บทความวิจัย

การตรวจวัดอัตราการปลดปล่อยเรดอนจากหมอนยางพารา ที่สุ่มตัวอย่างจากตลาดออนไลน์ในประเทศไทย

Measurement of ^{222}Rn Exhalation Rate from Natural Rubber Latex Pillows Randomed from Online Market in Thailand

สันติ รักษาวงศ์[1*] พชิรารัฐ โสลา[2] ฤทธิรอน สำราญ[2] และปัทมา พิศภักดิ์[3]

Santi Raksawong[1*], Phachirarat Sola[2], Rittiron Samran[2] and Pattama Pisapak[3]

บทคัดย่อ

เรดอนเป็นก๊าซกัมมันตรังสีที่มีอยู่ตามธรรมชาติและเป็นที่สนใจทั่วโลกเพราะมีผลกระทบต่อสุขภาพและเพิ่มโอกาสการป่วยเป็นโรคมะเร็งปอดหลังจากได้รับในปริมาณความเข้มข้นสูงเป็นระยะเวลาที่ยาวนาน การศึกษาครั้งนี้เพื่อวัดปริมาณความเข้มข้นของก๊าซเรดอน ปริมาณอัตราการปลดปล่อยและประเมินปริมาณรังสียังผลรายปีที่ได้รับอันเนื่องจากปริมาณก๊าซเรดอน เพื่อนำไปสู่การกำหนดค่ามาตรฐานควบคุมการปนเปื้อนก๊าซเรดอนในผลิตภัณฑ์จากยางพาราในประเทศไทย ตัวอย่างหมอนยางพาราที่สุ่มซื้อจากตลาดออนไลน์ในประเทศไทยถูกเก็บในถังวัดแบบปิดสนิทที่ต่อเข้ากับเครื่อง ATMOS 12 DPX ผลการตรวจวัดพบว่าปริมาณความเข้มข้นสมมูลของก๊าซเรดอนมีค่าระหว่าง 11 ± 2 และ 43 ± 5 Bq m^{-3} และมีค่าเฉลี่ย 17 ± 9 Bq m^{-3} ซึ่งค่าที่วัดได้มีค่าต่ำกว่าค่าสูงสุดที่สามารถปนเปื้อนได้ในอากาศที่ 148 และ 300 Bq m^{-3} ตามมาตรฐาน USEPA และ ICRP ตามลำดับ อัตราการปลดปล่อยก๊าซเรดอนจากหมอนยางพารามีค่าระหว่าง 12 ± 3 และ 60 ± 7 mBq m^{-2} h^{-1} และมีค่าเฉลี่ย 25.7 ± 14.4 mBq m^{-2} h^{-1} นอกจากนี้การประเมินปริมาณรังสียังผลรายปีที่ได้รับ พบว่ามีค่าอยู่ระหว่าง 0.12 ± 0.03 และ 0.43 ± 0.05 mSv y^{-1} ซึ่งยังต่ำกว่าค่าขีดจำกัดของการรับรังสียังผลรายปี สำหรับประชาชนทั่วไป (1.0 mSv y^{-1}) ตามมาตรฐานของ ICRP

คำสำคัญ: ก๊าซเรดอน หมอนยางพารา ผลกระทบด้านสุขภาพจากก๊าซเรดอน การปลดปล่อยก๊าซเรดอน

[1] อ.ดร., สาขาวิชาฟิสิกส์ คณะวิทยาศาสตร์และเทคโนโลยี มหาวิทยาลัยราชภัฏหมู่บ้านจอมบึง ราชบุรี 70150

[2] นักวิทยาศาสตร์นิวเคลียร์ สถาบันเทคโนโลยีนิวเคลียร์แห่งชาติ (องค์การมหาชน) นครนายก 26120

[3] อ.ดร., สาขาวิชาวิทยาศาสตร์ทั่วไป คณะวิทยาศาสตร์เทคโนโลยีและการเกษตร มหาวิทยาลัยราชภัฏยะลา ยะลา 95000

[1] Lecture, Dr., Physics Program, Faculty of Science and Technology, Muban Chombueng Rajabhat University, Ratchaburi, 70150, Thailand

[2] Nuclear Scientist, Thailand Institute of Nuclear Technology (Public Organization), Nakhon Nayok, 26120, Thailand

[3] Lecture, Dr., General Science Program, Faculty of Science Technology and Agriculture, Yala Rajabhat University, Yala, 95000, Thailand

