Radon

This article is a 'work in progress' incorporating new information whenever time permits.

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Radon

Radon is considered the second cause of lung cancer and the first in those who have never smoked (Torres-Durán 2013, Choi & Mazzone 2014, Laurier & Gay 2015). Hinojosa de la Garza (2014) reported that it was evident that lung cancer mortality was directly associated with locations with high levels of radon. Their study took into account a population which had been stable for more than 25 years, which they believe suggested spatial clustering of lung cancer deaths due to indoor radon concentrations. Geologic unit, well water, community, weather and unconventional natural gas development were associated with indoor radon concentrations (Casey 2015). Stopping smoking at age 50 years decreases the lifetime risk due to radon by around a half relative to continuing smoking, but the risk for ex-smokers remains about a factor of 5-7 higher than that for never-smokers. Radon mitigation used to reduce radon concentrations in homes can also have a substantial impact on lung cancer risk, even for persons in their 50's. Smokers in high-radon homes should both stop smoking and remediate their homes (Hunter 2015). In a study of lung cancer in never-smokers, by Torres-Durán (2015), the median residential radon concentration was 195 Bq m^{-3}, higher than the action levels recommended by the World Health Organisation.

Alpha particle emissions from inhaled radon decay products, and not radon itself, cause lung cancer. Alpha particles, which can only penetrate a short distance into bronchial epithelium, induce more biological damage than beta or gamma radiation, and can induce DNA base mutations and chromosomal strand breaks (Melloni 2014).

Radon and its decay products are the cause of 50% of the total radiation dose from natural sources. Thoron gas is one of the most common isotopes of radon. Indoor radon and thoron concentrations are not correlated, though thoron levels are comparatively low, between 0.5 and 6% of the radiation dose.

Public Health England recommends that radon levels should be reduced in homes where the average is more than 200 Bq m^{-3}. This recommendation has been endorsed by the Government. The Target Level of 100 Bq m^{-3} is the ideal outcome for remediation works in existing buildings and protective measures in new buildings. If the result of a radon assessment is between the Target and Action Levels, action to reduce the level should be seriously considered, especially if there is a smoker or ex-smoker in the home. Axelsson (2015) suggested that 35-40% of the radon attributed lung cancer cases can be prevented if radon levels higher than 100 Bq m^{-3} are lowered to 100 Bq m^{-3}.

In Canada, the estimated average thoron concentration is 9 becquerels per metre cubed (Bq m^{-3}), and the average radon concentration is 96 Bq m^{-3}, more than double the worldwide indoor radon concentration (Chen 2014). A study in Canada (Rauch & Henderson 2013) concluded "The radon potential map of Canada may communicate potential radon risk, but it was not designed for epidemiologic exposure assessment. Overall, the potential map classified 34 LHAs as higher than observed, and 10 LHAs as lower than observed. The potential map should only be used to inform exposure assessment in conjunction with observed radon concentrations." The results of a study by Branion-Calles (2015) contribute evidence supporting the use of a reference level lower than the current guideline of 200 Bq m^{-3} for the province of British Columbia.

In Kosovo, in two villages affected by depleted uranium, radon levels ranged from 82 to 432 Bq m^{-3}; the value of 400 Bq m^{-3} was exceeded in 2 of the 25 homes measured (Nafezi 2014). At least 15% of homes in Finland (Valmari 2014) were found to exceed their reference levels of 400 Bq m^{-3}.

In the USA, the results of the 1992 EPA National Radon Survey estimated that 1 in 15 homes (about 5.8 million) had an elevated radon level (Keith 2012).

The radon levels obtained in most assessed offices in Obafemi Awolowo University in Nigeria were found to be within the permissible reference levels. It was recommended that mitigation measures should be put in place in the few offices above permissible levels (Afolabi 2015).

In places of high radon concentration 222Rn daughters adhere to clothes, skin and hair, adding some radiative concentration to that due to radon and its progeny (Martín Sánchez 2013).

A survey by Nursan (2014) concluded that there was a necessity to inform the public about significant environmental risks such as radon gas. Well-educated middle-aged parent of high school students seemed to be inadequately informed. Signorelli & Limina (2002) said that due to the populations' low risk perception (caused by unawareness of the problem) radon is undoubtedly the environmental pollutant which has the most impact on public health. In Italy 4,000 cases of lung cancer are attributable to radon (about 11% of total lung cancer) have been estimated per year.

