Studying the Variation of Radon Level in Some Houses in Alexandria City, Egypt

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ABSTRACT

Inhalation of indoor radon has been recognized as one of the health hazards. In the present work a set of indoor radon measurements was carried out, in different Egyptian houses in Alexandria city, built of the same type of building materials, using time–integrated passive radon dosimeters containing LR-115 Type II solid state nuclear track detector. Measurements were carried out from October 2007 to June 2008. The results show that, the radon concentrations and the annual effective dose in these houses varied from (38.62 to 120.39) Bq m$^{-3}$ and (0.96 to 3.06) mSv y$^{-1}$ respectively. The mean values of radon concentrations in living rooms, bedrooms, bathrooms, and kitchens were: (50.93±7.14), (63.75±7.63), (105.36±14.67) and (82.38±8.35) Bq m$^{-3}$ respectively. Also the mean values of annual effective dose were (1.26±0.17), (1.58±0.185), (2.63±0.36) and (2.05±0.20) mSv y$^{-1}$, respectively. This data shows that, bathrooms and kitchens have significantly higher radon concentrations and annual radon dose.

Key Words: Radon concentration, LR-115 Type II detector, Passive radon monitors, Annual effective dose.

INTRODUCTION

In recent years, substantial attention has been paid to radon, particularly to the problems of exposure to radon and its progeny in building and dwellings. Nationwide measurements of radon activities in the indoor air of dwellings are continuously presented all over the world (1,2,3). Radon is a naturally occurring odorless, colorless, tasteless, and imperceptible to senses and chemically inert gas which is produced continuously from the natural decay $^{238}$U, $^{235}$U and $^{323}$Th. The radioisotope $^{222}$Rn, produced from the decay of $^{238}$U, is the main source (approximately 65 %) of internal radiation exposure to human life (ICRP, 1993). The measurement of radon in man's environment is of interest because of its alpha emitting nature. Radon decays with a half-life of 3.8 days into a series of short-lived daughter produced out of which $^{218}$Po and $^{214}$Po emit high-energy alpha particles which are highly effective in damaging tissues. The fact that radon, when inhaled during breathing can cause lung cancer in human beings is known since a long time ago (4,5). More than half of the radiation dose of natural origin of the population originates from radon (6). The general effects of radon to the human body are caused by its radioactivity and consequent risk of radiation-induced cancer. As an inert gas, radon has a low solubility in body fluids which lead to a uniform distribution.
of the gas throughout the body. Radon gas and its solid decay products are carcinogens. The greatest health risks come from exposure to the inhaled solid radon gas decay products that are produced during the radioactive decay of radon gas. Two of these decay products, polonium-218 and 214, present a significant radiological hazard. Once the radioactive decay products are inhaled into the lung, they undergo further radioactive decay, releasing small bursts of energy in the form of alpha particles that can either cause DNA breaks or create free radicals.

Most of our time is spent within buildings; therefore, the measurement and limitation of radon concentration of buildings are important\(^{7,8}\). The main natural sources of indoor radon are soil, building materials (sand, rocks, cement, etc.), tap water, natural energy sources used for cooking like (gas, coal, etc.) which contain traces of \(^{238}\)U. The topography, house construction type, soil characteristics, ventilation rate, wind direction, atmospheric pressure and even the life style of people. The dwellers may inhale air polluted with radon and its short-lived progeny, which can enter the lungs during inhalation and then undergo radioactive decay thereby, causing physical damage leading to chemical damage and ultimately biological damage. The continuous damage produced by alpha particles emitted from radon in lungs may cause cancer. The knowledge of radon levels in building is important in assessing population exposure. Radon in indoor spaces may originate from exhalation from rocks and soils around the building or from construction materials used in walls, floors, and ceilings. Indoor radon concentrations are almost always higher than outdoor concentrations. Once inside a building, the radon cannot easily escape. The sealing of buildings to conserve energy reduces the intake of outside air and worsens the situation. Radon levels are generally highest in cellars and basements because these areas are nearest to the source and are usually poorly ventilated. Radon can seep out of the ground and build up in confined spaces, particularly underground, e.g. in basements of buildings, caves, mines etc, and ground floor buildings. High concentrations can also be found in buildings because they are usually at slightly lower pressure than the surrounding atmosphere and so tend to suck in radon (from the soil) through cracks or gaps in the floor.

In the present investigations, the passive technique using the Solid State Nuclear Track Detectors (SSNTDs) has been utilized for the comparative study of the indoor radon level in the dwellings of Alexandria, Egypt. Nuclear track detection technique based on radon measurement with LR-115 type II detector was used during the currently conducted study because of its simplicity and long-term integrated read out, high sensitivity to alpha-particle radiation ruggedness, availability, ease of handling and low cost. The principle of this technique is based on the production of track in the detector due to alpha particles emitted from radon and its progeny. After exposure the tracks are made visible by chemical etching and counted manually under the optical microscope. The measurement track density is then converted into radon concentration. Also the annual effective dose received by the population has been assessed in the light of guidelines given by the International Commission on Radiological Protection\(^9\).