* Corresponding author: E-mail address: santirak@mcru.ac.th

(Received: June 4, 2020; Revised: August 10, 2020; Accepted: August 19, 2020)

Abstract

Radon is a natural radioactive gas, and it is increasingly interesting worldwide because it affects the human healthy and increases lung cancer risk when people receive high concentrations over extended periods of time by inhalation. The study was to measure the radon concentration, determine the radon exhalation rate, and estimate annual effective dose level in order to set up a policy on controlling the contamination of radon in the natural rubber latex products in Thailand, and the radon concentrations were measured from natural rubber latex pillows randomized from online market in Thailand by closed chamber system technique with ATMOS 12 DPX. The results showed that the equilibrium radon concentrations were ranged between 11 ± 2 and 43 ± 5 Bqm^{-3} with an average value of 17 ± 9 Bqm^{-3}. All measured radon concentrations were well below the allowed maximum contamination level of radon concentration in collected samples of 148 and 300 Bqm^{-3}, recommended by the USEPA and the ICRP, respectively. The exhalation rates from natural rubber latex pillows were ranged 12 ± 3 and 60 ± 7 mBq m^{-2} h^{-1} with an average value of 25.7 ± 14.4 mBq m^{-2} h^{-1}. The annual effective doses calculated for inhalation were between 0.12 ± 0.03 and 0.43 ± 0.05 mSv y^{-1}, and also well lower than the annual effective dose for general public (1.0 mSv y^{-1}) recommended by the ICRP.

Keywords: Radon Gas, Natural Rubber Latex Pillow, Health Risks from Radon, Radon Exhalation

Introduction

Radon-222 (^{222}Rn: $T_{1/2}$ = 3.824 days) is a naturally occurring radioactive gas generated from radium-226 (^{226}Ra) in the uranium-238 (^{238}U) decay series. It is one of the potential dangerous radioactive elements, known to be the second cause of lung cancer in the general population after smoking [1]. It emits ionizing radiation and decays its short-lived progeny which are heavy metals such as polonium-218, lead-214, bismuth-214, polonium-214, lead-210, bismuth-210, polonium-210, and stable lead-206 [1–7]. When radon gas and its progeny attracted to particulates in air are inhaled by human beings, they are exhaled and remain in the lungs. The radon and its daughter remaining in the lungs sequentially decay and release high energy alpha and beta particles to damage the lung tissue that is considered as important step in the carcinogenesis process [4, 7].

The radon is a major contributor to the annual effective dose from natural ionizing radiation [2, 5–6]. Because radon results from the natural decay of uranium, the main sources of which are in soils, rocks, plants, water, air, building materials, home accessories etc. It has been increasingly conducted worldwide to measure concentration in natural materials and to determine the exhalation rate and effective dose for government set up a policy on management. In Thailand, there is a little information on radon concentration in building materials and home accessories. For example, Srisuwan *et al*. [8] has been reported the radon concentration, exhalation rate in concrete and phosphogypsum (PG)-containing (50 % w/w) concrete samples. The obtained result showed that the radon concentrations were 119 ± 13 and 631 ± 25 Bq m^{-3} for concrete and PG-containing (50% w/w) concrete, respectively. and exhalation rates were 0.31 and 10.45 Bq m^{-2} h^{-1} for concrete and PG-containing concrete, respectively. Sola *et al*. [9] has also conducted and reported the radon concentration from building materials using in the Bangkok. The radon concentrations were between 12 ± 10 and 492 ± 12 Bq m^{-3}, the radon exhalation rates were range 0.060 ± 0.004 to 11.90 ± 0.31 Bq m^{-2} h^{-1} and high values were from the group of granite tile samples. In the southern Thailand, Kaewtubtim *et al*. [10] has been found the radon concentration, exhalation rate and effective dose in rock samples used for construction at the Yala province. The results showed that the radon concentrations were between 7.01 ± 7.01 and 547.21 ± 44.90 Bq m^{-3}, the radon exhalation rates were between 3.12 ± 0.94 and 165.46 ± 13.58 mBq m^{-2} h^{-1}, and the annual effective doses were between 0.18 ± 0.18 and 13.79 ± 1.13 mSv y^{-1}. The previous studies have shown high values in some building material types indicated that indoor radon concentrations are high.