Serbian radon levels depended on the geological background, with elevated levels in areas with vulcanite and granitoid rocks (Bossew 2013). A study by Zunić (2014) confirmed the strong influence of geological factors in the **Balkan** region on the variability of indoor radon, and large differences of radon concentrations could be found in different rooms of the same house and significant difference in radon concentrations in one season. Extensive measurements of radon in the town of Xanthi in northern **Greece** show that the part of the town overlying granite deposits and the outcrop of a uranium ore has exceptionally high indoor radon levels, with monthly means up to 1500 Bq m^{-3}. 40% of the properties in this part of the town exhibit radon levels above 200 Bq m^{-3} while 11% of the houses had radon levels above 400 Bq m^{-3} (Kourtidis 2015).

The European Council directive of 5 December 2013 on basic safety standards for protection against the dangers arising from exposure to ionising radiation (2013/59/Euratom) tightened up the radon levels allowed in the workplace and exposures in homes are regulated for the first time (Bochicchio 2014). Barros (2015) concluded that *"Because of the percentage of workplaces with elevated radon concentrations, additional surveys of workplace radon concentrations are needed, especially in areas of high radon potential, to assess the contribution of workplace radon exposure to an individual's overall radon exposure."*

Building materials

One of the most important indoor pollutants is radon from soils and building materials (Schram-Bijkerk 2013, Kumar 2013, Borgoni 2014). In a study in Romania, the main source of radon was the building sub-soil and the soil near the house (Cosma 2015). Indoor radon levels are lower in flats than houses, and in buildings with concrete foundations (Kropat 2013).

Radon levels were investigated in homes in **Turkey** where construction materials had included 22 different sorts of granite. The levels were between 23 and 461 Bq m^{-3} (Aykamis 2013). Carbonate rock tends to produce higher levels of indoor radon, whereas sedimentary rocks can produce only low levels (Kropat 2013). The Iranian study by Pirsaheb concluded that granite stone and adobe coverings could not be recommended for construction purposes.

The effect of changes in building construction techniques

It can accumulate in residential buildings. Breathing radon and radon progeny for extended periods can be hazardous to health and can lead to lung cancer. Air change rate, indoor temperature and moisture have significant effects on indoor radon concentration. Minimum radon levels were obtained at temperatures between 20 and 22°C and a relative humidity of 50-60% (Akbari 2013). Kropat (2013) found higher levels of radon at higher temperatures.

Modern energy-efficient architectural solutions and building construction technologies in combination with effective insulation reduce the air permeability of the building. As a result, the air exchange rate is significantly reduced and conditions for increased radon accumulation in indoor air are created. A study by Mohery (2013), short-lived radon decay products were measured in poorly ventilated living rooms. The maximum radon deposition fractions were found in the upper bronchial airway. In Russia, Yarmoshenko (2014), found a remarkable increase in the indoor radon concentration level in energy-efficient multi-storey buildings compared with older properties. Zhukovsky & Vasilyev (2014) also found radon concentration over 200 Bq m^{-3} when ventilation rates were low.

Jiránek & Kaćmařikova (2014) found that replacing existing windows by new ones decreased the annual energy need for heating 2.8 times, but also reduced the ventilation rate. As a consequence, the 1 year average indoor radon concentration values increased 3.4 times. The additional risk of lung cancer in the thermally retrofitted house increased to a value that is 125 % higher than before conversion.

Occupational exposures

Radon activity was measured in 34 workplaces in Algiers nuclear research centre between March 2007 and June 2013. The indoor radon levels ranged from 2 to 628 Bq m^{-3} (Ait Ziane 2014). With no intervention on occupational radon exposure, estimated lung cancer mortality by age 90 was 16%. Lung cancer mortality was reduced for all interventions (Edwards 2014).

Duan (2015) found a dose-response association between occupational environmental radon exposure and the risk of lung cancer. The increased risk is particularly apparent when the cumulative exposure to radon is beyond that resulting from exposure to the recommended limit concentration for a prolonged period of time.