**DERIVATION OF THE INDOOR RADON EFFECTIVE DOSE RATES**

In order to estimated the annual effective doses indoors, one has to take into account the conversion coefficient from absorbed dose in air to effective dose and the indoor occupancy
factor. In the UNSCEAR 2000 Report, a value of 9.0 nSv h\(^{-1}\) per Bq m\(^{-3}\) was used for the conversion factor (effective dose received by adults per unit \(^{222}\)Rn activity per unit of air volume), 0.4 for the equilibrium factor of \(^{222}\)Rn indoors and 0.8 for the indoor occupancy factor. Hence, the effective dose rate indoors in units of m Sv y\(^{-1}\), \(H_E\), is calculated by the following formula:

\[ H_E = C_{Rn} \cdot F \cdot T \cdot D \] (1)

Where \(C_{Rn}\) is the measured \(^{222}\)Rn concentration (in Bq m\(^{-3}\)), \(F\) is the \(^{222}\)Rn equilibrium factor indoors (0.4), \(T\) is the indoor occupancy time \((0.8 \times 24 \times 365.25 = 7010 \text{ h y}^{-1}\)), and \(D\) is the dose conversion factor \((9.0 \times 10^{-6} \text{ mSv h}^{-1} \text{ per Bq m}^{-3}\) ). As an arithmetic example, for a measured 222Rn concentration of 40.0 Bq m\(^{-3}\) the above formula yield an effective dose equivalent to the population which is equal to 1.0 mSv y\(^{-1}\).

**EXPERIMENTAL TECHNIQUE**

In the present investigations the indoor \(^{222}\)Rn concentration has been studied in 10 hoses. The houses were carefully chosen so that the construction and operation do not vary significantly. The dwellings under study were built, in general using different materials, cement, sand, stones, and bricks, iron structure, marble and concrete as the construction materials. Several of these materials are expected to contribute significantly to sources of indoor radon. Each house having from two to three rooms with size approximately \((3 \times 4 \times 3)\) m\(^{3}\) with one window and a door. A room without window is considered to be poorly ventilated while that with one or more windows with ventilators is well ventilated. Experimental method for radon detection and measurement are based on alpha-counting of radon and its daughters. Active and passive devices are available in the literature for this purpose. In the present investigations we have utilized the passive method using the SSNTDs. which are sensitive to alpha particles in the energy range of the particle emitted by Radon. SSNTDs also have the advantage to be mostly unaffected by humidity, low temperatures, moderate heating and light \(^{10}\).

The LR-115 Type 2 (Pelliculable) plastic track detectors each with a size of about (1.5 cm × 2 cm) fixed at the top inside the cylindrical can. The sensitive lower surface of the detector is freely exposed to the emergent radon so that it is capable of recording the alpha-particles resulting from the decay of radon in the can. The radon detectors were suspended at the center of the room. On an average, about 80 LR-115 type II detector, were distributed inside the houses of each selected site. These houses are chosen to be representative of the region of Alexandria. In each house, at least four detectors were placed in different rooms i.e., living room, bedroom, kitchen, and bathroom, at a height of about 3 m above the floor. The exposure time in all houses was almost from October 2007 to June 2008, this period covers almost the whole year. After 6 months exposure, the detectors were subjected to chemical processing in a 10 M analytical grade sodium hydroxide solution at (60 ±1)ºC, for 90 min, in a constant temperature water bath to enlarge the latent tracks produced by alpha particles from the decay of radon. After the etching, the detectors were washed for 30 minutes with running cold water, then with distilled water and finally with a 50% water/alcohol solution. After a few minutes of drying in air, the detector were ready for track counting. The etched tracks were counted using an optical microscope (Zeiss at 400× magnification). The area of
one field of view was calculated by stage micrometer and the track density was calculated in terms of number of tracks per cm$^{-2}$. The average background track density was determined by processing an unexposed films LR-115 type II detector under identical etching condition. The measured track densities were corrected for background. The errors ($\pm 1\sigma$) in the track densities were calculated by multiplying track density with $\left(\frac{1}{N}\right)^{1/2}$, where $N$ is the total number of tracks counted in a sample. In order to obtain a reasonably good statistics of tracks, 70–130 fields of view were selected randomly on each of the detector surface. The track densities of the two detectors in each dosimeter, installed at a location, were averaged. The track densities were then converted into radon concentration by applying the conversion factor for LR-115 type II detectors in the can-technique dosimeters as $0.032 \text{ tracks cm}^{-2} \text{ d}^{-1}$ per Bq m$^{-3}$. The calibration process for the dosimeters used in this survey was carried out at the Radiation laboratory of physics department in faculty of science Alexandria University, Egypt. Where a number of LR-115 type II detectors inside cylindrical can exposed to a known activity concentration of $^{226}\text{Ra}$, C°, (radon source).