Now, the natural rubber latex pillows and mattresses have increasingly been used. Because, organic latex stands out from the rest as it is durable, biodegradable, and environmentally friendly. In China and Korea, people believe that the negative ion can prohibit the growth of mildew, mold, and bacteria making the pillows hypoallergenic and antimicrobial in nature and enhance the quality of their sleep, so the monazite powder is added in the natural latex pillows and mattresses [11]. It is an ore containing radioactive thorium to generate the anion production, and it can raise levels of radon emitted [11–12]. When people receive high concentrations over extended periods of time by inhalation, it probably makes an increased lung cancer risk. Thus, radon concentration of the natural rubber latex pillows selected from online market was measured to calculate radon exhalation rate and annual effective dose. The estimation of annual effective dose was compared with the safe limit of health risks recommended by international agencies, which might lead to set up a policy on controlling the contamination of radon in the natural rubber latex products in Thailand.

Methodology

A total of 12 natural rubber latex pillows were collected from online market in Thailand and sent to the Radon Research Laboratory of Thailand Institute of Nuclear Technology (Public Organization) which the excellent and high accuracy measurement method. The radon concentration is carried out using the ATMOS 12 DPX detector calibrated by the Swedish Radiation Protection Authority (SSI), with the counting deviation of ±10 % (1 S.D.). Each natural latex pillow sample was placed in a closed chamber with the volume of 0.11 m^{-3}, and the chamber was connected through two vents to the inlet and outlet of ATMOS 12 DPX as shown in Figure 1. To ensure the chamber did not leak, the closed chamber was performed by evacuating air from the container to –10 bars then leave for 6 h with which the vacuum gauge should remain the same. After leak test, the protection of radon-free air into the chamber, it was filled by allowing the air flow through the activated charcoal canister until the pressure in the chamber is equal outside. The closed chamber was kept for more than 21 days for radon-free air in chamber decayed to low intrinsic background [7], and the radioactive equilibrium between radon and radium was reached. The measurement of emitted radon inside the chamber was for 3 h during equilibrium period.

Radon Exhalation Rate

Because radon exhalation rate is controlled by two main parameters: radon generation (containing radium in the sample) and transport through the solid matrix its porosity, grain size, material sample geometry, etc., one of the possible ways to measure the rate of exhalation from the material sample is by the measuring of the radon concentration in a closed chamber or container [5, 13–14]. The radon exhalation rate, E, which expresses per unit surface area (Bq $m^{-2}h^{-1}$) of a natural material and radon concentration, **C** (Bq m^{-3}) measured in a closed-chamber system are described by several authors [4, 15–16], according to Eq. (1).

$$C(t) = C_0e^{-\lambda t} + C_{eq}(1-e^{-\lambda t}) \tag{1}$$

where C(t), is the radon concentration at time t, C_0 is the initial radon concentration and C_{eq} is equilibrium concentration. After measuring the radon concentration at a given time C(t) and calculating the radon exhalation rate E can be determined by formula:

$$E = \frac{C_{eq}\lambda V}{S} \tag{2}$$

where C_{eq} is equilibrium concentration , λ is radon decay constant ; 2.1×10^{6} (s^{-1}), V is volume of the chamber minus volume of the specimen (m^3), S is external surface area of the source (m^2), and E is radon exhalation rate of the source per unit surface area or mass (Bq m^{-2} h^{-1} or Bq kg^{-1} h^{-1}) [13].

Annual Effective Dose

The annual effective dose from inhalation of radon (AED_{Inh}) releasing from the natural rubber latex pillow is calculated using by Eq. (3) recommended by the United Nations Scientific Committee on Effects of Atomic Radiation [17]:

$$AED_{Inh} = C\times F\times T\times D_f \tag{3}$$

where C is the radon activity concentration (Bq m^{-3}), F is the equilibrium factor between radon and its progenies as 0.4, T is the normal sleeping time as 8 hours per night; 2,920 hr y^{-1} and D_f is the inhalation dose conversion factor for radon as 9.0 μSv hr^{-1} Bq^{-1} m^3 [17]. The estimation of the AED_{Inh} from collected samples was compared with the general public annual effective dose limit, 1.0 mSv y^{-1} recommended by the International Commission on Radiological Protection (ICRP).

Figure 1 The equipment set up to measure radon concentration and radon exhalation rate, which the natural rubber latex pillows were placed inside the closed-chamber with connected to the pulse counting ionization chamber (ATMOS 12 DPX).

