ТЕХНІКА ТА МЕТОДИ ЕКСПЕРИМЕНТУ

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H. A. Abdel-Ghany, D. H. Shabaan

Physics Department, Faculty of Women for Arts, Science and Education, Ain-Shams University, Cairo, Egypt

DOES NATURAL GAS INCREASE THE INDOOR RADON LEVELS?

The natural gas is naturally occurring hydrocarbon consists mainly of methane and includes varying amounts of other hydrocarbons, carbon dioxide and other impurities such as: nitrogen, and hydrogen sulfide. It is used domestically and industrially as a preferable energy source compared to coal and oil. Because natural gas is found in deep underground natural formations or associated with other underground hydrocarbon reservoirs, there is a potential to contain radon as a contaminant. This work was designated to measure indoor radon concentrations in dwellings supplied with natural gas compared with those not supplied with it, where radon level was estimated using solid state nuclear track detectors (CR-39). The results showed that radon concentration was significantly higher in dwellings supplied with natural gas, where it was 252.30 versus 136.19 Bqm^{-3} in dwelling not supplied with natural gas ($P < 0.001$). The mean values of radon exhalation rate was $0.02 \pm 6.34 \cdot 10^{-4}$ $Bq \cdot m^{-2} \cdot h^{-1}$ in dwellings supplied with natural gas and 0.01 ± 0.008 $Bq \cdot m^{-2} \cdot h^{-1}$in dwellings lacking it. In addition, a significant difference was observed in the mean annual effective doses (4.33 and 2.34 $mSv \cdot y^{-1}$, respectively) between both groups. Conclusively, the data indicate that natural gas may represent a potential source of indoor radon.

Keywords: natural gas, radon concentration, radon exhalation rate, nuclear track detectors, annual effective dose.

Introduction

Radon is considered one of the most dangerous radioactive elements in human's environment. Its gaseous natures allows it to spread through the atmosphere and leaks indoor, where it inhaled by human and causes serious health problems. The greatest fraction of natural radiation exposure results from inhalation of the decay products of radon, which represent more than 50 % of the total dose from natural source both indoor and in work places (Fig. 1). On inhaling these daughters, which are short lived ^{218}Po and ^{214}Po, a major fraction will be retained in the lung and may induce lung cancer [1, 2].

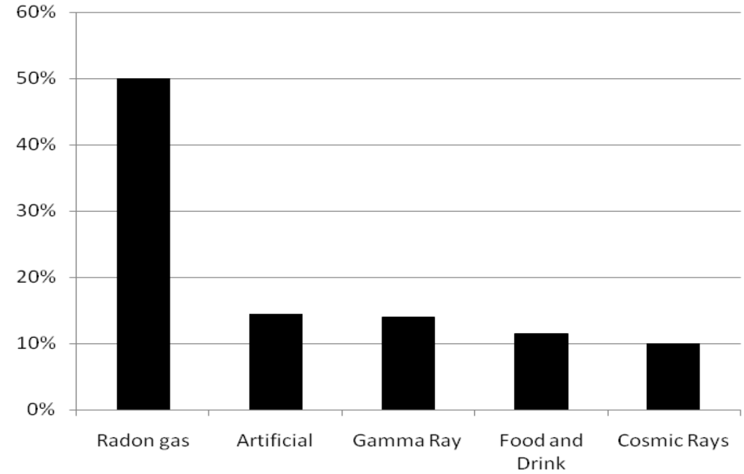


Fig. 1. Radiation sources [19].

The literature, including our previous work, has extensively documented many of the building materials as a potential source of indoor radon [3]. In addition, water supply and the cracks in building materials represent additional factors that deliver radon to the indoor environment [4 - 7]. In addition to these factors, the natural gas, used domestically, may represent a potential source of indoor radon [8].

