ARTICLE

# Lower Cancer Risk in Medium High Radon

Esther TÓTH,[1] István LÁZÁR,[1] David SELMECZI,[1] George MARX[2]

[1]RAD Lauder Laboratory, Budapest, [2]Atomic Physics Department, Eötvös University, Budapest, Hungary

**Radon exposure was shown to be carcinogenic and suggested as a possible causative factor for lung cancer in man. A hypothesis is introduced that medium high radon (between 110 and 165 Bq/m$^3$) causes lower cancer risk among women younger than 61 years, independent of the type of cancer. The presented results verify this statement with a probability of not less than 98%.** (Pathology Oncology Research Vol 4, No 2, 125–129, 1998)

*Key words:* cancer risk, radon

### *Introduction*

In 1992 elevated radon level were found in some houses in a North East Hungarian village Mátraderecske. The RAD Lauder Laboratory made an extended survey of the indoor radon activity concentrations in the last five years. During this time the cancer incidents were collected from the last 20 years.

### *Materials and Methods*

Radon activity concentrations were measured at pillow level in the bedrooms between 1992 and 1996.[1,2] The measurements were made with CR39 track-detectors in three seasons: Autumn, Winter and Spring of each year. In Summer radon levels were very low, their values were estimated from the measured data. Yearly averages were calculated from the measured data by day weighted method. The distribution of indoor radon activity concentrations showed wide range from 20 Bq/m$^3$ (20 alpha-decays in a second in a cubic meter of air, 0.5 pCi/l) up to 1660 Bq/m$^3$ (45 pCi/l) as a yearly average. In Mátraderecske the average radon level of the five years was 195 Bq/m$^3$ (5.3 pCi/l), the median being 143 Bq/m$^3$ (3.9 pCi/l). *Figure 1* shows an example of the distribution of radon in the bedrooms in the year 1996 September to 1997 September. The distribution is a lognormal one.

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*Correspondence:* Esther TÓTH, RAD Lauder Laboratory, Budakeszi út 48, H–1121 Budapest, Hungary. Tel: (36) (1) 275-2241, fax: (36) (1) 275-2610. e-mail: et@rad.lauder.hu

The population of Mátraderecske was 2489 in 1992. Hungarians belong to the main European, Caucasian race. The inhabitants of Mátraderecske belong to the Hungarian ethnic group palotz. Because the mobility of the population of Mátraderecske is very low, they were chosen for an international assessment in genetics in 1990.[3] There is no heavy industry in or around the village, and there is no high air pollution due to transit traffic. It is usual for people to live in the same house after marriage till the end of their lives. A few people moved to the village in the last 15 years, but they were not included in our assessment. 1972 inhabitants (1040 females, 932 males) were tested from the point of view of radon activity concentrations in their bedrooms.

Cancers taken into account were those listed in the International Number of Diseases from 140 to 204. All the cancers were medically documented including histological evidence. The cancers were collected from 1971 to 1993 (23-year time interval). The following data are known for each case: sex, birth, age of morbidity, type of cancer (IND code), smoking habit and the bedroom radon level in the last five years. The total number of the cancers between 1971 and 1993 was 151 (79 females and 72 males). As a first approximation we used the cancer register of the local county division of the National Public Health Service. Then, with the help of local doctors and nurses a more detailed and more precise cancer register was composed. (Nurses helped to identify the houses and the rooms where the persons had lived 15–20 years before their cancer was diagnosed.)

Cancer frequencies were calculated knowing the average radon level of each person. This is being the main advantage of the method used in this study. The disadvantage is that the size of the population studied was not large enough to make a more detailed age adjustment.

