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Radon Concentrations in Houses Around the Plomin Coal-Fired Power Plant

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ABSTRACT

Investigation of radon activity concentration in houses around the Plomin coal-fired power plant (Istrian Peninsula) started in the winter of 1990 upon the assumption that certain old houses in this region were built using mortar and plaster prepared from slag and ash.

This paper presents the results of a preliminary investigation carried out in the winter of 1990 and spring of 1991, when the difference between radon levels in old and newly built houses was first noted, and the subsequent data obtained by radon measurements in 40 selected houses in the period from 1992 to 1994.

The average annual radon activity concentrations in the old houses ranged from 55 Bqm^{-3} to 426 Bqm^{-3} (mean value 146 ± 91 Bqm^{-3}) and in more recently built houses from 16 Bqm^{-3} to 67 Bqm^{-3} (mean value 36 ± 13 Bqm^{-3}). The average annual effective doses from inhalation of radon progeny for the inhabitants living in the old and newly build houses were estimated to be 2·7 mSv and 0·7 mSv, respectively. Copyright © 1996 Elsevier Science Ltd.

INTRODUCTION

Current estimates indicate that on average over 50% of the total radiation exposure to man from all natural and man-made sources is due to the inhalation of the naturally occurring radioactive radon and its short-lived

decay products (UNSCEAR, 1993). In recognition of the worldwide importance of this source term, many countries are engaged in radon surveys within their national programmes, and many others are planning surveys for the future. In the Republic of Croatia the investigation of radon has not been organized on a national basis. Over the past few years the Department of Radiation Protection of the Institute for Medical Research and Occupational Health in Zagreb has been investigating indoor radon activity concentrations in dwellings and selected workplaces. Elevated radon concentrations detected at certain locations pointed to a need for a more detailed investigation of radon levels and an evaluation of associated risk from inhalation of radon and its decay products for the population of the area (Lokobauer *et al.*, 1993, 1994).

Preliminary investigations of radon activity concentrations in houses around the Plomin coal-fired power plant (Istrian Peninsula) started in autumn 1990 upon the assumption that certain old stone houses in the region of Labin were built using slag and ash in preparing mortar and plaster (Fig. 1).

For the past century, the Labin area has been a major energy producing area for the Istrian Peninsula. Continuous coal mining started in the second half of the 18th century. Coal was mined in the mines of Labin, Raša, Vinež, Strmac, Ripenda and Tupljak. Slag and ash resulting from coal production were piled close to the mine sites. By the middle of the 20th century, the local houses were built mostly from stone, and the slag and ash from waste piles were frequently used as constructive components.

In 1971 the Plomin coal-fired power plant (Plomin CFPP) began to operate using locally mined coal. Its impact on the environment has been studied for years. In the eighties, the uranium activity concentration measured in coal from the local mines was 250–300 $Bq\,kg^{-1}$, which was 10–15 times higher than the average world value (Marović, 1985).

Due to the practice of using slag and ash in the construction of houses, and the fact that coal from local mines contained high uranium activity, indoor radon measurements were started at the end of 1990 and were continued until the spring of 1994 within the International Atomic Energy Agency coordinated research programme 'Radon in the Human Environment'.

MATERIAL AND METHODS

Radon detectors were set up in selected houses at several locations up to 30 km from the Plomin plant (see Fig. 1). The houses included in the study

