Hindawi Publishing Corporation
Science and Technology of Nuclear Installations
Volume 2015, Article ID 738019, 5 pages
http://dx.doi.org/10.1155/2015/738019

*Research Article*

# Monitoring of $^{220}$Rn Concentrations in Buildings of Kufa Technical Institute, Iraq

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Received 7 November 2015; Revised 19 November 2015; Accepted 22 November 2015

Academic Editor: Massimo Zucchetti



This paper presents the measurements of thoron and the progeny in fifteen buildings in Kufa Technical Institute, Iraq, from June 2015 to April 2015 using RAD-7 detectors. Also, annual effective dose rate was calculated in all buildings under study. The thoron concentration varies from 05.35 ± 0.58 Bq/m$^3$ to 53.50 ± 1.82 Bq/m$^3$ with an average 18.39 ± 4.18 Bq/m$^3$. The concentration of thoron daughters was found to vary from 0.14 mWL to 1.44 mWL with an average 0.53 ± 0.11 mWL. The annual effective doses due to thoron mainly vary from 0.042 mSv/y to 0.81 mSv/y with an average 0.20 ± 0.06 mSv/y. The preliminary results in this study indicate that they may be suitable for evaluating the indoor $^{220}$Rn and its progeny concentrations whenever the public exposure to $^{220}$Rn and its progeny is taken into account. During this survey, the continuous difficulty in measuring thoron was also pointed out, due to its short half-life and faults in the measuring system.

## 1. Introduction

Radon isotopes are chemically inert radioactive gases that occur in the environment as a result of the decay of radioactive elements in soil and minerals [1, 2]. Thoron ($^{220}$Rn) is one of three naturally occurring radon isotopes which results from the decay of thorium $^{232}$Th series. It has a half-life equal to 55 seconds. In indoor environments, the air mixing time is usually much larger than the half-life of $^{220}$Rn; the $^{220}$Rn concentration is highly nonuniform, so it is difficult to obtain a representative value of indoor $^{220}$Rn concentrations [3]. Moreover, from the view of dose contribution, $^{220}$Rn progeny is much more important than $^{220}$Rn. Therefore, it is desirable to know the concentrations of $^{220}$Rn progeny. Thoron can still be a hazard since its progeny $^{212}$Pb with a half-life of 10.6 h can accumulate to significant levels in breathable air [4]. The main source of the indoor thoron concentration is the surrounding building material. In the traditional dwellings, this is the bare soil floor, either soil in cave dwellings or unburned adobe bricks and unplastered stone in aboveground dwellings. It is assumed that the inhalation dose to the human beings from thoron and its progeny is negligible although recent studies in many countries have revealed that this may not be entirely correct [5]. Thoron and its progeny contribute little to the radiation dose in normal background region due to its small half-life. Increased concentrations of thoron ($^{220}$Rn) were recently measured in residential traditional dwellings in China [6–8], India [9, 10], and Iraq [11]. The aim of the present work is to determine the thoron concentration in buildings of Kufa Technical Institute using RAD-7 (radon monitoring system) of Durridge Company (USA). Also Thoron progeny (in mWL) and annual effective dose (in mSv/y) were calculated using standard equations found in ICRP and UNSCEAR.

## 2. Study Area

Kufa Technical Institute was established in 1980, with location of latitude 32°3′34″N and longitude 44°24′18″E with a total area 268035 m$^2$ [12], shown in Figure 1.

