Measurement of the Radon Equilibrium Factor in Ottawa Dwellings

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Abstract. The degree of radioactive equilibrium between radon and its short-lived radioactive decay products can be expressed as the equilibrium factor "F". It is often assumed to be 0.40 for assessing risk. While this is usually a reasonable assumption, there are cases where the equilibrium factor can differ from 0.40 significantly due to various housing and environmental factors. Because the effective dose depends strongly on the F value, it is important for risk assessment to know the normal range of the F factor for settings specific to Canada. For this purpose, measurements were undertaken at several Ottawa homes with a wide range of radon concentrations. The experimental homes were detached houses with a composite structure of brick, concrete blocks and wood. The hourly variation of radon concentration and its decay products concentration were observed employing a portable ionisation chamber (permitting the continuous radon monitoring as well as the determination of selected parameters -- air temperature, pressure and humidity), Lucas type passive scintillation cell and a working level monitor. The calculated F value lay between 0.20 - 0.52. In addition, the diurnal variation of the F value was observed and the indoor environment was monitored.

KEYWORDS: Radon, Radon decay products, Equilibrium factor.

1. Introduction

Radon is a radioactive inert gas present in the earth's crust which originates naturally from the disintegration of the radium (^{226}Ra) in the uranium (^{238}U) decay series. The health hazard of indoor exposure does not come from radon itself, but rather from its progeny, when they, or dust particles carrying them, lodge in the respiratory tract [1]. Human exposure to high concentrations of radon gas has been correlated with lung cancer incidence, although the effect at low doses is not well defined. Due to elevated concentrations frequently found indoors, residential radon research is still in progress [2].

The equilibrium factor, a measure of the degree of radioactive equilibrium between radon and its short-lived radioactive decay products, is often assumed to be 0.40 for risk assessment. While this is usually a reasonable assumption, there are cases where the equilibrium factor can differ from 0.40 significantly due to various housing and environmental factors. Because the effective dose depends strongly on the F value, it is important for risk assessment to know the normal range of the F factor for settings specific to Canada. A pilot study was carried out the in the present investigation to observe the variation in equilibrium factor ''F'' due to the persisting variance in radon and their decay products at some houses in Ottawa, Canada. The hourly variation of equilibrium factors with the indoor air environment was also monitored.

2. Materials and Methods

The study was conducted in the suburban area located in the southwest corner of the city of Ottawa and also in the West Part of the township of Hull. The basement and first floor of the detached houses with a composite structure of brick, concrete blocks and wood were selected as the site of study. In order to estimate the F value, two main sets of apparatus were deployed.

For the hourly variation of radon concentration, a portable passive radiation monitor AB-4 was used. This monitor uses photomultiplier tube (PMT) technology to detect photons generated by a Lucas type passive scintillation cell detector. Radon enters the Lucas cell through a permeable membrane. As the radon decays it emits an alpha particle that strikes the silver activated Zinc-Sulfide coating inside the