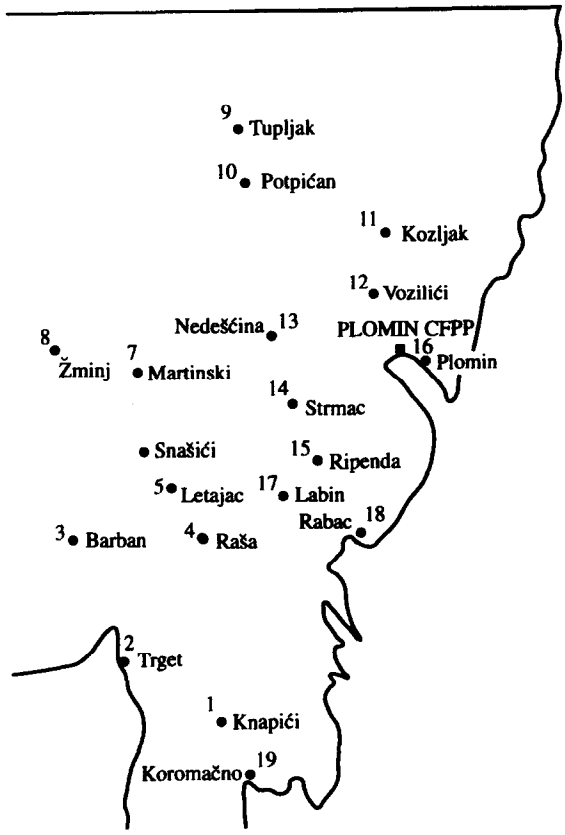

Fig. 1. Selected locations for radon measurement in houses around the Plomin coal-fired power plant.

were mostly built in the period 1850–1930, made from stone and therefore possibly using slag and ash as well. For the purpose of comparison some more recently built houses from the same locations, built in the period 1940–1990 from bricks and cement, were also included in the study. From the latter group, emphasis was given to radon determination in houses built during the seventies and eighties which were adjacent to an area used largely for cement production (Koromačno cement industry, location 19). The Koromačno cement industry in that period utilized coal from the local resources and produced cement with a certain percentage (5–10%) of slag.

On the Istrian Peninsula, as in most of South Croatia, old and more recently built houses are similarly constructed, due to tradition and also to the karstic terrain, which does not allow basement construction. Similarly, heating systems for old and newer houses do not differ significantly, elec-

tric heating being the most common. In all considered houses, there was no other ventilation, except natural.

All radon measurements in old and more recently built houses were taken on the ground floor. Radon activity concentrations were measured by solid state nuclear track detectors, Kodak Pathe LR-115 films, type II. Investigations were performed by means of open (cassette) and filtered detectors (diffusion chamber). The detectors in diffusion chambers with a volume of 0·24 dm^3 were covered with a glassfibre filter of 0·07 $kg\,m^{-2}$ surface density. The detectors were exposed indoors (at the locations of interest) over a period of 2–6 months, and were then etched in 2·5 N NaOH aqueous solution at 60°C for 90 min. The track densities of bare and filtered detectors were counted visually using an optical microscope, magnification 10 × 15.

The Kodak LR-115 films in the diffusion chambers and cassettes were calibrated at the National Radiological Protection Board, Didcot, Great Britain.

RESULTS AND DISCUSSION

Data from the preliminary investigation carried out in the winter of 1990 and spring of 1991 in old houses (built with a certain amount of slag and ash) and more recently built houses (from brick and cement) in the area of the Plomin CFPP using bare detectors are shown in Fig. 2.

The difference determined in radon activity concentrations between the old and newly built houses pointed to the need for more detailed investigations. Investigations that followed in the period from spring 1992 to spring 1994 were performed in 40 houses at 19 locations using detectors in diffusion chambers in order to determine radon concentrations as accurately as possible. Since preliminary investigations also showed differences in radon activity concentrations in winter and in spring (approximately 30% higher concentrations in winter), the measurements were continued seasonally in the periods spring, summer and autumn–winter. Results obtained are given in Table 1.

The mild Mediterranean climate, characteristic of this area, led to relatively slight seasonal variations in indoor radon activity concentrations. The mean indoor radon activity concentration determined for the season spring–summer was $70 \pm 71\ Bqm^{-3}$ and for the season autumn–winter $94 \pm 92\ Bqm^{-3}$.

As indicated by the data related to the eight houses built during the 70s and 80s using a cement with a certain percentage of ash and slag, elevated indoor radon concentrations were not detected in any period of the year.