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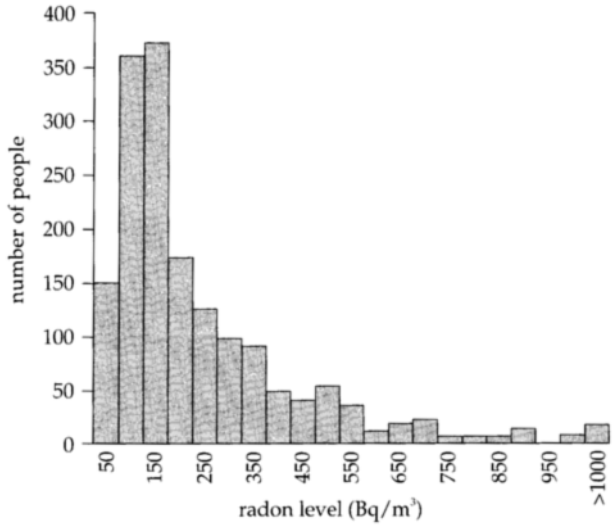


***Figure 1.*** *Distribution of people on the yearly average of the radon activity concentration of their bedrooms in the year 1996/97*

### *Results*

After the first year of the radon measurement (Summer 1993) the male and female population was divided into four equal groups according to the radon level of their bedrooms. (Each group had about the same number of people, in the case of men about 155 persons, in the case of women 165 persons.) In order to do this, the median value of the radon concentrations was taken (171 Bq/m³) and then again the medians of the two halves of the population groups. *Figure 2* shows the number of cancer cases versus radon level (data known in 1993) in Mátraderecske for the four groups of males and females. A minimum between 124 Bq/m³ and 170 Bq/m³ appeared for the woman population. Traditionally women do not smoke (only 3 from the 79 cancer patients) and they stay in the village. For males there is a slightly increasing trend, no minimum. Males take jobs outside the village, mainly in nearby mines (61 % of the cancer patients were smokers.)

Since in 1993 the registered number of cancer cases was uncertain and small, the number of people was estimated from the number of measured homes, and radon results were available for one year only, thus the result in *Figure 2* only calls the attention to the problem.

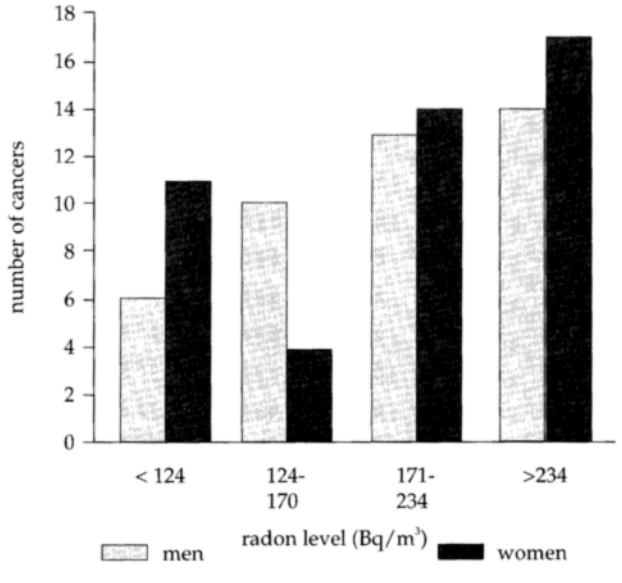


***Figure 2.*** *Number of cancer cases in groups of equal number of men/women versus radon activity concentration*

***Table 1a.*** **Men and radon (age adjusted)**

| *Average of radon yearly averages (1992–96) (Bq/m³)* | *<107* | | *108–165* | | *166–270* | | *270<* | |
|---|---|---|---|---|---|---|---|---|
| *Age (years)* | *All men* | *rB* | *All men* | *rB* | *All men* | *rB* | *All men* | *rB* |
| 30–60 | 146 | 3 | 104 | 8 | 95 | 14 | 91 | 4 |
| 61– | 30 | 9 | 37 | 10 | 37 | 11 | 38 | 13 |
| sum | 176 | 12 | 141 | 18 | 132 | 25 | 129 | 17 |
| frequency | | | | | | | | |
| 30–60 | 2.1% | | 7.7% | | 14.7% | | 4.4% | |
| 61– | 30% | | 27% | | 30% | | 34% | |
| all | 7% | | 13% | | 19% | | 13% | |