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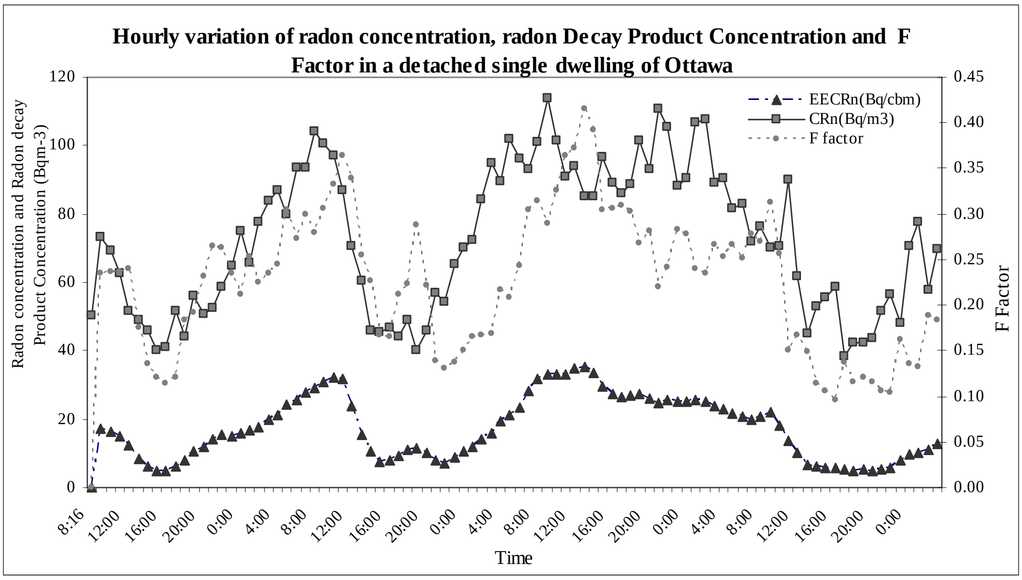
cell. The energy of the alpha particle is converted to a light pulse which is amplified by the PMT and counted over the programmed measurement interval. The detection limit for radon was estimated as 0.034 count per min.. The count rates at one-hour intervals were converted into hourly radon concentration. The AB-4 also monitors the indoor air environment by recording the room temperature, relative humidity and pressure. A portable Working Level (WL) meter, manufactured by Tracerlab Ltd, was selected for the hourly variation of the Equilibrium Equivalent Concentration (EEC) of Rn, because the meter requires low electric power and has a low-noise pump. These systems were set up in the children's toy room/family room in the basement as representative of a room with a large occupancy factor. Alpha GUARD (Genitron Instrument GmbH), a portable radon (^{222}Rn) monitoring device, was employed in some of the sites to monitor indoor radon concentration due to a shortage of AB-4's. It also has sensors for temperature, pressure and relative humidity. In it, a cylindrical ionization chamber was used to detect the alpha particles emitted from the decaying radon. A glass fibre filter over the mouth of the chamber prevents aerosol particles and radon decay products from coming into the chamber. Radon concentration was measured using the gas diffusion mode [3].

All the monitors were operated continuously for four or more days. Since a significant difference in the life pattern of inhabitants was not observed between weekdays and weekends, the information obtained can be assumed to be representative of average monthly values.

Table 1: "F" factors in Ottawa Dwellings.

Site	Floor	C_{Rn}(Bqm^{-3})	Std Dev	C_{RnDP}(Bqm^{-3})	Std Dev	Ave F
1	Basement	115.70	22.71	32.60	10.90	0.30
2	Basement	80.90	31.70	33.10	17.70	0.40
3	Basement	146.30	21.77	74.20	21.77	0.52
4	Basement	72.85	21.44	17.47	9.29	0.23
5	Basement	229.50	65.50	74.73	26.49	0.32
6	Basement	265.80	19.20	66.00	27.10	0.24
7	Basement	106.86	31.23	42.68	12.25	0.40
8	First floor	46.20	11.50	11.66	4.90	0.25
9	First floor	281.80	31.50	132.20	41.40	0.48
10	First floor	336.20	26.70	66.98	75.50	0.20
11	First floor	1739.08	209.26	349.18	66.32	0.40