Results and Discussions

The measured radon concentration C (t), calculated equilibrium radon concentration C_{eq}, exhalation rate and annual effective does from natural rubber latex pillows which were sampled from Thai's online market are shown in Table 1. The measured and equilibrium radon concentrations are quite same which indicate that the measuring time is closes to equilibrium time of radon and the background in the chamber decayed insurable to zero. The measured radon concentrations ranged between 11 ± 3 and 41 ± 5 Bq m^{-3} with an average value (mean ± S.D) of 17 ± 8 Bq m^{-3}, and the equilibrium radon concentrations calculated from Eq. (2) ranged between 11 ± 2 and 43 ± 5 Bq m^{-3} with an average value (mean ± S.D) of 17 ± 9 Bq m^{-3} All of the results, there is one sample of natural rubber latex pillows in No.3 shown that the radon concentration is slightly higher than the worldwide average of indoor radon concentration as 39 Bq m^{-3}, [17–18]. Normally, the radon should have low in natural rubber latex, but it is probably high from adding some fillers contaminated the radionuclide radium–226 and thorium–232 in the natural rubber latex foam before make the pillows and some materials such as monazite powder [11-12] for protecting the bacteria or dust mites in the pillow.

All measured radon concentrations from the collected pillows were well below the allowed maximum contamination level (MCL) of indoor radon concentration in collected samples of 148 recommended by the USEPA [1] and 300 Bq m^{-3} also recommended by the ICRP [19] and WHO [1].

Table 1 Radon concentration, equilibrium radon concentration, radon exhalation rate and annual effective does from studied samples of natural rubber latex pillows that were available from online market in Thailand.

Sample No.	Measured Radon Concentration, (Bq m^{-3})	Equilibrium Radon Concentration (Bq m^{-3})	Exhalation Rate (mBq m^{-2} h^{-1})	Annual Effective Dose (mSv y^{-1})
1	18 ± 3	19 ± 3	21 ± 4	0.19 ± 0.03
2	18 ± 3	19 ± 3	22 ± 4	0.19 ± 0.03
3	41 ± 5	43 ± 5	60 ± 7	0.43 ± 0.05
4	22 ± 4	23 ± 4	37 ± 7	0.23 ± 0.04
5	13 ± 3	13 ± 3	19 ± 4	0.14 ± 0.03
6	13 ± 2	14 ± 2	22 ± 3	0.14 ± 0.02
7	11 ± 3	12 ± 3	18 ± 5	0.12 ± 0.03
8	11 ± 2	12 ± 2	13 ± 2	0.12 ± 0.02
9	11 ± 3	12 ± 3	12 ± 3	0.12 ± 0.03
10	11 ± 2	11 ± 2	18 ± 3	0.12 ± 0.02
11	15 ± 3	16 ± 3	45 ± 9	0.16 ± 0.03
12	16 ± 3	17 ± 3	21 ± 4	0.17 ± 0.03
Min	11	11	12	0.12
Max	41	43	60	0.43
Mean	17	17	25.7	0.18
S.D.	8	9	14.4	0.09

The exhalation rates of natural rubber latex pillows calculated from Eq. (3) are shown in the Table 1. The boxplots and frequency distributions of equilibrium radon concentration and exhalation rate are shown as Figure 2. The obtained results of exhalation rates ranged 11 ± 3 and 60 ± 7 mBq m^{-2} h^{-1} with an average value (mean ± S.D) of 25.7 ± 14.4 mBq m^{-2} h^{-1} . From frequency distribution of exhalation rate, two samples are higher than others, because the emission of radon from the materials depends upon radium concentration in material, emanation factor, porosity and density of the material [20].

The annual effective doses were found between 0.12 ± 0.03 and 0.43 ± 0.05 mSv y^{-1}, which well lower than the worldwide average annual effective dose from radon inhalation (1.2 mSv y^{-1}) reported by UNCEAR, and limitation of public exposure (1.0 mSv y^{-1}) and the largely radon exposure based on optimization with a reference level (10.0 mSv y^{-1}) recommended by the ICRP [18] and ICRP [21], respectively. Although, annual effective doses are lower than public exposure, but indoor radon concentration in the bedroom are concerned because radon are released from building materials. It can summarize with radon released from the pillow to high radon concentration which has to cause the health effect.