Worldwide, natural gas is used domestically and industrially, where supplying dwellings with this gas is expanding specially in big cities. Because natural gas is exclusively obtained from underground sources, it may hypothesized that it contains trace amounts of radon. These amounts may increase the levels of indoor radon; especially the gas is not affected by combustion and passes through the flame. Due to its hazardous effects on human health, many of the occupational health studies have repeatedly investigated radon exposure in mines [9]. Also, many studies have been undertaken to evaluate the potential building up of ^{222}Rn delivered through natural gas [10 - 13]. Some studies had monitored radon concentrations in natural gas emerged from oil well heads and estimated population exposure due to the use of natural gas [14]. Thus, there is consensus agreement that the use of large quantities of natural gas and longer exposure times in commercial premises, such as kitchens and restaurants, could, in principle, lead to higher indoor radon levels and exposure of human health to some health problems. In recent years, although the usage of natural gas for domestic use in Egypt has rapidly increased, few studies had investigated the potential of building up of radon levels due to the excessive consumptions of natural gas. This triggers the interest of monitoring radon levels in homes supplied with natural gas.

Materials and Methods

CR-39 nuclear track detector (Intercast, Italy) with a 500 μm thickness was used in this work. Radon measurements were made in the kitchens of fifteen different dwellings, located in Cairo city, not supplied with natural gas and another fifteen dwellings supplied with natural gas. All dwellings investigated were inhabited and natural gas was used on a regular daily manner and have similar construction pattern. The detector matrix was fragmented into squares (1X1 Cm), lightly cleaned with absolute alcohol and then mounted in cans as previously described [15]. Measurements were made in triplicates for each kitchen. Cups were left at room temperature for 30 days exposure time. During this period, alpha particles from the decay of radon daughters bombard the CR-39 nuclear track detectors in the cup (Fig. 2).

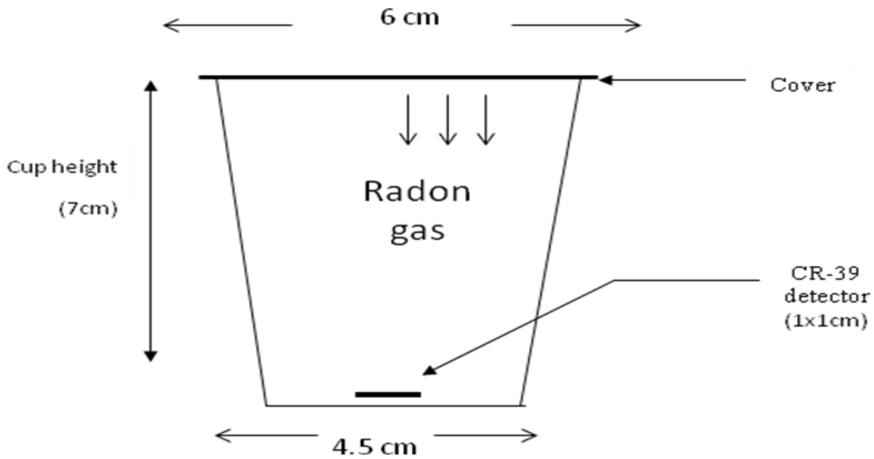


Fig. 2. The geometry of CR-39 track detector.

After exposure the detectors were chemically etched in a 6 N NaOH at 70 °C for 6 h to reveal the tracks, which were counted under optical microscope. The density of tracks counted was assumed proportional to the ^{222}Rn exposure. Average specific activity of radon in the dye samples is calculated using the formula [16].

$$C_{Rn}\left(\mathrm{Bq\cdot m^{-3}}\right)=\frac{\rho_{Rn}}{kt}, \qquad (1)$$

where ρ_{Rn} – the radon track density, track/cm^2; k – the efficiency factor for CR-39 track detector. This factor depends on the detector efficiency for detection of alpha particles emitted from radon and its progeny [17], and t – the exposure time (30 days). As the inhalation of Rn gas and its daughters represent a major risk factor, the exhalation rate was calculated from the following equation according to Khan et al. and Abu-Jarad [18, 19]:

$$E_x=\frac{CV\lambda}{A\left[t+\frac{1}{\lambda}\left(e^{-\lambda t}-1\right)\right]}, \qquad (2)$$