**RESULTS AND DISCUSSION**

Table (1) summarizes the results of indoor radon concentration levels, and the annual absorbed dose, measured in different compartments (living room, bedroom, bathroom, and kitchen), of ten different houses in Alexandria city. Where the observation have been taken from October, 2007 to June, 2008. The data show that the indoor concentration obtained in the present investigations, varies from (38.62 to 120.39) Bq m$^{-3}$, with overall average value $(75.60 \pm 9.44)$ Bq m$^{-3}$, which is much lower than the recommended ICRP action level of 200-600 Bq m$^{-3}$ (ICRP, 1993). The lowest value concentration was found in the living room, 38.62 Bq m$^{-3}$, whereas the highest concentration was found in the bathroom, 120.39 Bq m$^{-3}$. The annual effective dose equivalent from the corresponding measured radon concentration in different houses has been calculated using equation 1, which varies from (0.96 to 3.06) mSv y$^{-1}$ with an average value of $(1.89 \pm 0.23)$ mSv y$^{-1}$. The lowest value was observed in a living room, while the highest was in the bathroom. In the present survey the annual effective dose received by the resident less than the range of action level (3-10 mSv y$^{-1}$) recommended by ICRP (1993). The comparison of annual absorbed dose in the same compartments (living room, bedroom, bathroom and kitchen) for different hoses is presented in Figure (1). The results show that the annual absorbed dose varied with the location. The highest values were observed in bathrooms in the range 2.18 to 3.06 mSv y$^{-1}$, that are probably due to water works and the building materials, which are usually considered as important income paths of radon in building and they can consequently increases the radon component. The lowest values were found in living room in the range from 0.96 to 1.56 mSv y$^{-1}$, which is probably due to high ventilation. The mean value of the radon concentration in living rooms, bedrooms, bathrooms, and kitchens were: $\{50.93 \pm 7.14\}$, $\{63.75 \pm 7.63\}$, $\{105.36 \pm 14.67\}$ and $\{82.38 \pm 8.35\}$ Bq m$^{-3}$ respectively (Figure 2a). The mean value of the annual effective dose equivalent from the corresponding measured radon concentration, were: $(1.26 \pm 0.17)$, $(1.58 \pm 0.185)$, $(2.63 \pm 0.36)$ and $(2.05 \pm 0.20)$ mSv y$^{-1}$, respectively (Figure 2b).

The results indicate that radon concentrations in some compartments like kitchens and bathrooms, in all apartments we investigated, were significantly higher than the radon concentrations measured in living rooms and bedrooms, whereas no significant difference was
observed between kitchens versus bathrooms and bedrooms versus kitchens. Although kitchens and bathrooms are constructed mainly from the same skeletal building materials (concrete and cement blocks), the finishing materials used in such compartments, largely differ from that used in other locations within the same apartment. Ceramic, in particular is used extensively to replace the traditional painting materials, commonly used in living room and bedrooms (11). Previous reports have indicated that ceramic is a potential source of radon, from where radon is mainly emerging from the decay of thorium and uranium in these materials (12). Another factor explaining the high levels of radon and exhalation rates in these compartments, are the poor ventilation status due to the relatively narrow openings. Using natural gas in houses (13), and supplying kitchens and bathrooms with water originated from underground sources are considered as a potential source for indoor radon (14).

CONCLUSION

This work reports that kitchens and bathrooms have relatively high their radon content compared to other compartments of the same dwelling. It is suggested that improvement of ventilation in such compartments is easily possible by simply reducing radon content of their ambient air. The observed level of the indoor radon concentration in Alexandria City is within the permissible level as set by monitoring agencies of different countries. Consequently, the health hazards related to radiation are expected to be negligible. Occupants of these dwellings are therefore, relatively safe. Proper regulatory standards like natural and forced ventilation should be implemented to make the dwellings more clean and safe. It is encouraged to carry similar studies in other regions in Egypt.

Acknowledgments

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References

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**Figure Captions**

Figure (1): Comparison of annual absorbed dose in the same location for ten houses (mSv y⁻¹).

Figure (2): The mean radon concentration (A) and annual absorbed dose (B) in different rooms.

Table (1): The radon concentration in ten houses in Alexandria city (Bq/m³). (from October, 2007 to June, 2008)
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Figure (2): The mean radon concentration (A) and annual absorbed dose (B) in different rooms.