The institute includes nearly fifteen buildings which are Pharmacy Department, dwelling, Cars Department, workshops, Student Housing, Analyses Departments, incubation, Electricity Department, Deanship of Institute, Deanship of

Table 1: Sites of measurements in studied area for taking samples.

| No. | Name of Building | Code of Building | Coordinates | |
|---|---|---|---|---|
| | | | Lat. (deg) | Long. (deg) |
| 1 | Pharmacy Department | B1 | 44°40′48.04″N | 32°05′69.93″E |
| 2 | Dwelling | B2 | 44°40′45.22″N | 32°05′92.29″E |
| 3 | Cars of Department | B3 | 44°40′58.78″N | 32°05′72.86″E |
| 4 | workshops | B4 | 44°40′60.89″N | 32°05′75.52″E |
| 5 | Student Housing | B5 | 44°40′41.61″N | 32°05′91.93″E |
| 6 | Analyses Departments | B6 | 44°40′47.06″N | 32°05′72.58″E |
| 7 | Incubation | B7 | 44°40′44.51″N | 32°05′83.73″E |
| 8 | Electricity Department | B8 | 44°40′50.79″N | 32°05′73.02″E |
| 9 | Deanship of Institute | B9 | 44°40′59.04″N | 32°05′78.78″E |
| 10 | Deanship of Healthy Technical | B10 | 44°40′46.15″N | 32°05′80.50″E |
| 11 | School | B11 | 44°40′57.49″N | 32°06′03.53″E |
| 12 | Agricultural Department | B12 | 44°40′53.13″N | 32°05′96.67″E |
| 13 | Mechanics of Department | B13 | 44°40′57.26″N | 32°05′74.36″E |
| 14 | Nursing Department | B14 | 44°40′47.13″N | 32°05′90.67″E |
| 15 | Community Health Department | B15 | 44°40′47.06″N | 32°05′72.58″E |

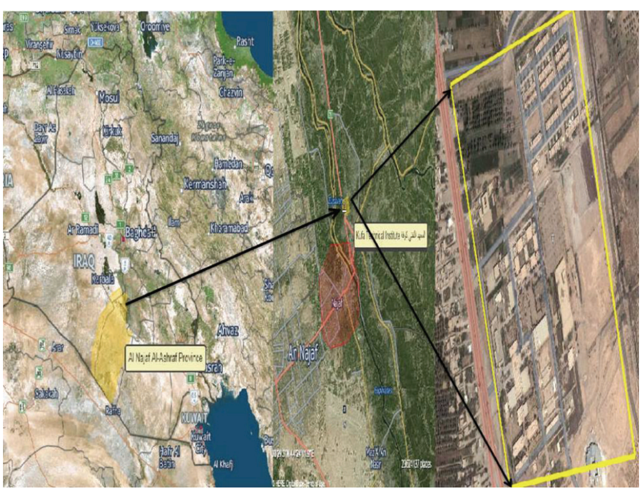

Figure 1: Map of Kufa Technical Institute.

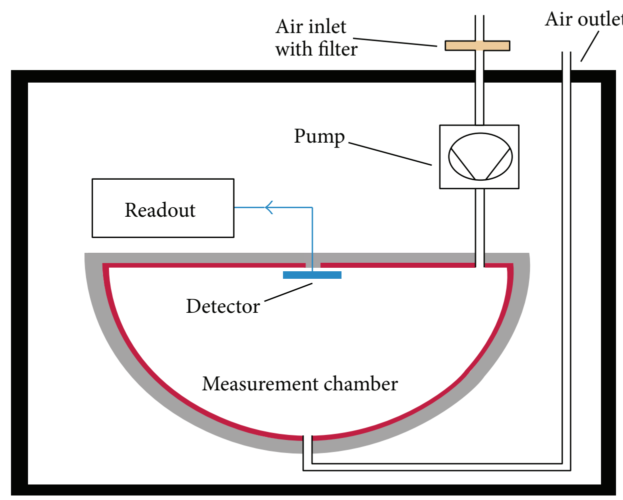


Figure 2: Measurement chamber of the RAD-7 detector [13].

Healthy Technical Department, school, Faculty of Agriculture, Mechanics Department, Nursing Department, and Community Health Department. The study area was chosen for the following reasons: these buildings are easy to access and it is easy to deal with educated people and that will reduce the losses in distributed detectors; it is easy to distribute and collect detectors in governmental buildings compared to other places; these buildings are highly populated by people who spend long time in the buildings and these buildings are located in the center of Najaf Governorate and form a large portion of Najaf city.

