Original Research Article

Radon Concentrationsin the Environments of Some Primary Schools in Khidir City, Al-Muthanna Province, Iraq

Abstract

Indoor radon concentrations in 13 primary schools were conductedin Khidir City, Muthanna Province, Iraq, using LR-115 solid-statenuclear track detector type II. The study aims to estimate indoor radon levels in the internal environment of the classrooms for three months (from 1st September to 30th November 2023). Radon concentrations were varied from (0.1 Bq/m^3) to (14.13 Bq/m^3), with a mean value of (5.61 Bq/m^3). The investigated levels were lower than the permissible limits referenced by UNSCEAR and WHO. Moreover, the annual effective dose (AED) has been calculated due to inhalation, which varied from the value of (0.029352 mSv/yr) to the value of (0.081145 mSv/yr), with a mean value of (0.016205 mSv/yr). AED values obtained were found to be lower than the allowed value of (0.1 mSv/yr) reported by UNSCEAR and much lower than the permissible limit (1 mSv/yr) proposed by WHO.However, the results obtained indicate that the indoor radon concentrations were significantly affected by the floor level of the classroom (negatively correlated) and the school building age (positively correlated).Consequently, all results have revealed that the radon concentrations and the associated inhalation radon dose does not pose any kind of healthhazardto the occupational stuff and students.

Keywords: Indoor radon, Track detector, Primary schools, Annual effective dose, Iraq.

---

1. Introduction

Radon is a chemically inert, noblegas with no color or odor, produced naturally due to radium disintegration, anda member of the uranium decay chain. Radon has three natural isotopes (except more than 20 artificial isotopes), which are: Radon (^{222}Rn) with a half-life of (3.82 days), thoron (^{220}Rn) with a half-life of (55.6 sec), and actinon (^{219}Rn) with a half-life of (33.75 µsec). Due toit's a relatively long half-life, radon is more interesting and consideredthe most dangerous isotope among the others. ^{222}Rn is found in trace amounts in soils and building materials, as well as in waterthat enters the residential environment through fissures and openings in concrete floors and walls, drainage pipelines, connecting sections of structures, hollow block walls, and heating, ventilation,and air conditioning (HVAC) ducts[1]. Radon-222 and its progeny can be considered the largest contributor to the global population's annual effective dosage (50% of the total dose)[2]. The most risk doesn't come from radon itself but from its products produced by radon decay during respiration and deposit close to soft tissues of the lungs. These products are alpha emitters, such as Po^{218} and Po^{214}, which decay by releasing alpha particles that can be effective at such close distance, and the interaction between these alpha particles and living cells may result in physiological damage leading to the formation of cancerous tumors. Therefore, The chance of developing lung cancer after long-term radon exposure is elevated[3]. The radium content of the building materials, the infiltration of radon gas from the ground into the building through the pores and cracks at the building's base, the infiltration of radon through open windows and doors due to pressure and temperature differences inside the building, and the infiltration of dissolved radon into the dwellings due to water usage are all major factors in the formation of radon concentrations in buildings[4]. One, the permeability and porosity of the bedrock and soils, and two, the building's structure and construction, as well as the type, design, operation, and maintenance of the HVAC system, are the most important factors that control the migration and accumulation of radon gas in buildings. The chimney effect is exacerbated by environmental variables such as temperature (overheating in the winter months generates a chimney effect, which sucks soil gases such as radon into the dwelling), wind speed, and wind direction [5].

The lungs of children differ from those of adults in terms of size, shape, and breathing rate, which makes the child more vulnerable to radiation hazards. Hence, the risk of lung cancer in children due to radon exposure may be almost twice as high as in adults exposed to the same amount of radiation [6]. Furthermore, according to the equations of annual effective dose proposed by UNSCEAR, there is a big difference in the conversion factor between adultsand children to consider the physiological differences between them and therefore calculate the exact received dose [7, 8]. Hence, monitoring radon concentration in the building or the facilities where most residents or visitors are children is essential. Concerning this, and regarding the lack of such studies in the study area, the purpose of this study was to check indoor radon levels in some primary schools of Khidir City, Muthanna Province, Iraq, and see if there were any radon-related health hazards to the staff and students of the study schools.