where E_x – the radon exhalation rate, Bq/m^2/h; C – the integrated radon exposure, Bq · m^{-3}h; V – the effective volume of the cylindrical container, m^3; λ – the radon decay constant, h^{-1}; t – the exposure time, h, A – the area of can [20]. The annual effective dose equivalent D, mSv · y^{-1}, was computed from the integrated specific activity of ^{222}Rn using the formula

$$D=\frac{0.4C\left(3.88\ \mathrm{mSv\cdot WLM^{-1}}\right)7000\ \mathrm{h}}{\left(3700\ \mathrm{Bq\cdot m^{-3}}\right)170\ \mathrm{h}}, \qquad (3)$$

where C – the integrated specific activity of ^{222}Rn, Bq · m^{-3}; 3.88 mSv·WLM^{-1} – the ICRP conversion factor. The other factors are to take account of the house occupancy factor [21].

Results and Discussion

The indoor radon concentrations and annual effective dose were investigated in a group of fifteen dwellings supplied with natural gas and compared with the corresponding levels measured in another 15 dwellings not supplied with natural gas. The indoor radon concentrations were significantly higher (P < 0.001) in homes supplied with natural gas, where the range of radon concentration was 200.1 - - 289.9 Bq · m^{-3} compared to 78.0 - 177.9 Bq · m^{-3}, in kitchens of homes not supplied with natural gas (Tables 1 and 2). The average indoor radon level has increased by 46 % due to the consumption of natural gas. This observation agrees with some previous studies. G. Y. Sent and his coworkers, [22] for instance have reported a dramatic increase (from 22.8 to 707.8 Bq · m^{-3}, 96.77 %), in the indoor radon levels in dwellings using natural gas. Also, they found that the indoor radon concentrations in kitchens were higher than the living rooms.

Table 1. **Track density, radon concentration, radon exhalation rate and annual effective dose in dwellings not supplied with natural gas**

No. of dwellings	Track density, Track cm^{-2}	Radon concentration, Bq · m^{-3}	Radon exhalation rate, Bq · $m^{-2}h^{-1}$	Annual effective dose, mSv · y^{-1}
1	1428.57	166.55	0.013	2.86
2	2489.79	96.35	0.007	1.65
3	1020.40	140.96	0.011	2.42
4	408.16	175.58	0.014	3.01
5	1020.40	113.87	0.009	1.95
6	2040.81	177.92	0.142	3.06
7	1632.65	80.67	0.006	1.38
8	1020.40	77.98	0.006	1.34
9	1428.57	164.55	0.013	2.83
10	816.32	151.17	0.012	2.60
11	1632.65	163.34	0.013	2.80
12	612.24	113.37	0.009	1.95
13	2040.81	103.94	0.008	1.78
14	1428.57	165.44	0.0132	2.84
15	816.32	151.17	0.012	2.60

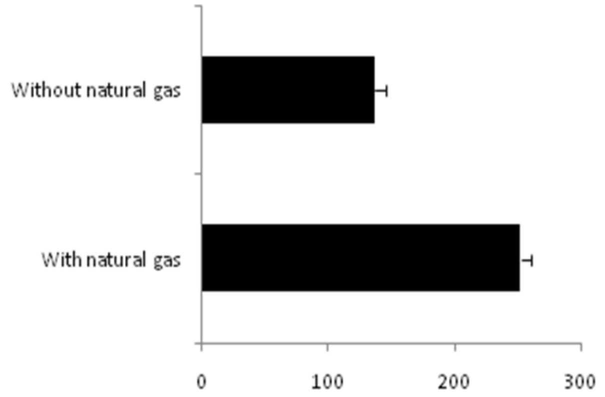
Table 2. **Track density, radon concentration, radon exhalation rate and annual effective dose in dwellings supplied with natural gas**

No. of dwellings	Track density, Track cm^{-2}	Radon concentration, Bq · m^{-3}	Radon exhalation rate, Bq · m^{-2} · h^{-1}	Annual effective dose, mSv · y^{-1}
1	4244.89	286.77	0.022	4.93
2	2836.73	225.34	0.018	3.87
3	4081.63	255.31	0.020	4.39
4	5306.12	282.61	0.022	4.86
5	3673.46	280.88	0.022	4.83
6	2857.14	229.87	0.018	3.95
7	5510.20	220.14	0.017	3.78
8	5714.28	200.12	0.016	3.44
9	4693.87	256.37	0.020	4.40
10	5306.12	282.77	0.022	4.86
11	6122.44	233.89	0.018	4.02
12	4265.30	289.87	0.023	4.98
13	4204.08	211.47	0.016	3.63
14	3489.79	246.81	0.0197	4.24
15	4224.48	282.31	0.022	4.85