## 3. Materials and Methods

This title includes important steps (materials and methods), for measuring the thoron concentrations in building under study, location and collection of the samples, experimental setup, and calculation of all the thoron progeny and the annual effective dose.

*3.1. Location and Collection of the Samples.* In the present study 15 buildings were chosen as fair distribution in Kufa Technical Institute. The buildings were determined using GPS as shown in Table 1; Table 1 showed the sites of measurement in studied area for taking samples designed according to name of building, code of building, and coordinates.

*3.2. Experimental Setup for Measurement of Thoron Concentration.* The RAD-7 internal sample cell is a 0.7 $dm^3$ conducting hemisphere with a 2200 V potential relative to the detector that is placed at the center of the hemisphere (see Figure 2).

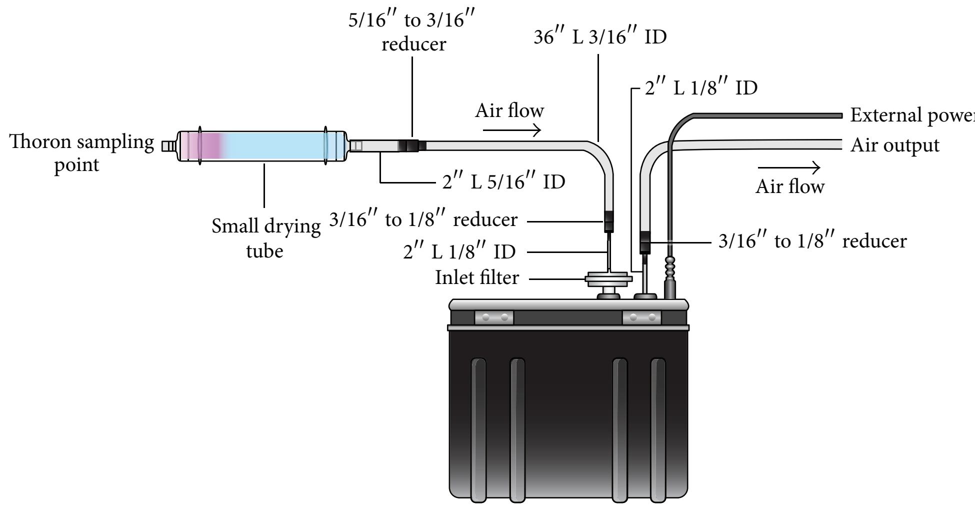


Figure 3: Experimental setup for operating the counting system for thoron measurements.

The detector operates in external relative humidity ranging from 0% to 95% and internal humidities of 0% to 10% with the low detection threshold of 4 Bq/m$^3$ and an upper linear detection limit of 400 kBq/m$^3$. The detector was calibrated with an accuracy of 5%. RAD-7 separates $^{222}$Rn and $^{220}$Rn signals by their progenies' unique $\alpha$-particle energies with little cross interference which means that it counts two isotopes at the same time [13]. RAD-7 responds virtually instantly to the presence of thoron. Its time constant for the response to thoron is less than 1 min. As mentioned above, the RAD-7 calculates thoron concentration on the basis of the count rate in the alpha line of $^{216}$Po (energy 6.78 MeV), the first decay product of thoron gas. Thoron calibration precision is ±25%. The measurements were done using the "thoron protocol" with a 5 or 30 min repeating cycle [13]. For each thoron concentration the experiment was repeated about 24 times (one day). Figure 3 shows experimental setup of RAD-7 detector for measuring thoron concentration.

*3.3. Calculation of Thoron Progeny Concentration and Annual Effective Dose.* The thoron progeny levels or PAEC values (in mWL) were calculated by using the equation [14, 15]

$$\text{PAEC (mWL)} = \frac{C_T \times F_T}{3.7}, \quad (1)$$

where $F_T$ is equilibrium factor for thoron having the value (0.1) [16].