***Table 1b.*** **Women and radon (age adjusted)**

| *Average of radon yearly averages (1992–96) (Bq/m³)* | *<107* | | *108–165* | | *166–270* | | *270<* | |
|---|---|---|---|---|---|---|---|---|
| *Age* | *All women* | *rB* | *All women* | *rB* | *All women* | *rB* | *All women* | *rB* |
| 30–60 | 131 | 9 | 115 | 1 | 107 | 8 | 103 | 12 |
| 61– | 36 | 12 | 47 | 11 | 55 | 11 | 61 | 15 |
| sum | 167 | 21 | 162 | 12 | 162 | 19 | 164 | 27 |
| frequency | | | | | | | | |
| 30–40 | 6.9% | | 0.9% | | 7.5% | | 11.7% | |
| 61– | 33% | | 23% | | 20% | | 25% | |
| all | 13% | | 7% | | 12% | | 16% | |

population age is in 1988 rB: cancer cases 1971–1993

After getting the results of the five-year radon measurements and finishing the collection of more detailed cancer data, the inhabitants and cancer patients were grouped based on radon levels in their bedrooms and on their age (*Table 1a* for men and *Table 1b* for women). The radon levels are the averages of the measured yearly averages in the last five years. Age means the morbidity age of the cancer patients, and in the case of healthy people it means their age in 1988. The same results yield more information if the cancer types are also introduced (*Table 2a* for men and *Table 2b* for women).

It deserves attention that for the 456 women of the age group 30–60 years the cancer frequencies are 6.9 % below 107 Bq/m$^3$, 0.9 % between 108–165 Bq/m$^3$, 7.5 % between 166–270 Bq/m$^3$, 11.6 % above 271 Bq/m$^3$. The statement that there is a minimum of cancer incidence between 108 and 165 Bq/m$^3$ for women of age 30–60 has a probability of not less than 98%.

For a more appropriate statistical analysis the cancers in this small village were collected not only for one year, but for a longer, 23 year period. This means that in order to calculate the frequency of the cancers in different age groups one should decide the reference groups. In *Table 1* the reference groups consisted of the people who in 1988 were of the same age as the cancer morbidity age. (So the ages of the healthy people are their age in 1988, while the ages of cancer patients are the morbidity ages in the year when the cancers were discovered.) By this method some of the cancer patients do not meet with their real age group. *Tables 3a* and *3b* show the number of cases and the cancer frequency with the following conditions:

four groups according to the radon level, and in each group
three subgroups give the number of
healthy people and the cancer patients: *all*
patients of morbidity age is *below* 61 years: *cyou*
patients of morbidity age is *above* 61 years: *cold*
two groups are by their birth: *1900–1930* or *1931–1950*

One can see a minimum again also by this method: the statement that the cancer frequency in the radon interval 108–165 Bq/m$^3$ is smaller than below or above this radon level can be made with a probability of not less than 98% in the case of cancers of age group 40–60 years among

*Table 2a.* **Men and radon (age adjusted and cancer type)**

| radon (Bq/m$^3$) | | –107 | | | | 108–165 | | | | 166–270 | | | | >270 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| age (years) | | 30–40 | 41–50 | 51–60 | 61– | 30–40 | 41–50 | 51–60 | 61– | 30–40 | 41–50 | 51–60 | 61– | 30–40 | 41–50 | 51–60 | 61– |
| number of all men | | 69 | 44 | 33 | 30 | 46 | 26 | 32 | 37 | 30 | 32 | 33 | 37 | 27 | 23 | 41 | 38 |
| Cancer type | | | | | | | | | | | | | | | | | |
| IND | Malignant neoplasm of | | | | | | | | | | | | | | | | |
| 146 | oropharynx | | | | | | x | | | | | | | | | x | |
| 151 | stomach | | x | | xx | | | x | x | | xx | | xxx | | | | xxx |
| 152 | small intestine (+duodenum) | | | | | | | | | | | x | | | | | x |
| 154 | rectum | | | | | | | x | x | | | | | | | x | |
| 155 | liver | | | | | | | | x | | | | x | | | | x |
| 157 | pancreas | | | | | | | | | | | x | | | | | xx |
| 161 | larynx | | | | x | | | | | | xx | x | x | | | | x |
| 162 | trachea, bronchus and lung | | x | | xx | | | | xxxx | | x | xxx | | | | | xxx |
| 163 | pleura | | | | | | | | | | | | | | | x | |
| 170 | bone | | | | | | | | | | | | | | | x | |
| 172 | skin | | | | x | | x | | | | x | | xx | | | | xx |
| 185 | prostate | | | | x | | | x | | x | | | xx | | | | |
| 188 | bladder | | | | x | | | | x | | | | x | | | | |
| 189 | kidney | | | | | x | x | x | | | | | | | | | |
| 196 | lymph nodes (secondary) | x | | | | | | | x | | | | x | | | | |
| 199 | multiple cancer | | | | | | | | | | x | | | | | | |
| 202 | lymphoid and histiocytic tissue | | | | x | | | | | | | | | | | | |
| 203 | multiple myeloma | | | | | | | | x | | | | | | | | |
| | sum: | 1 | 2 | 0 | 9 | 1 | 3 | 4 | 10 | 1 | 7 | 6 | 11 | 0 | 0 | 4 | 13 |
| | frequency | 1% | 5% | 0% | 30% | 2% | 12% | 13% | 27% | 3% | 22% | 18% | 30% | 0% | 0% | 10% | 34% |
| | younger than 61 | | 2.1% | | | | 7.7% | | | | 14.7% | | | | 4.4% | | |