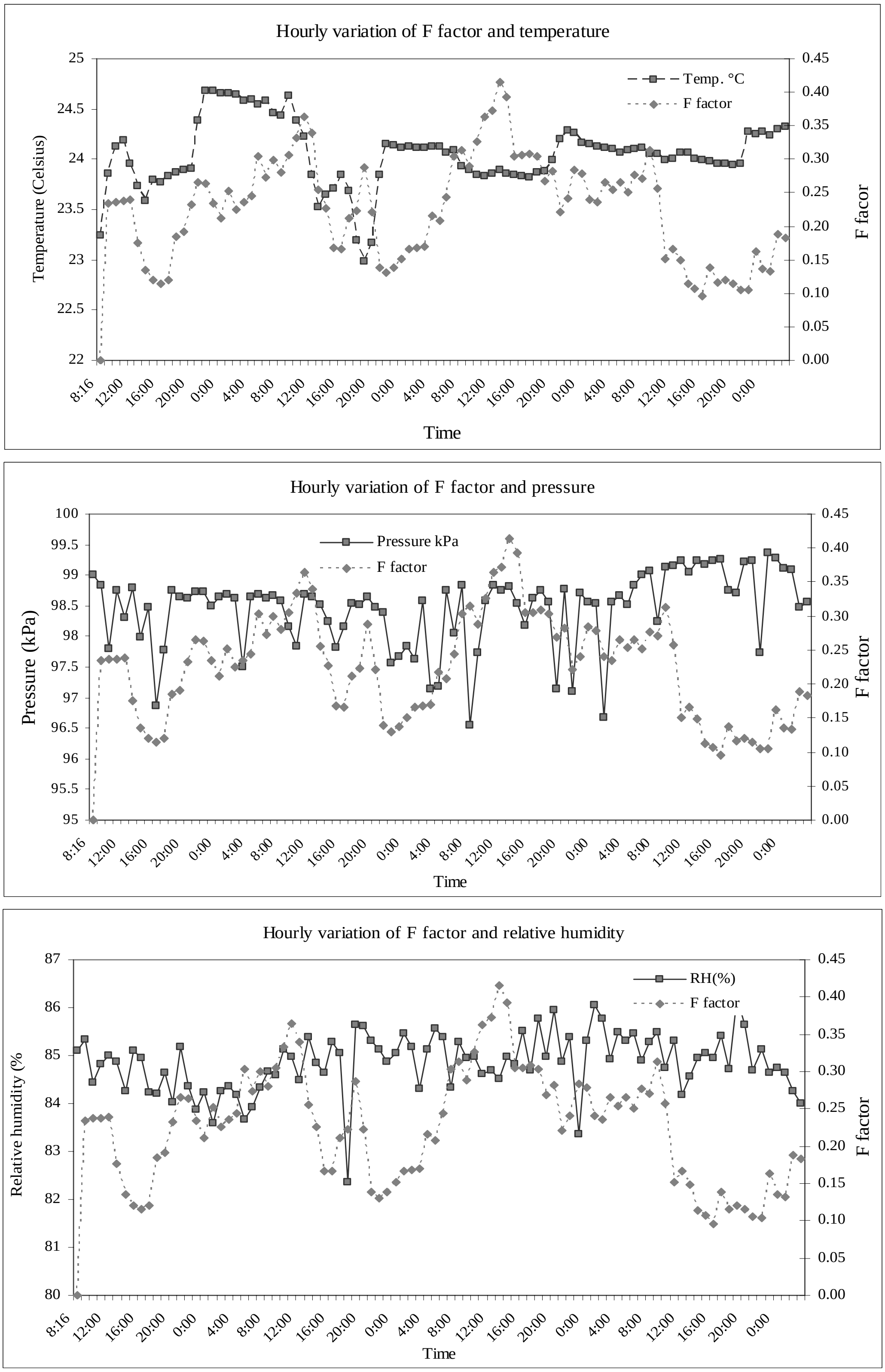
Figure 1: Hourly variation of "F" factor with the change of radon and decay product concentration



3. RESULTS AND DISCUSSIONS

The F values were calculated as a ratio between radon concentration and EEC_{Rn} for the experimental sites (Table 1).

Fig. 2: Indoor environment monitoring with the variation of F value



The mean of F = 0.34 ± 0.10 found for the dwellings is lower than the UNSCEAR suggested world average value of 0.4 for indoors [4]. Figure 1 shows the variation of radon concentration (C_{Rn}), radon decay products concentration (C_{RnDP}) and the F value in the Ottawa dwellings. The ‘ventilation rate’ is considered to be the most effective parameter affecting the F value. So the indoor air environment was also carefully monitored for temperature, air pressure and relative humidity.

The variation in the F value is based mainly on the changes in the activities of the inhabitants [5]. The correspondence between F value and environmental parameters are depicted in Fig. 2. It was noted that the F value varied directly with temperature and air pressure and inversely with relative humidity.

Changes in life style and activity would also lead to variation in several other important dosimetric parameters, such as occupancy factor, size distribution of radon progeny, unattached fraction ratio of progeny, breathing rates, etc. In fact the conversion factor ($mSv.(Bq.h.m^{-3})^{-1}$) utilised in the radon dosimetric calculation generally includes a larger uncertainty than the physical or environmental parameters experimentally estimated. If it is necessary to determine the radon effective dose over a shorter period than one year, the time variation of each physical or environmental parameter including F value should be taken into account.

4. **Conclusion**

The time variation of the F value in the basements and first floor of several detached houses in Ottawa was estimated and discussed. During the short testing periods, the F value varied from 0.20 to 0.52 with an average value of 0.34 and a standard deviation of 0.10. The results indicate that the F value of 0.4 recommended by UNSCEAR and ICRP is a reasonable value for those Canadian homes tested. To confirm this finding, more and long-term measurements are needed.

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