The annual effective doses due to the exposure to thoron and progeny in the building of study area were calculated by the formula [17]

$$\begin{aligned} &\text{Annual effective dose}\left(\text{mSv/y}\right) \\ &\quad = C_T\left(\text{Bq/m}^3\right) \times F \times t\,(\text{h}) \\ &\quad\quad \times D\,(\text{nSv/h})\text{ per}\left(\text{Bq/m}^3\right), \end{aligned} \quad (2)$$

where $C_T$ is the measured thoron concentration (in Bq m$^{-3}$), $F$ is the average of equilibrium factor for thoron and progeny [18], $t$ is the indoor occupancy time (in dwelling = 7000 h/y but in other buildings = 2190 h/y), and $D$ is the dose conversion factor, which converts activity concentration to effective dose rate, $D = 40$ nSv/h per Bq/m$^3$.

*3.4. Statistical Evaluation.* Statistical analysis for evaluation of the results was done by calculating arithmetic mean and standard deviation for thoron concentrations, thoron progeny concentrations, and annual effective dose measurements. All these measurements had been done for all samples under study. Results were expressed as mean ± standard deviation for each building. The results were evaluated by Student's unpaired $t$-tests.

## 4. Results and Discussion

The aim of the studies has been to find an approximate mean and range of thoron concentrations, thoron progeny, and annual effective dose in buildings in order to assess the possible health hazards from thoron indoors in buildings of Kufa Technical Institute, Iraq. Table 2 represents the measurement of the mean thoron concentrations values ± standard deviation (SD) in Bq/m$^3$ in buildings of Kufa Technical Institute. The value of thoron concentration varies from 05.35 to 53.50 Bq/m$^3$ with an average of 18.39 ± 4.18 Bq/m$^3$. Also from Table 2, it is found that for some of the buildings such as B13, B14, and B15 thoron concentrations do not appear, because the value of thoron concentrations is less than value of detection limit which is equal to 4 Bq/m$^3$ [13]. Figure 4 shows the percentage of thoron concentrations in all buildings under study. Table 3 and Figure 5 show the mean values of thoron progeny concentrations and the annual effective dose in building under study which was calculated for each sample using (1) and (2), respectively. The thoron

Table 2: Results of thoron concentrations in study area.

| No. | Code Building | Average of Thoron Concentrations in (Bq/m$^3$) |
|---|---|---|
| 1 | B1 | 53.50 ± 1.82 |
| 2 | B2 | 32.10 ± 1.41 |
| 3 | B3 | 21.40 ± 1.16 |
| 4 | B4 | 18.73 ± 1.10 |
| 5 | B5 | 17.83 ± 1.05 |
| 6 | B6 | 16.80 ± 1.02 |
| 7 | B7 | 14.26 ± 0.81 |
| 8 | B8 | 12.04 ± 0.87 |
| 9 | B9 | 10.68 ± 0.41 |
| 10 | B10 | 10.03 ± 0.79 |
| 11 | B11 | 08.03 ± 0.71 |
| 12 | B12 | 05.35 ± 0.58 |
| 13 | B13 | BDL |
| 14 | B14 | BDL |
| 15 | B15 | BDL |
| Average ± S.D | | **18.39 ± 4.18** |

Table 3: Results of thoron progeny concentration and annual effective dose in study area.

| No. | Code Building | PAEC (mWL) | Annual effective dose (mSv/y) |
|---|---|---|---|
| 1 | B1 | 1.44 | 0.42 |
| 2 | B2 | 0.86 | 0.81 |
| 3 | B3 | 0.57 | 0.16 |
| 4 | B4 | 0.51 | 0.15 |
| 5 | B5 | 0.48 | 0.14 |
| 6 | B6 | 0.45 | 0.13 |
| 7 | B7 | 0.38 | 0.11 |
| 8 | B8 | 0.32 | 0.09 |
| 9 | B9 | 0.28 | 0.08 |
| 10 | B10 | 0.27 | 0.07 |
| 11 | B11 | 0.21 | 0.06 |
| 12 | B12 | 0.14 | 0.04 |
| 13 | B13 | — | — |
| 14 | B14 | — | — |
| 15 | B15 | — | — |
| Average ± S.D | | **0.53 ± 0.11** | **0.20 ± 0.06** |