*Table 2b.* **Women and radon (age adjusted and cancer type)**

| | radon (Bq/m³) | –107 | | | | 108–165 | | | | 166–270 | | | | >270 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | age (years) | 30–40 | 41–50 | 51–60 | 61– | 30–40 | 41–50 | 51–60 | 61– | 30–40 | 41–50 | 51–60 | 61– | 30–40 | 41–50 | 51–60 | 61– |
| | number of all women | 58 | 42 | 31 | 36 | 43 | 35 | 37 | 47 | 30 | 36 | 41 | 55 | 27 | 41 | 35 | 61 |
| Cancer type | | | | | | | | | | | | | | | | | |
| IND | Malignant neoplasm of | | | | | | | | | | | | | | | | |
| 142 | major salivary glands | | | | | | | | | x | | | | | | | |
| 146 | oropharynx | | x | | | | | | | | | | | | | | |
| 151 | stomach | | | | xxx | | | | | | | | x | | | | xxx |
| 152 | small intestine (+ duodenum) | x | | x | x | | | | x | | | | xxx | | | | x |
| 154 | rectum | | | | x | | | | x | | | | x | | | | xx |
| 155 | liver | | | | | | | | | | | | x | | | x | |
| 156 | gallbladder | | | | | | | | | | | | x | | | | |
| 157 | pancreas | | | | | | | | | | | | | | | | x |
| 158 | retro- and peritoneum | | | | | | | | | | | | | | | x | |
| 162 | trachea, bronchus and lung | | x | | x | | | | | | | | | | | x | |
| 171 | connective and other soft tissue | | x | | | | | | | | | | | | | | x |
| 172 | skin | x | | x | xxxxx | | | | xxxx | | | x | x | | | | xxxx |
| 174 | female breast | x | | | | | | | | | xxxx | x | x | x | | xx | xx |
| 180 | cervix uteri | | x | | | | | | xx | | | | | | | xx | x |
| 182 | body of uterus | | | | x | | | | x | | | | | | | xx | |
| 183 | ovary and uterine adnexa | | | | | | | | x | | x | | x | | | x | |
| 188 | bladder | | | | | | | | | | | | | | x | | |
| 193 | thyroid gland | | | | | | | | | | | | x | | | | |
| 196 | lymph nodes (secondary) | | | | | | | | x | | | | | | | | |
| 199 | multiple cancer | | | | | | | x | | | | | | | | | |
| | sum: | 3 | 4 | 2 | 12 | 0 | 0 | 1 | 11 | 1 | 5 | 2 | 11 | 1 | 1 | 10 | 15 |
| | frequency | 5% | 10% | 6% | 33% | 0% | 0% | 3% | 23% | 3% | 14% | 5% | 20% | 4% | 2% | 29% | 25% |
| | younger than 61 | | 6.9% | | | | 0.9% | | | | 7.5% | | | | 11.7% | | |

women born between 1931 and 1950. In the case of men and in the case of women older than 60 years one cannot find a minimum in cancer frequency in relation to the radon level.

### *Discussion*

From our radon and cancer data a minimum can be seen in cancer frequency at the radon level between 110 and 170 Bq/m³ among women of the age 30-60 with a probability not less than 98%.