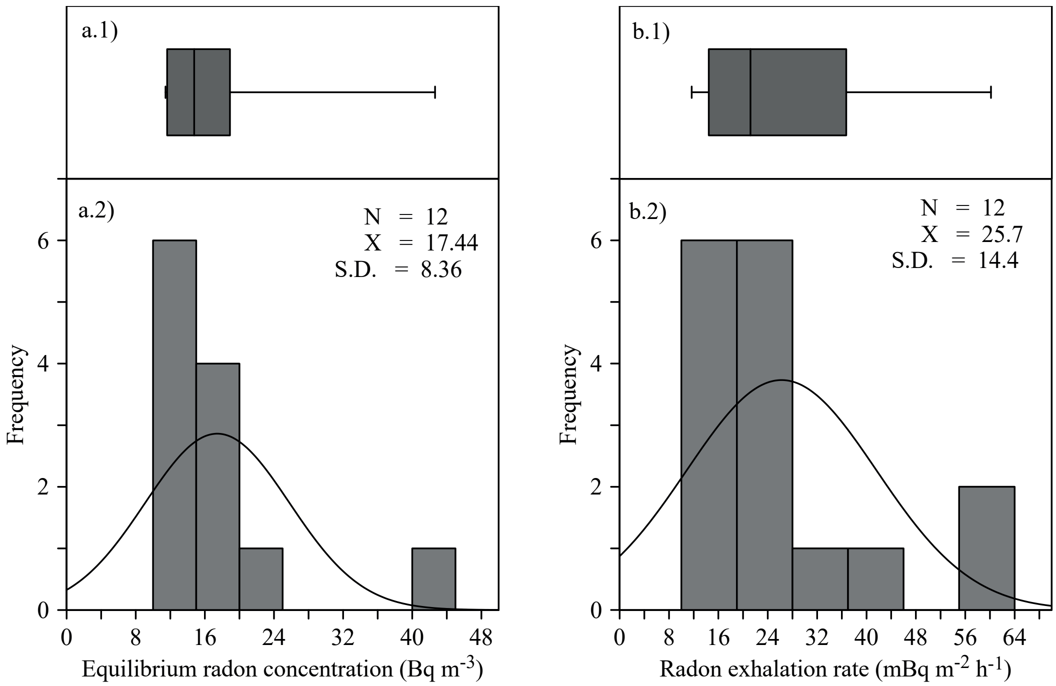

Figure 2 a.1) and b.1) boxplot of equilibrium radon concentration and radon exhalation rate, respectively and a.2) and b.2) frequency distribution of equilibrium radon concentration and radon exhalation rate, respectively

Conclusion

This study shows the equilibrium radon concentrations ranged between 11 ± 2 and 43 ± 5 Bq m^{-3} with an average value of 17 ± 9 Bq m^{-3}. All measured radon concentrations were well below the allowed maximum contamination level of radon concentration in collected samples of 148 and 300 Bq m^{-3}, recommended by the USEPA and the ICRP, respectively. The exhalation rates from natural rubber latex pillows ranged 12 ± 3 and 60 ± 7 mBq m^{-2} h^{-1} with an average value of 25.7 ± 14.4 mBq m^{-2} h^{-1}. The annual effective doses calculated for inhalation were between 0.12 ± 0.03 and 0.43 ± 0.05 mSv y^{-1}, and also well lower than the worldwide average annual effective dose from radon inhalation (1.2 mSv y^{-1}), limitation of public exposure (1.0 mSv y^{-1}) and the largely radon exposure based on optimization with a reference level (10.0 mSv y^{-1}). The measured radon concentrations from natural rubber latex pillows will pose none significantly serious health risks. However, these data must be regarded as preliminary and in the further extensive studies should be done on large scale.

Acknowledgements

All of facilities of this research were supported by Faculty of Science and Technology, Muban Chombueng Rajabhat University and Thailand Institute of Nuclear Technology (Public Organization). We also thank those anonymous reviewers for their insightful suggestion and critical reviews of the manuscript.

Conflict of interest

The authors declare that they have no conflict of interest and this research did not receive any specific grant from any funding agency in the public, commercial or not-for profit sector.

References

[1] World Health Organization (WHO). (2009). *Handbook on Indoor Radon: A Public Health Perspective*. Geneva: WHO Press.

[2] International Commission on Radiological Protection (ICRP). (1993). *Protection Against Radon-222 at Home and at Work*. ICRP Publication 65. Annuals of the ICRP 23(2). Oxford: Pergamon Press.

[3] Fior, L., Corrêa, J. N., Paschuk, S. A., Denyak, V. V, Schelin, H. R., Soreanu Pecequilo, B. R., & Kappke, J. (2012). Activity measurements of radon from construction materials. *AppliedRadiation and Isotopes*, *70*(7), 1407–1410. DOI:10.1016/j.apradiso.2011. 11.036.

