RADON MEASUREMENTS IN GREECE

E. Georgiou, K. Ntalles, M. Molfetas, A. Athanassiadis and C. Proukakis.
Dept. Med. Physics, Medical School, Goudi, Athens, Greece.

INTRODUCTION

The naturally occuring radioactive gas Radon-222 is formed by the decay of Radium-226, which is present at low activities in most soils (about 20-30 Bq/Kg), with the exception of uraniferous deposits, where the concentration is much higher (UNSCEAR 1984). Radon usually enters the atmosphere by diffusion out of the soil, but its inhalation may have a transport component attributed to falling atmosphere pressure, which might occur either outdoors or indoors. Indoors concentrations are higher than outdoors. The main source of radon in houses appears to be the soil. Quantitavely, radon is the most significant source of collective dose to the earth's population (UNSCEAR 1982). At the same time it is a controllable natural source, unlike other natural sources, as e.g. potassium-40 which is under homeostatic control in the human body and its isotopic composition is constant.

For the above reasons, extensive surveys of radon concentration in spas, mines, caves and most important, in dwellings, have been carried out in many countries (Wrixon et al 1984, Swedjemark and Mjokes 1984, Letourneau et al 1984, Schmier and Wicke 1985, Green et al 1985, McAuley and McLaughlin 1985). A possible association between lung cancer and geological outcrop has been postulated (Fleischer 1986). In almost all the studies, a small percentage of dwellings were found to have a very high radon concentration.

Studies of radon concentration in greek spas (Danali et al 1986), in a cave (Papastefanou et al 1986), in constituents of the greek cement (Maraziotis 1985), in building materials in Greece (Siotis and Wrixon 1984, Papastefanou et al 1984) and in greek mines (Georgiou et al 1986) have been published. Some preliminary studies of radon concentration in greek dwellings have been published (Papastefanou er al 1984, Proukakis et al 1987).

MATERIALS AND METHODS

In order to get an idea of the problem in Greece we decided to carry out a national survey. Two different sites were selected: Athens, where domicile about 40% of the greek population and Domatia, a small village in northern Greece 600 Km from Athens, located in an area known to have soil with increased uranium concentration. Also, another series of measurements were carried out in ancient (5th century B.C.) and contemporary silver mines in Laurium, a town 50 Km south of Athens. It is from these mines that the ancient town of Athens was exploiting the silver. About 1000 ancient mining shafts and tunnels have been preserved until now. Some of them were extended last century and used until 1963.

Passive detectors measuring intergrated alpha sxposure from radon (Track etch, Terradex Co.) were used for our measurements.

In Laurium mines, 30 spots were selected, comparable in terms of depth and geological setting, divided in 3 groups (ancient, contemporary sites and modern tunnels pathed along ancient ones). Ventilation data for these spots were available. In Athens, modern apartments of the same economical and social level have been chosen. The detectors were installed in first floor apartments of building blocks most of which have been built in the seventies. We have chosen first floor apartments because the propability to find increased radon concentration was greater there than in higher levels of the same building, provided that the ventilation remains the same. So, the values that we measured ought to be the maximum for the given building under identical ventilation conditions. In Domatia, the houses are built in a traditional way, that is from local stones. In all houses, the detectors were installed in bedrooms, where people spend aproximately one third of their lifetime, for a period of six months (Spring - Summer - Autumn). During this hot period of the year, house's ventilation is high since people leave windows open.

RESULTS

Twelve of the dosimeters installed in Laurium have been lost (16% missing). The results of the measurements in the remaining are shown in Tables 1,2 and 3 for Laurium, Athens and Domatia respectively. Mean values ($\pm$SE) expressed in Bq/m^3 were: for Laurium 2828.4 $\pm$ 799, for Athens 24.0 $\pm$ 3.5 and for Domatia 135.7 $\pm$ 26.2 with ranges 8 - 10095.2 Bq/m^3, 3 - 136.2 Bq/m^3 and 7.4 - 492.1 Bq/m^3 respectively.

Table 1

Radon Concentration in Ancient and Contemporary Greek Silver Mines (Laurium, Attiki)

Spot	Bq/m^3	Spot	Bq/m^3
1	780.6	10	7186.7
2	222.6	11	8508.7
3	6922.2	12	4342.2
4	96.9	13	4927.1
5	10095.2	14	305.1
6	406.4	15	110.2
7	342.9	16	238.1
8	717.1	17	28.6
9	5672.3	18	8.0

DISCUSSION

The large differences of radon concentration found among the different shafts in Laurium are probably due to differences in ventilation, as there is a strong negative correlation (r= -0.98) between air flow and radiation exposure of the dosimeters. It is concluded that in ancient tunnels, due to their ventilation network still operating after 2500 years radiation exposure is maintained in comparable levels with that of contemporary mines.