The large variability in the values obtained may not attributed to other intervening radon sources such as the nature of soil beneath the buildings, types of building materials used, ventilation conditions or water supply, where radon easily dissolves in water and finds its way to dwellings specially that supplied with underground water. In this work, the possible participation of these intervening factors was eliminated, where the chosen investigated buildings are located in the same housing compound, having the same design, built with same construction materials and supplied with the same water source. In addition, the height of the dwellings above the ground was considered. This study design may support the natural gas-related increase in radon levels and the variability of measurements may be attributed to the rate of gas consumption. Specially, hot air ovens electrical heaters may substitute the natural gas in different domestic uses.

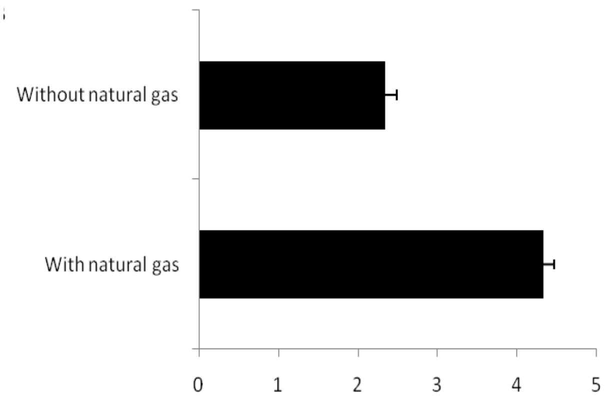
Radon exhalation studies were also carried out in the investigated dwellings, where the results showed a significant differences ($P < 0.001$) between radon exhalation rate in dwellings using natural gas and without usage it. The mean values of radon exhalation rate were: 0.02 ± 0.006 and 0.01 ± 0.008 $Bq \cdot m^{-2} \cdot h^{-1}$ in dwellings supplied and not supplied with natural gas, respectively (see Tables 1 and 2).

Also, the annual effective dose equivalent was estimated from the corresponding measured radon concentration (see Tables 1 and 2). The data indicated that the annual effective dose in kitchens supplied with natural gas was higher than those without natural gas. The annual effective doses were 3.44 to 4.98 $mSv \cdot y^{-1}$ and 1.34 to 3.06 $mSv \cdot y^{-1}$, respectively. Annual effective dose reported through other studies was higher than (3 - 10 $mSv \cdot y^{-1}$), which is the lower than the limits recommended by ICRP [21]. Fig. 3 summarizes the difference between the average of radon concentrations and annual effective dose in dwellings supplied and not supplied with natural gas. Radon can represent not only hazardous factor emerged from natural gas. Air pollution from natural gas stoves was reported. Some studies [23] showed that the natural gas stoves emit nitrogen dioxide (NO_2), carbon monoxide (CO), and formaldehyde (HCHO), each of which can exacerbate various respiratory and other health ailments. In addition, natural gas brings harmful chemicals into homes through the methane it contains. Methane (which gives the flame its blue color as it does in propane) is known to cause asphyxia (severely deficient supply of oxygen) and death. It typically contains impurities and additives including radon and other radioactive materials.



Radon concentrations, $Bq \cdot m^{-2}$

a



Annual effective dose, $mSv \cdot y^{-1}$

b

Fig. 3. Average radon concentrations (*a*) and annual effective dose (*b*) in different dwellings supplied and not supplied with natural gas.

Conclusion

This study concluded that indoor radon levels, radon exhalation rate and the annual effective dose in dwellings supplied with natural gas are higher than their values recorded in dwellings not supplied with the natural gas. Improvement of ventilation of such compartments is suggested to improve the air quality and reduce the risk of radon inhalation.