[4] Maged, A. F., Ismail, L. Z., & Moussa, N. L. A. (2012). Environmental risk assessment of radon from ceramic tiles. *Radioprotection*, *47*(3), 403–411. DOI:10.1051/radiopro/ 2012011.

[5] Perna, A. F. N., Paschuk, S. A., Corrêa, J. N., Narloch, D. C., Barreto, R. C., Claro, F. D., & Denyak, V. (2018). Exhalation rate of radon-222 from concrete and cement mortar. *Nukleonika*, *63*(3), 65–72. DOI:10.2478/nuka-2018-0008.

[6] Sarrou, I., & Pashalidis, I. (2017). Radon exhalation from granite countertops and expected indoor radon levels. *Journal of Radioanalytical and Nuclear Chemistry*, *311*(1), 913–916. DOI: 10.1007/s10967-016-5108-7.

[7] Stajic, J. M., & Nikezic, D. (2015). Measurement of radon exhalation rates from some building materials used in Serbian construction. *Journal of Radioanalytical and Nuclear Chemistry*, *303*(3), 1943–1947. DOI:10.1007/s10967-014-3726-5.

[8] Srisuwan, T., Wanabonges, P., & Tantasavasdi, C. (2012). The influence of finishing materials on radon exhalation from concrete with phosphogypsum additives. *The Journal of Architectural /Planning Research and Studies*, *9*(2), 105–112.

[9] Sola, P., Srinuttrakul, W., Laoharojanaphand, S., & Suwankot, N. (2014). Estimation of indoor radon and the annual effective dose from building materials by ionization chamber measurement. *Journal of Radioanalytical and Nuclear Chemistry*, *302*(3), 1531–1535. DOI: 10.1007/s10967-014-3716-7.

[10] Kaewtubtim, P., Sola, P., & Kongpakdee, T. (2019). Radon concentration and radon exhalation rate from rock samples used for construction at northern part of Yala province. *Rajamangala University of Technology Krungthep Research Journal*, *13*(2), 187–197.

[11] The Korea Times. (2018). *Tourists exposed to harmful latex in Thailand* (Online). Retrieved 20 March 2020, from http://www.koreatimes.co.kr/www/news/nation/2018/06/356_250111. html.

[12] The Korea Bizwire. (2018). *Radon Detected in 80% of Latex Products* (Online). Retrieved 20 March 2020, from http://koreabizwire.com/radon-detected-in-80-of-latex-products/121374.

[13] Kovler, K. (2007). Measurements of radon exhalation rate for monitoring cement hydration. *Materials and Structures*, *40*(4), 419–430. DOI:10.1617/s11527-006-9149-1.

[14] Hassan, N. M., Hosoda, M., Ishikawa, T., Sorimachi, A., Sahoo, S. K., Tokonami, S., & Fukushi, M. (2009). Radon migration process and its influence factors: review. *Japanese Journal of Health Physics*, *44*(2), 218–231. DOI:10.5453/jhps.44.218.

[15] Krisiuk, E. M. (1980). Airborne radioactivity in buildings. *Health Physics*, *38*(2), 199–202.

[16] Kovler, K., Perevalov, A., Steiner, V., & Metzger, L.A. (2005). Radon exhalation of cementitious materials made with coal fly ash: Part 1 – scientific background and testing of the cement and fly ash emanation. *Journal of Environmental Radioactivity*, *82*(3), 321–334. DOI: 10.1016/ j.jenvrad.2005.02.004.

[17] United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). (2000). *Sources and Effects of Ionizing Radiation, Annex B. I*. UNSCEAR Report to the United Nations General Assembly. New York: United Nations Publication.

[18] International Commission on Radiological Protection (ICRP). (1991). *1990 Recommendations of the International Commission on Radiological Protection*. ICRP Publication 60. Annual of the ICRP 21 (1-3). Oxford: Pergamon Press.

[19]International Commission on Radiological Protection (ICRP).(2007). *The 2007 Recommendations of the International Commission on Radiological Protection*. ICRP Publication 103. Annual of the ICRP 37 (2–4). Oxford: Elsevier Ltd.

[20] Bala, P., Kumar, V., & Mehra, R. (2017). Measurement of radon exhalation rate in various building materials and soil samples. *Journal of Earth System Science*, *126*(2), 31. DOI: 10.1007/ s12040-017-0797-z.

[21] International Commission on Radiological Protection (ICRP). (2014). *Radiological Protection against Radon Exposure*. ICRP Publication 126. Annual of the ICRP 43(3). London: Sage Publications Ltd.