In a study by Rossetti & Esposito (2015), as a result of 8695 measurements in underground workplaces, it was found that the mean radon concentration is higher than that from previous maps elaborated for dwellings and a significant radon concentration was also found in regions traditionally considered as low-risk areas. Elevated levels of radon in public workplaces in Brisbane, Australia were largely found in basements and ground floor levels and in rooms with concrete flooring (Alharbi & Akber 2015).

In Castañar cave, in Spain, cave guides received a total effective dose of 6.41 mSv in 4 months. Public visitors would receive about 12% of the total effective dose permitted at each visit in autumn and about 8-9% in summer (Alvarez-Gallego 2015).

In Polish caves which are open to tourists, as well as providing jobs, it was found that in 67% of the routes the average concentration of radon exceeded 300 Bq m^{-3} and in 22 underground routes it exceeded 1000 Bq m^{-3} (Olszewski 2015). This may be an organizational, legal and health problem. It is necessary to develop a program of measures to reduce radon concentrations in underground routes, especially routes located in the former mines.

Ground disturbances (earthquakes, etc.)

Tectonic movement and meteorological events are accompanied by radon release. Not only magnitude of earthquakes but also distance from the measurement site should be used for identifying radon anomalies (Içhedef 2014, Briestensky 2014, Zhou 2015).

Areas of high radon activity were located near areas of high flow accumulation showing new submarine groundwater discharge (Rapaglia 2015).

Weather changes

Long-term measurements of radon levels in the soil shows a high variability in concentration depending on the daily changes in atmospheric pressure. It was also found that typical annual radon activity concentration in the soil air was disturbed by mild winter and heavy summer precipitation (Műllerova 2014). Vasilyev & Zhukovsky (2013) confirmed the seasonal variations of radon concentrations. In a study by Moreno (2016) it was found that radon measurements presented a wide range of values. The highest soil radon levels in the vicinity of the Amer fault were found close to the fractured areas and showed very important fluctuations repeated every year, with values in summer much higher than in winter. Indoor radon measurements were taken during and after Superstorm Sandy on the US East Coast, and from the normal level of 70 Bq m^{-3} it increased up to 1500 Bq m^{-3} during the storm. The outdoor radon concentration was not significantly affected (Kotrappa 2013).

The following conclusions were drawn as a result of a study on vegetable growing circumstances by Li (2016): Firstly, the average radon levels in typical months in Shouguang county are all much higher than that in ordinary dwellings in China, diurnal and seasonal variations in radon levels are observed inside greenhouses. Secondly, temperature and relative humidity may play a role indirectly through affecting soil moisture and other factors.

Water supplies

Another **Turkish** study showed that some spa waters contained radon at higher levels than our action levels. If people bathe indoors in such spa waters the levels of radon they inhale could add significantly to their exposure (Oner 2013). Radon-contaminated drinking water from private wells in the USA was felt to present a significant public health concern (Cappello 2013). Significantly high levels of radon gas were found in Iranian water (Pirsaheb 2013). Yang reported (2014) that wells within 5 km of granitic intrusions are at risk of containing high levels of radon.

At least 10% of people living in the Czech Republic are supplied with water from private sources (wells and boreholes). The official guideline limit does not apply to private sources of drinking water. Radon in water influences human health by ingestion and also by inhalation when radon is released from water during showering and cooking (Otahal 2014, Moldovan 2014).

Health Effects

Radon changed a total of 208 genes in lung cells, 32% upregulated and 68% downregulated and depended on the dose. Further analysis showed them to be involved in biological processes related to cell cycle control/mitosis, chromosome instability and cell differentiation (Chauhan & Howland 2014).

Chen (2013) found that among those people living in homes with very high radon concentrations, it is typically parents of young children that demonstrate a great deal of concern. They want to know the risk of developing lung cancer when a child has lived in a home with high radon for a few years. The results of the study demonstrated clearly that the higher the radon concentration, the sooner remedial measures should be undertaken.