Using a different method for studying lung cancer, Cohen[4] had seen the downwards slope from 10 to about 200 Bq/m³, and Pershagen[5,6] had seen the slope climbing up from about 400 Bq/m³. This means that their results do not exclude a minimum as it was found by us. Bogen[7] demonstrates the biological plausability of Cohen's interprepation of US lung-cancer mortality patterns on the basis of a specific, well-defined mechanism of action: nonlinear dose-response resulting from competition between: (i) extinction (via alpha-induced cell killing) within preexisting premalignant foci, and (ii) the induction of new premalignant foci. Almost all the studies concentrate on radon induced lung cancers. The correlation of other cancers with radon are mentioned in Kondo's book.[8] In Japan, in a cancer mortality survey of the Misasa spa area with high radon background, Mifune[9] found a lower cancer risk in relation to all kinds of cancers as compared to the control area.

Our analysis addressed a variety of cancer types. Perhaps due to a low level of aerosols, lung cancer in Mátraderecske is very rare. In the case of women there were only three lung cancers out of the total number of 79 patients.

The population of Mátraderecske is ethnically homogenous, they live in the same location with a low level of industrial (chemical) pollution. Studying the population of a wider region would bring several other carcinogenic factors (smoking, industry, air pollution) into the survey. Therefore our plan is to investigate a few other remote villages with similar homogenous populations and with a wide spectrum of indoor activity concentrations, including houses above 1000 Bq/m³.

*Table 3a.* **Men and radon (birth date and age adjusted)**

| Radon B/m$^3$ | | <107 | | | 108–165 | | | 166–270 | | | >271 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| birth | all | cyou | cold | all | cyou | cold | all | cyou | cold | all | cyou | cold |
| 1900–1930 | 37 | 1 | 9 | 49 | 4 | 10 | 48 | 7 | 10 | 49 | 1 | 13 |
| 1931–1950 | 88 | 2 | | 54 | 4 | | 63 | 6 | 1 | 61 | 3 | |
| 1900–1930 | | 3% | 24% | | 8% | 20% | | 15% | 21% | | 2% | 27% |
| 1931–1950 | | 2% | | | 7% | | | 10% | | | 5% | |

*Table 3b.* **Women and radon (birth date and age adjusted)**

| Radon Bq/m$^3$ | | <107 | | | 108–165 | | | 166–270 | | | >271 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| birth | all | cyou | cold | all | cyou | cold | all | cyou | cold | all | cyou | cold |
| 1900–1930 | 44 | 4 | 11 | 55 | 1 | 11 | 65 | 1 | 11 | 71 | 9 | 13 |
| 1931–1950 | 78 | 6 | | 75 | | | 77 | 7 | | 67 | 2 | |
| 1900–1930 | | 9% | 25% | | 2% | 20% | | 2% | 17% | | 13% | 18% |
| 1931–1950 | | 8% | | | 0% | | | 9% | | | 3% | |

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***References***

1. *Tóth E, et al:* High radon activity in north-east Hungary. Physica Scripta 50:726-730, 1994.
2. *Tóth E, et al:* Radon variation in a Hungarian village. Environmental Geology 31:123-127, 1997.
3. *Czeizel A, Beakmann H-G, Goedde HW* (eds) Genetics of the Hungarian population, Springer, Berlin p3, pp319-321, 1991.
4. *Cohen BL:* Compilation and integration of studies of radon levels in US homes by states and counties. Critical reviews in Environmental Control 22:234-364, 1992.
5. *Pershagen G, et al:* Residential radon exposure and lung cancer in Swedish women. Health Phys 63:179-186, 1992.
6. *Pershagen G, et al:* Residential radon exposure and lung cancer in Sweden. N Engl J Med 330:159-164, 1994.
7. *Bogen KT:* Do U. S. county data disprove linear no-threshold predictions of lung Cancer risk for residential radon? – A preliminary assessment of biological plausibility. Human and Ecological Risk Assessment 3:157-186, 1997.
8. *Kondo S:* Health effects of low-level radiation. Kinki University Press, Osaka pp 63-64, 1993.
9. *Mifune M, et al:* Cancer mortality survey in a spa area (Misasa, Japan) with a high radon background. Jpn J Cancer Res 83, 1-5,