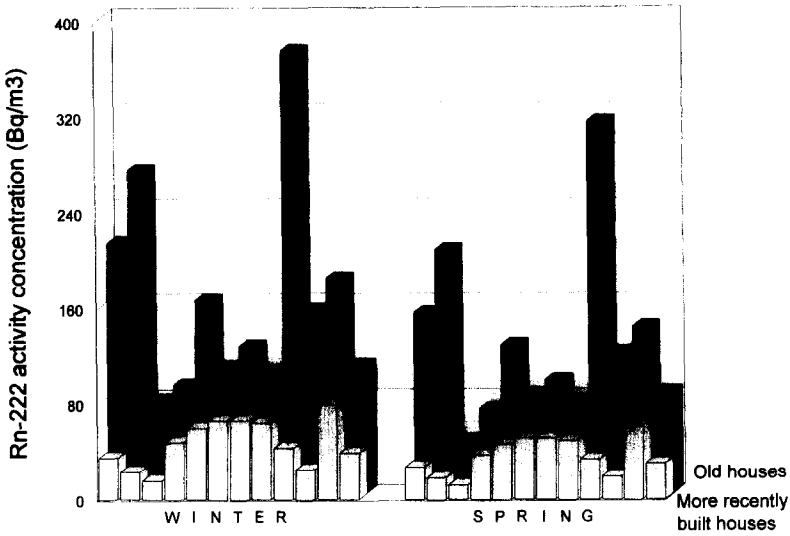

Fig. 2. Preliminary investigations of radon activity concentrations in houses around the Plomin coal-fired power plant.

Average annual radon activity concentrations measured in old and recently built houses are given in Fig. 3. In the old houses the annual radon activity concentrations ranged from 55 to 426 Bqm^{-3} (mean value 146 ± 91 Bqm^{-3}) depending on the quantity of ash and slag incorporated in building material or on their renovations up to now. In more recently built houses the annual radon activity concentrations ranged from 16 Bqm^{-3} to 67 Bqm^{-3} (mean value 36 ± 13 Bqm^{-3}). It should be noted that the lower resistance of older buildings against radon from subsoil could also be a contributing factor for higher concentrations. However, further investigation on that subject is needed.

Cement containing coal slag (5–10%) used for preparation of cement, mortar or plaster did not result in above average indoor radon concentrations in newer houses. Since slag was not used as a direct component of mortar, the overall percentage of slag in it was very low. This was not the case for lime mortar prepared for use in the construction of older houses.

On the basis of radon activity measurements, assuming that inhabitants of Labin area spend 60% of the time at home, the corresponding effective doses from inhalation of radon decay products are estimated following the UNSCEAR recommendations (1993). The average annual effective doses to inhabitants of the Labin area from inhalation of radon progeny in the old and newly built houses are estimated to be 2·7 mSv and 0·7 mSv, respectively.

TABLE 1

Average Radon Activity Concentrations Measured Seasonally in Old (o) and More Recently Built (n) Houses at Selected Locations Around the Plomin Coal-Fired Power Plant

Location No.		*Spring*	*Summer*	*Autumn–Winter*
		Activity concentration (Bqm^{-3})		
1	o	177 ± 15	163 ± 9	226 ± 9
	n	27 ± 8	27 ± 4	52 ± 5
2	o	79 ± 11	66 ± 8	70 ± 5
	n	23 ± 8	11 ± 4	28 ± 3
3	o	205 ± 12	193 ± 12	194 ± 9
	n	25 ± 7	16 ± 4	38 ± 4
4	o	59 ± 10	52 ± 11	65 ± 10
	n	16 ± 4	15 ± 4	17 ± 4
5	o	80 ± 11	63 ± 7	128 ± 7
	n	33 ± 8	24 ± 5	42 ± 4
6	o	154 ± 13	159 ± 9	232 ± 10
	n	56 ± 11	50 ± 7	80 ± 6
7	o	93 ± 11	72 ± 8	95 ± 6
	n	44 ± 8	23 ± 5	36 ± 4
8	o	88 ± 11	70 ± 8	127 ± 7
	n	27 ± 8	24 ± 5	27 ± 4
9	n	21 ± 6	20 ± 5	26 ± 4[a]
10	n	29 ± 7	38 ± 4	40 ± 4[a]
11	o	166 ± 15	107 ± 9	184 ± 9
	n	52 ± 11	24 ± 5	71 ± 6
12	o	410 ± 23	322 ± 16	485 ± 18
	n	42 ± 10	38 ± 6	40 ± 4
	n	51 ± 5	34 ± 7	44 ± 8[a]
13	o	114 ± 12	89 ± 9	144 ± 8
	n	29 ± 9	16 ± 4	39 ± 4
14	o	136 ± 13	119 ± 10	143 ± 8
	n	65 ± 10	51 ± 7	66 ± 5
15	o	127 ± 11	74 ± 6	131 ± 7
	n	50 ± 9	42 ± 6	84 ± 6
	o	207 ± 15	188 ± 16	233 ± 10
	o	74 ± 9	77 ± 9	132 ± 7
	n	30 ± 8	26 ± 5	64 ± 5[a]
16	n	16 ± 6	18 ± 4	28 ± 4[a]
17	n	33 ± 8	14 ± 4	21 ± 3[a]
	n	18 ± 7	20 ± 5	27 ± 4[a]
	n	28 ± 7	27 ± 5	29 ± 4[a]
18	n	23 ± 8	35 ± 5	38 ± 4[a]
	n	29 ± 4	26 ± 4	45 ± 7[a]
19	o	56 ± 9	46 ± 6	58 ± 5
	n	35 ± 8	31 ± 5	36 ± 4