2. Literature Review

Indoor radon activity concentrations in some schoolsin Muthanna province, Iraq, estimated by Farhood et al.in 2020 using a canary radon monitoring system; the study found that the radon concentrations fluctuated from (2 ± 0.7 Bq/ m^3) to (63 ± 4.0 Bq/m^3) with a mean value of (17.13±1.67 Bq/m^3), while the mean effective dose due to inhalation varied from (0.008 mSv.y^{-1}) to (0.258 mSv/yr), with an average of (0.07 ± 0.006 mSv/yr)[9].

In 2019, Abdalsattar K. Hashim and Sara S. Nayif investigated radon in air concentration levels in several schools in Karbala City, Iraq, with plastic detectors LR-115 type II and CN-85. Radon concentrations ranged between (13.140 Bq/m^3) and (38.439 Bq/m^3), with an average value of (25.408 and 25.317 Bq/m^3) for LR-115 and CN-85 detectors, respectively. The mean annual effective dose is (0.028 mSv.y-1) and (0.020 mSv.y-1) for both detectors [10].

Mothana Jasim and Sameera Ahmed (2023) determined radon gas concentration in indoor environments of some schools in Diyala Province, Iraq, using a CR-39 plastic detector. Radon in air levels were within the range of (8.825 – 50.395 Bq/m^3), with an average value of (25.257 Bq/m^3)[11].

UNDER PEER REVIEW

In Kuwait (2018), L. Al-Awadi and A. R. Khan measured indoor radon concentrations in different schools using CR-39 nuclear track detectors. The radon in air concentrations varied from (7 ± 1 Bq/m^3) to (404 ± 21 Bq/m^3).

3. Study Area

The current study aimed to estimate indoor radon levels in selected primary schools in Khidir City, Muthanna Province, Iraq. Khidir City is located in the south of Muthanna Province, 30 km south of Samawa City, the capital of the province, see Fig. 1. The number of investigated schools were 13 primary schools on the west side of the city, on the western side of the Euphrates River, the schools were distributed in different soils including agricultural, sandy, and saline. On the other hand, the schools differed in terms of building materials and the age of the buildings.

Figure (1): The location of the study area.

4. Materials and Methods

The study covered 13 primary schools; the schools' locations are determined using a global positioning system and documented using Google Earth software, as shown in Fig.2. As mentioned previously, the schools are distributed on different kinds of soil, as well as the schools are built with different building materials and at different periods, hence it is expected that it will be a visual fluctuation in radon levels between them. Further, some school buildings have one floor, and some have two. So, the strategy of the study aimed to assess the radon concentrations in these schools and thus make several comparisons between these concentrations in terms of soil, age of buildings, and the amount of height above the ground.

Solid state nuclear track detector (LR-115) type II is used to measure alpha particles emitted by radon and its progenies. The detector was cut into small pieces (2cm x 2cm) and placed in one-end opened cups provided with a filter to ensure that dust does not enter inside the dosemeter, and the dosemeters were suspended from the ceilings of the classrooms so that the open end was facing the ground in an average of 4 detectors for each school whose one floor, and 8 for those two. The dosemeters are left there for three months during the first term (from 1^{st} September to 30^{th} November 2023); andat the end of the exposure period, the detectors are taken off and brought to the lab for processing. The analysis included etching detectors with 2.5 N NaOH solution at 60 C for 120 minutes [12]. The tracks were calculated using an optical microscope with (400x) magnification. Radon concentration in (Bq/m^3) can be estimated from the following equation [13]:

$$C_{Rn} = \rho / KT (1)$$

Where (C_{Rn})is the radon concentration (Bq/m^3), (K) is the calibration factor of LR-115 Type II detector, which is equal to (0.0344 ± 0.002) (track $cm^{-2}/Bq\ m^{-3}.day$)[14], (ρ) is the track density (average track count per cm^2), (T) is the exposure time (day).

Figure (2): The locations of the studied schools.

5. Results and Discussion

Radon concentrations were estimated in 13 primary schools during the first semester in the winter season using LR-115 Type 2 nuclear track detectors. The obtained results are summarized in Table (1).

