb-to-total Pb ratio of 0.298 fg/ng, compared to 0.075 fg/ng among those in low-radon environments. These results support the potential utility of toenail ^{210}Pb as a biomarker for cumulative radon exposure. Building on this proof-of-concept study, we are expanding the investigation to a large-scale validation trial cohort of Canadian participants to further evaluate the predictive value of this approach for radon exposure assessment and associated lung cancer risk.