[a]The houses built in the seventies and eighties from cement with a certain percentage of slag and ash.

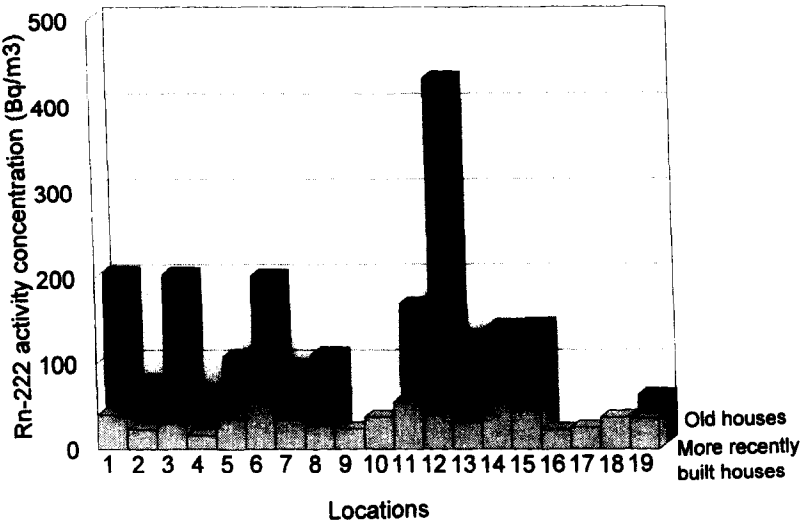

Fig. 3. Average annual radon activity concentrations in selected houses around the Plomin coal-fired power plant.

CONCLUSION

Investigations performed in houses around the Plomin CFPP revealed significant differences in radon levels between the old and newly built houses. The fact that these houses were situated at close proximity to each other points to building materials as a major source of elevated radon activity concentrations in the older houses. With a view to making a risk assessment study concerning the exposed population in this area as accurate as possible, investigations were continued on an expanded network, as a part of the joint project 'Elevated radon concentrations and related healths effects' with the IAEA.

ACKNOWLEDGEMENT

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REFERENCES

Lokobauer, N., Franić, Z., Bauman, A. & Horvat, Đ. (1993). *Radon in Houses around the Plomin Coal-Fired Power Plant.* International Symposium on Radon Reduction Technology, Minneapolis, pp. 9–55.

Lokobauer, N., Franić, Z. & Senčar, J. (1994). *Radon in Houses around the Plomin Coal-Fired Power Plant.* Proceedings of the Second Symposium of the Croatian Radiation Protection Association, Zagreb, pp. 295–8.

Marović, G. (1985). *Enhanced Natural Radioactivity around a Coal-Fired Power Plant.* M.Sc. Thesis. Technological Faculty, University of Zagreb, 1985. (In Croatian.)

UNSCEAR 1993: *Sources and Effects of Ionizing Radiation.* United Nations Scientific Committee on the Effects of Atomic Radiation, United Nations, New York, 1993.