Table (1): Radon concentrations of investigated schools

UNDER REVIEW

No.	School name	Rn Concent. (Bq.m^{-3})			
		min	max	mean	medium
1	Al Fateh	0.23	7.77	3.65	3.39
2	Al Fasaha	0.38	5.12	3.98	3.15
3	Al Biader	0.6	6.99	4.34	4.46
4	Al Miqdad	0.99	8.34	4.47	4.62
5	Anwar Al Jawadain	0.1	5.59	2.43	2.28
6	Al Riadh	0.6	4.98	2.84	2.82
7	Al Zawraa	3.07	12.79	7.65	7.41
8	Ashaab Al Kisaa	1.92	19.98	8.25	7.58
9	Al Ihtidaa	0.21	10.14	5.99	7.11
10	Al Mustafa	0.84	5.02	2.68	2.42
11	Al Buraq	2.21	3.97	2.91	2.82
12	Al Aiaat	0.22	14.21	5.4	3.63
13	Al Kindy	1.69	14.13	8.79	9.97

The results showed that the low radon concentration was observed in Anwar Aljawadain school, which ranged between (0.1 Bq/m^3) and (5.59 Bq/m^3), with a mean value of (2.43 Bq/m^3). This lower value may be attributed to the building of the school being established recently;the modern design of the buildings helps to provide better ventilation; since good ventilation plays a major role in reducing indoor radon levels[15].Besides, the ground of the classrooms does not have many cracks that may contribute to seeping radon soil gas into the internal environment. On the other hand, the highest radon concentration was recorded in Al Kindy school, found to be within the range of (1.69-14.13 Bq/m^3), with a mean value of (8.79 Bq/m^3); the reason behind this may be due to the old and dilapidated school building, where the old buildings have poor ventilation, the floor contains an abundance of cracks which helps to flow more amount of radon inside. Moreover, the school region is characterized by sandy soil and its inability to retain radon gas as much as the clay soil [16]. The following histogram (Fig. 3) shows the variation of radon concentration levels in the school under study.

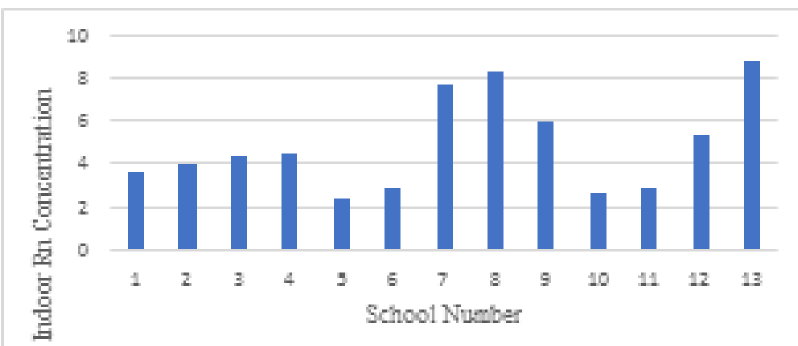

Figure (3): Mean indoor radon concentrations

UNDER PEER REVIEW

From the radiology point of view, radon concentrations carried out in all schools were found to be much lower than referenced values reported by international organizationssuch as UNSCEAR and WHO.

On the other hand, to determine the effect of the height from the ground on the indoor radon concentration, the measurements dealt with the difference in air radon levels between the same rows of classrooms in the schools that contain two floors; the results indicated an observable difference between the classrooms on the ground floor and those facing it on the second floor.

Furthermore, the annual effective dose due to inhalation has been conducted using the following equation [4,8]:

$$AED = C_{Rn} \times F \times d \times u \times t (2)$$

Where AED is the annual effective dose (Sv/yr), C_{Rn} is the radon concentration (Bq/m^3), F is the equilibrium factor between radon and its decay product (=0.4 for buildings), d is the dose conversion factor (1.43 Sv/(J hm^{-3})), u unit factor (5.56×10^{-9} $Jm^{-3}/Bq\ m^{-3}$), t time spent annually inside the building (hour/year). If people stay in the building for 5 hours a day, the time (5×210 = 1050 h/yr).The calculatedAnnual effective dose values ranged from (0.029352 mSv/yr) to (0.081145 mSv/yr), with a mean value of (0.016205 mSv/yr). Annual effective dose values obtained were found to be lower than the allowed value of (0.1 mSv/yr) reported by UNSCEAR [8] and much lower than the permissible limit of (1 mSv/yr) proposed by WHO[17].