Table 2

Radon Concentration in Athenian Dwellings

Spot	Bq/m^3	Spot	Bq/m^3	Spot	Bq/m^3
1	33.3	20	18.5	39	9.3
2	14.8	21	4.5	40	12.2
3	11.1	22	16.3	41	9.6
4	18.5	23	6.3	42	12.6
5	88.8	24	3.0	43	15.9
6	25.9	25	40.7	44	16.7
7	55.5	26	8.1	45	69.9
8	62.9	27	9.6	46	136.2
9	70.3	28	11.1	47	82.6
10	33.3	29	5.6	48	9.3
11	44.4	30	7.4	49	30.0
12	7.4	31	3.7	50	35.5
13	18.5	32	5.5	51	7.4
14	14.8	33	12.6	52	6.6
15	22.2	34	8.5	53	10.4
16	7.4	35	17.4	54	9.3
17	7.4	36	37.4	55	17.4
18	48.1	37	4.8		
19	14.8	38	8.9		

Table 3

Radon Concentration in Dwellings in the village Domatia (Macedonia)

Spot	Bq/m^3	Spot	Bq/m^3
1	88.8	10	7.4
2	492.1	11	162.8
3	111.0	12	122.1
4	37.0	13	122.1
5	318.2	14	129.5
6	144.3	15	22.2
7	85.1	16	66.6
8	162.8	17	136.9
9	48.1	18	185.0

In all but one (No.46) cases from measurements held in Athens, radon levels were lower than those reported in other countries (Gessel 1983, Schmier and Wicke 1985), a finding partially explained from the high ventilation during the time of measurements. Our values were 3 fold higher than the annual average of the population - weighted radon concentration in outdoor air (UNSCEAR 1984). Our results are in agreement with those of Proukakis et al (1987). Papastefanou et al (1984), reported radon measurements performed by solid-state nuclear track detectors in 15 dwellings made of bricks and concrete located in northern Greece and a mean concentration of 148 Bq/m^3 with a range between 104-381 Bq/m^3 was reported.

As far as Domatia measurements are concerned, our results clearly indicate that there is a large difference between Athens and Domatia and that in Domatia there are some dwellings exceeding the action level for remedial action of EPA (Hanson 1987) and of the Nordic countries (Nordic countries 1986).

Our future plans include surveys of other areas in Greece and studies correlating the indoor radon concentration with the uranium concentration of the soil around the house.

REFERENCES

Brill D. et al (1987) J. Nucl. Med. Vol 28, 1095
Danali S. et al (1986) Health Phys. Vol 50, 509
Fleischer R. (1986) Health Phys. Vol 50, 823
Georgiou E. et al (1986) Nucl. Med Vol. 25, A136
Gessel T.F. (1983) Health Phys. Vol 45, 289
Green B. et al (1985) Science of the Total Environment Vol 45, 459
Hanson B. (1987) J. Nucl. Med. Vol 28, 1987
Letourneau E.G. et al (1984) Rad. Prot. Dos. Vol 7, 303
Maraziotis E. (1985) Health Phys. Vol 49, 302
McAuley I.R. and McLaughlin J.P. (1985) Science of the Total Environment Vol 45, 319
Nordic countries (1986): Naturally occuring radiation in the Nordic countries - Recommendations The Radiation Protection Institutes in Denmark, Finland, Iceland, Norway and Sweden
Papastefanou C. et al (1984) Health Phys. Vol 47, 775
Papastefanou C. et al (1986) Health Phys. Vol 50, 281
Proukakis C. et al (1986) B.N.E.S. Conference on Health Effects of low dose ionising radiation - recent advances and their implications, London
Schmier H. and Wicke A. (1985) The Science of the Total Environment Vol 45, 307
Siotis I. and Wrixon A. (1984) Rad. Prot. Dos. Vol 7, 101
Swedjemark G. and Mjones L. (1984) Rad. Prot. Dos. Vol 7, 341
United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) (1982), New York
United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) (1984) Document A/AC. 82/R.420
Wrixon A.D. et al (1984) Rad. Prot. Dos. Vol 7, 321