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Х. А. Абдель Гані, Д. Х. Шабаан

Фізичне відділення, факультет мистецтва, науки і освіти,
Каїрський державний університет «Айн-Шамс», Каїр, Єгипет

ЧИ ПІДВИЩУЄ РАДОН, ЩО МІСТИТЬСЯ В ПРИРОДНОМУ ГАЗІ, ЙОГО РІВЕНЬ УСЕРЕДИНІ ПРИМІЩЕНЬ?

Натуральний газ містить головним чином метан та кількість, що змінюється, інших вуглеводнів, двоокису вуглецю та інших домішків, таких як азот, сірководень. Газ використовується в будинках та промисловості як переважаюче джерело енергії порівняно з вугіллям та нафтою. Оскільки природний газ знаходиться в природних формаціях на великих глибинах або в інших підземних вуглеводневих резервуарах, він потенційно може бути забруднений радоном. У даній роботі поставлено задачу вимірювання концентрації радону всередині житлових приміщень, до яких надходить природний газ, порівняно з тими, куди він не надходить, де рівень радону оцінювався з використанням твердотільних ядерних трекових детекторів (CR-39). Результати вказують на те, що концентрації значно вищі в приміщеннях, де використовується природний газ, а саме 252,30 проти 136,19 Бк · м$^{-3}$ в приміщеннях, де природний газ не використовується (P <0,001). Середня величина швидкості випаровування була 0,02 ± 6,34 · 10^{-4} Бк · м$^{-2}$ · год$^{-1}$ у приміщеннях, де використовується природний газ, і 0,01 ± ± 0,008 Бк · м$^{-2}$ · год$^{-1}$, в приміщеннях, де він не використовується. Спостерігали також істотну різницю в середніх річних ефективних дозах: 4,33 і 2,34 мЗв · рік$^{-1}$ відповідно. Таким чином, дані вказують на те, що природний газ є потенційним джерелом радону всередині приміщення.

Ключові слова: природний газ, концентрація радону, швидкість випаровування радону, ядерні трекові детектори, річна ефективна доза.

Х. А. Абдель Гани, Д. Х. Шабаан

Физическое отделение, факультет искусства, науки и образования,
Каирский государственный университет «Айн-Шамс», Каир, Египет

ПОВЫШАЕТ ЛИ РАДОН, СОДЕРЖАЩИЙСЯ В ПРИРОДНОМ ГАЗЕ, ЕГО УРОВЕНЬ ВНУТРИ ПОМЕЩЕНИЙ?

Натуральный газ содержит главным образом метан и включает изменяющиеся количества других углеводородов, двуокиси углерода и другие примеси, такие как азот, сероводород. Газ используется в домах и промышленности как предпочтительный источник энергии по сравнению с углем и нефтью. Поскольку природный газ находится в природных формациях на больших глубинах или в других подземных углеводородных резервуарах, он потенциально может быть загрязнен радоном. В данной работе поставлена задача измерения концентрации радона внутри жилых помещений, в которые поставляется природный газ, по сравнению с теми, куда он не поставляется, где уровень радона оценивался с использованием твердотельных ядерных трековых детекторов (CR-39). Результаты указывают на то, что концентрации значительно выше в помещениях, где используется природный газ, а именно 252,30 против 136,19 Бк · м$^{-3}$ в помещениях, где природный газ не используется ($P < 0{,}001$). Средняя величина скорости испарения была $0{,}02 \pm 6{,}34 \cdot 10^{-4}$ Бк · м$^{-2}$ · ч$^{-1}$ в помещениях, где используется природный газ, и $0{,}01 \pm 0{,}008$ Бк · м$^{-2}$ · ч$^{-1}$, в помещениях, где он не используется. Отмечали также существенную разницу в средних годовых эффективных дозах: 4,33 и 2,34 мЗв · год$^{-1}$ соответственно. Таким образом, данные указывают на то, что природный газ представляет потенциальный источник радона внутри помещения.

Ключевые слова: природный газ, концентрация радона, скорость испарения радона, ядерные трековые детекторы, годовая эффективная доза.

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