6. Conclusion

The current study conducted indoor radon activity concentration in environments of 13 primary schools in Khidir City, south of Iraq, using LR-115 nuclear track detector type II. Radon concentrations were within the range of (0.1 – 14.13 Bq/m^3), with a mean value of (5.61 Bq/m^3). The investigated levels were found to be lower than the permissible limits referenced by UNSCEAR and WHO. On the other hand, the annual effective dose has been calculated due to inhalation, which varied from the lowest value of (0.029352 mSv/yr) to the highest value of (0.081145 mSv/yr), with a mean value of (0.016205 mSv/yr). Annual effective dose values obtained were found to be lower than the allowed value (0.1 mSv/yr) reported by UNSCEAR and much lower than the permissible limit (1 mSv/yr) proposed by WHO.Consequently, the estimated radon concentration has no significant health hazard to the occupied stuff and students, and the studied schools are radiologically safe, as per international standards.However, The present study is the first at the national level (in Iraq) to investigate radon (Rn^{222}) concentrations in primary schools of Khidir City, Al-Muthanna Province, Iraq.

UNDER PEER REVIEW

7. References

[1] H. Hassanvand, M. S. Hassanvand, M. Birjandi, B. Kamarehie, and A. Jafari, "Indoor radon measurement in dwellings of Khorramabad City, Iran," *Iran. J. Med. Phys.*, vol. 15, no. 1, pp. 19–27, 2018.

[2] M. Adelikhah, A. Shahrokhi, M. Imani, S. Chalupnik, and T. Kovács, "Radiological assessment of indoor radon and thoron concentrations and indoor radon map of dwellings in mashhad, iran," *Int. J. Environ. Res. Public Health*, vol. 18, no. 1, pp. 1–15, 2021.

[3] M. Hoffmann *et al.*, "First map of residential indoor radon measurements in Azerbaijan," *Radiat. Prot. Dosimetry*, vol. 175, no. 2, pp. 186–193, 2017.

[4] O. Günay, S. Aközcan, and F. Kulalı, "Measurement of indoor radon concentration and annual effective dose estimation for a university campus in Istanbul," *Arab. J. Geosci.*, vol. 12, no. 5, 2019.

[5] J. D. Appleton and J. C. H. Miles, "A statistical evaluation of the geogenic controls on indoor radon concentrations and radon risk," *J. Environ. Radioact.*, vol. 101, no. 10, pp. 799–803, 2010.

[6] A. for T. S. and R. Disease, "Case Studies in Environmental Medicine (CSEM): Radon Toxicity," 2012.

[7] UNSCEAR, "Sources and effects of ionizing radiation," United Nations, New York, 2010.

[8] UNSCEAR, "SOURCES AND EFFECTS OF IONIZING RADIATION," 2008.

[9] A. K. Farhood, A. M. Ali, and A. A. Abojassim, "Measuring of airborne radon concentration inside some schools of Al-Samawa city, Iraq," *AIP Conf. Proc.*, vol. 2290, 2020.

[10] A. K. Hashim and S. S. Nayif, "Assessment of Internal Exposure to Radon in Schools in Karbala, Iraq," *J. Radiat. Nucl. Appl.*, vol. 4, no. 1, pp. 25–34, 2019..

[11] A. You, M. Be, and I. In, "Determining the Level of Radon Gas in the Classrooms of Diyala Governorate Schools," 2023.

[12] O. Günay, M. M. Saç, M. İçhedef, and C. Taşköprü, "Soil gas radon concentrations along the Ganos Fault (GF)," *Arab. J. Geosci.*, vol. 11, no. 9, 2018.

[13] H. Singh Virk, "Toxicology Soil Gas Radon Concentration in a Residential Area of Surrey (BC) Canada using LR-115 Type II Plastic Detector," *A J. Texology*, vol. 12, no. 2, 2022.

[14] B. S. Journal, "Determination the Concentration of the Radon in some Drinking Bottled Water in Baghdad using LR-115 Detector," *Baghdad Sci. J.*, vol. 9, no. 4, pp. 741–745, 2012.

[15] D. Xie, M. Liao, and K. J. Kearfott, "Influence of environmental factors on indoor radon concentration levels in the basement and ground floor of a building - A case study," *Radiat. Meas.*, vol. 82, pp. 52–58, 2015.

[16] A. A. Sharrad and A. K. Farhood, "Radon concentration Measurementsin Soil Gas of Sawa Lake, Samawa City – South of Iraq" *Int. J. Adv. Res.*, vol. 7, no. 6, pp. 170–177, 2019.

[17] C. Streffer, "The ICRP 2007 recommendations," *Radiat. Prot. Dosimetry*, vol. 127, no. 1–4, pp. 2–7, 2007.

UNDER PEER REVIEW