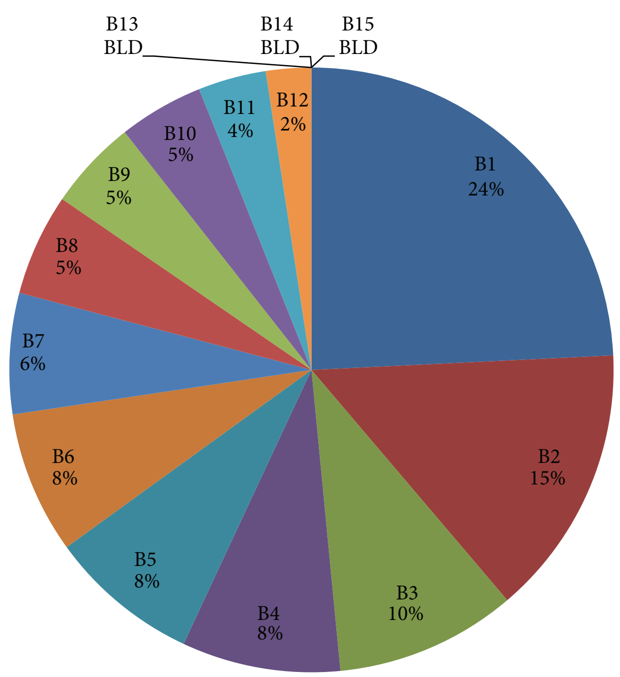


Figure 4: The percentage of the thoron concentrations in all buildings of Kufa Technical Institute.

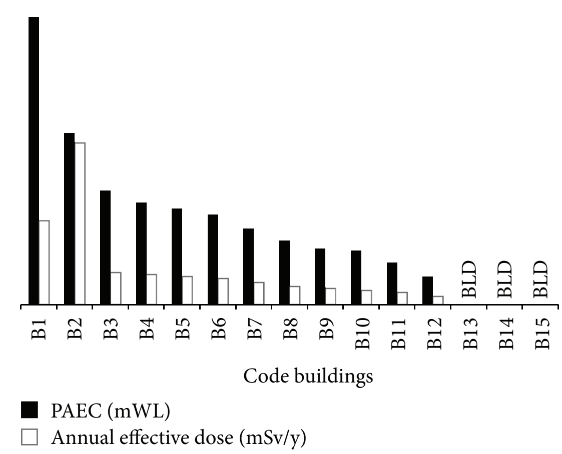


Figure 5: Results of thoron progeny concentrations and the annual effective dose in building under study.

progeny concentrations in the buildings under study varied from 0.14 to 1.44 mWL with an average of 0.53 ± 0.11 mWL, while the annual effective dose received by the inhabitants in the buildings under study varied from 0.04 to 0.42 mSv/y with an average of 0.20 ± 0.06 mSv/y. The results vary because different factors determine indoor thoron concentrations such as the different building material and ventilation rate and one important factor is the geology. The results of thoron concentrations, thoron progeny concentrations, and the annual effective dose are lower than the safe limits recommended by ICRP, 1993, and ICRP, 2011 [14, 19]. The average of thoron concentration obtained in this study was compared with other similar studies in literature and this is presented in Table 4.

## 5. Conclusion

Indoor thoron concentrations, thoron progeny concentrations, and annual effective dose received by the general public have been determined for the selected residences of buildings in Kufa Technical Institute and found under the safe limit laid down by ICRP and UNSCEAR. Present study concludes that

Table 4: Comparison of thoron concentration rate of the present study with other studies of the different countries.

| Number | Country | Average of thoron concentrations (Bq/m$^3$) | References |
|---|---|---|---|
| 1 | Romania | 53 | [20] |
| 2 | India | 10.6, 14.4 | [21, 22] |
| 3 | Iran | 34 | [23] |
| 4 | Present study | 18.39 | — |

the buildings are safe without posing significant radiological threat to the human beings.

## Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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