Exposure to radon is the second leading cause of lung cancer, especially for women in developed countries (Serke 2013), and the risk is significantly higher for smokers than for nonsmokers. Bräuner (2012) found a positive association between radon and lung cancer risk. Lung cancer in those who have never smoked accounts for between 9 and 28% of all lung cancer cases (Hubaux 2012, Truta 2014). Exposure to radon can lead to genetic and epigenetic alterations in tumour genomes, impacting genes and pathways involved in lung cancer development.

A study by Bräuner (2013) found significant associations and exposure-response patterns between long-term residential radon exposure in a general population and risk of primary brain tumours. Another study (Bräuner 2015) found that long-term residential radon exposure may contribute to development of basal cell carcinoma of the skin, though radon levels were calculated rather than measured and more follow-up is recommended.

In Spain, 14% of Galician municipalities had radon concentrations above the United States Environmental Protection Agency (USEPA) action level. There was a significant correlation between residential radon and oesophageal cancer mortality for males (Ruano-Ravina 2014).

Bräuner (2010) suggested that air pollution from traffic might enhance the effect of radon on the risk of childhood leukaemia, and Pedersen (2014) suggested that distance to powerlines together with domestic radon levels may impact the risk of childhood leukaemia. Schwartz & Klug (2015) found that incidence rates for chronic lymphocytic leukaemia (CLL) were significantly correlated with residential radon levels.

A large proportion of radon-attributable lung cancer deaths in Ontario are from exposures below the **Canadian** guideline. Peterson (2013) felt that testing and remediation may prevent a portion of radon-related lung cancer deaths.

In the first study of residential radon and birth defects, Langlois (2016) found significant associations with cleft lip with or without cleft palate and cystic hygroma / lymphangioma. They also found non-significant associations with three skeletal defects, Down syndrome, other specified anomalies of the brain, and other specified anomalies of the bladder and urethra.

Remediation

Lantz (2013) strongly supports public communication efforts that promote residential radon testing and remediation. A questionnaire study of 23 European countries found that approximately 26,000 homes have been remediated, but millions have not yet been done. The number is increasing due to the rare use of radon prevention.

A study by the Health Protection Agency (Howarth 2013) determined the long term effectiveness of commonly used radon remedial methods over 15 years. The overall failure rate was 63%, with roughly equal rates for passive and active type systems. It was also found that all types of remedial measure can last more than 10 years, but also found examples for all measures that failed in less than 5 years. The HPA advises that homes should be retested every 5-10 years.

Measuring radon levels in your home, school and workplace

Measuring radon levels has never been easier than with the Canary radon meter, which can give you the information you need to find out if you and your family are at risk from this invisible gas.

Kitto (2014) measured radon levels in 186 schools in New York State. Some rooms in the schools had more than 740 Bq m^{-3}. Short-term radon measurements in the schools showed little correlation to basement and first-floor radon results from single-family homes in the towns.

Radon was measured in three nurseries and a primary school in a rural area with nongranite soil in north **Portugal.** Radon concentrations surpassed by severalfold the recommended guidelines and thresholds, and excessive levels of health concern were sporadically found (Sousa 2015). Radon concentrations were measured in 45 classrooms from 13 public primary schools located in Porto, **Portugal**. In all schools, radon concentrations ranged from 56 to 889 Bq m^{-3}. The results showed that the limit of 100 Bq m^{-3} established by WHO IAQ guidelines was exceeded in 92 % of the measurements, as well as 8 % of the measurements exceeded the limit of 400 Bq m^{-3} established by the national legislation (Madureira 2015).

Hungary, **Poland** and **Slovakia** have higher radon levels than the world average. Radon concentrations are more than 200 Bq m^{-3} in about 87% of cases. Homes with radon concentration of about 800 Bq m^{-3} were found in Poland and Slovakia (Műllerova 2014). In **Turkey**, indoor radon concentrations were found between 1 and 1400 Bq m^{-3} (Celebi 2015).

In **Albania**, where an initial 10% of homes were measured, the indoor radon concentrations ranged from 14 to 1238 Bq m^{-3} (Tushe 2015).

All it takes is 24 hours per room to put your mind at rest, or to establish that remediation measures are needed, or old measures taken are no longer effective. EMFields **hires** or **sells** the radon Canary meter in the UK, and sells the meter all over the world. http://www.emfields-solutions.com/detectors/canary.asp You can buy online, or phone during working hours – 01353 778814.

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