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Measuring Radon Concentration in the College of Education for Pure Sciences at the University of Anbar and Its Effects on Public Health

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Abstract

This study aimed to reduce the risks of lung cancer linked to radon gas concentrations. To ensure public safety in the college and avoid the danger of radiation, and to achieve the goals of sustainable development in providing a suitable, clean, and hazard-free environment. These reasons led to research on measuring indoor radon levels in the Physics department, which is part of the College of Education at Anbar University. The study was conducted over a period of approximately 40 days, during which CR-39 detectors were exposed to indoor air in the halls and laboratories. After that, take the detectors to etching in NaOH solution at 6.0N for a temperature of 70 ± 1 °C using a water bath for 1.0 h. The radon concentration range of these areas is from (67 to 104) Bq/m^3, with an average value of 76.6 Bq/m^3. The radon concentration in the building was found within the recommended range. Furthermore, the annual effective dose (AED) and the cancer risk factor related to chronological age were both below the recommended limits. It highlights the importance of ensuring a healthy environment for all students and staff. When comparing the radiation levels of the samples investigated with internationally accepted values, the current results showed that they were within permissible limits.

Keywords: Radon, CR-39 track detector, The radon concentration levels, Lung cancer

1. Introduction

In the past fifty years, radioactive pollution has increased. Initially, radiation sources were limited to cosmic rays and other natural sources, such as rays from rocks and natural elements like potassium. However, human intervention has added significant radiation, polluting the air, water, and food (Ahmed & Farhan, 2022; Thorne, 2003). There have been numerous definitions of pollution, which include the release of waste from different activities and the presence of any substance or energy in an abnormal location. The release of waste or excess energy can directly or indirectly cause harm to the environment and humans. The presence of substances at concentrations higher than their approved limits can be harmful (Righi et al., 2005). Pollutants are substances or effects that unfavorably change the properties of the environment, alter the growth rate of living organisms, directly affect the food cycle, and have toxic or radioactive effects. In general, pollution leads to damage to the normal functioning of living organisms as a result of these factors (Das, 2021). The release of chemicals, toxic substances, and radioactive materials into the air or water can cause harm to human health and the natural environment (Farhan et al., 2022). This can affect water, soil, crops, and animals. Additionally, smoke, dust, and chemical gases can harm the environment. Long-term harm can result from the absorption of pollutants in the body, including carcinogenic or radioactive materials (Mitra et al., 2022).

In many countries around the world, natural radiation exposure is measured for various reasons, such as epidemiological studies, site selection for

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nuclear facilities, and emergency preparedness. In Iraq, exposure measurements have been conducted for over twenty years as part of the Environmental Radioactivity Monitoring Program and the Radioactivity Monitoring Program for the Tuwaitha Site. These programs aim to control the potential danger to people living near the site. Natural radioactivity includes radioactive elements found in the Earth's crust and non-terrestrial elements. It is classified into series such as thorium decay (^{232}Th) series, neptunium (^{237}Np) decay series, uranium (^{238}U) decay series, and the actinium (^{235}U) decay series (Ahmed et al., 2024; Fujii et al., 1990). Natural radioactivity, or background radiation, from naturally occurring radionuclides, is crucial for the population's radiation exposure. One main reason is that radon gas is released from the soil and rock where it is naturally generated and depends on the presence of uranium, estimated to be present at a rate of 3 parts per million (ppm).

Many studies have been conducted to measure the concentrations of uranium, radon gas, and other radioactive elements using detectors (SSNTDS). In 1991, radon concentrations in Sweden's soil were determined using the CR-39 nuclear track detector, with levels ranging from (2.8–111.1) kBq/m^3. In Al-Najaf Governorate, radon levels varied from 74.28 to 478.13 Bq/m^3, with an average of 183.68 Bq/m^3 (Tawfiq et al., 2012). At Al-Iraqia University's College of Dentistry, concentrations varied from 28.42 to 233.49 Bq/m^3, averaging 90.28 Bq/m^3 (Hassan et al., 2024). Radon concentrations were examined in different building materials. The radon concentration in natural stone is 121.95 Bq/m^3, while the concentration in Turkish red granite is 383.3 Bq/m3. Additionally, he radon levels found in Iraqi Kashi and Egyptian ceramics are similar to those in natural stone (Najam et al., 2013). In Ibn Al-Haitham College reported two samples exceeding the permissible range of 200-300 Bq/m^3, with values of 445.87 and 436.79 Bq/m^3 (Salim & Ebrahiem, 2018). The radon concentrations measured using a CR-39 detector at Al-Qadisiyah University varied between 96.9 and 270.5 Bq/m^3 (Obayes & Oudah, 2022). These studies emphasize the variability of radon concentrations across different locations and materials. This underscores the importance of monitoring for potential health risks. Therefore, it is important to study the levels of radon and thorium gases in different locations to control their levels and determine their potential danger to the human body (Al-kubaisi & Farhan, 2018; Fawaz & Ahmed, 2014; Grzywa-Celińska et al., 2020). Lung cancer represents a significant public health challenge is the leading cause of cancer-related deaths worldwide. Smoking is responsible for approximately 80% of lung cancer cases, while radon gas exposure is a major risk factor that affects between 10% and 15% of the population. Lung cancer caused by radon exposure accounts for about 21,000 deaths each year. Furthermore, active smokers face a 25-fold increased risk of developing lung cancer compared to nonsmokers (Schabath & Cote, 2019). This research aims to measure the concentrations of radon-222 (^{222}Rn) and thorium-220 (^{220}Rn) gases in the Pure Sciences building of the College of Education, specifically within the Department of Physics at the University of Anbar, by using a CR-39 detector.

2. Methodology

The preparation and use of CR-39 thin film detectors is one of the most widely used methods for determining and calculating the concentration of Radon (^{222}Rn) and Thoron (^{220}Rn), which are decay products of the uranium series. Alpha particle track parameters can be determined by using CR-39 detectors. The CR-39 detector was cut into small pieces of 1.0×1.0 cm^2 and 200 μm thickness. Slices of CR 39 nuclear track detector, which have dimensions of 1.0×1.0 cm^2, are placed inside plastic cylindrical Vessels or cans with a height of 10 cm and a diameter of 5 cm. This system was suspended in the halls, rooms, and laboratories of the Physics Department, located in the center of Anbar governorate, as shown in Fig. 1, for 40 days at various heights. A piece of wool cloth was placed over the system openings to ensure that the radon gas diffused through the system. After emitting alpha particles by radon decay, the particles diffuse through the system. These particles strike detecting materials and create damaged areas called alpha tracks. These tracks reveal information about these particles.

After 40 days, detectors were taken from the Physics Department building to the laboratory. To endorse the tracks produced by Radon (^{222}Rn) and Thoron (^{220}Rn) in the CR-39 detector, a 6.0 N concentration NaOH solution at a temperature of 70 ± 1°C was used in a water bath over to 1.0 h. The tracks on the surface of the CR-39 detector were determined after chemical etching, using a digital camera fixed on an optical microscope with 400x magnification. The camera is connected to a computer with a specific program to transfer track images to a device for storage and analysis. The density of the tracks for background radiation (BG = 65.25 tracks cm^{-3}) was subtracted, and concentrations were calculated using the following equations:

The formula to determine of Radon (^{222}Rn) concentration in unit (Bq/m^3) is (Durrani & Ilic, 1997; Hashim

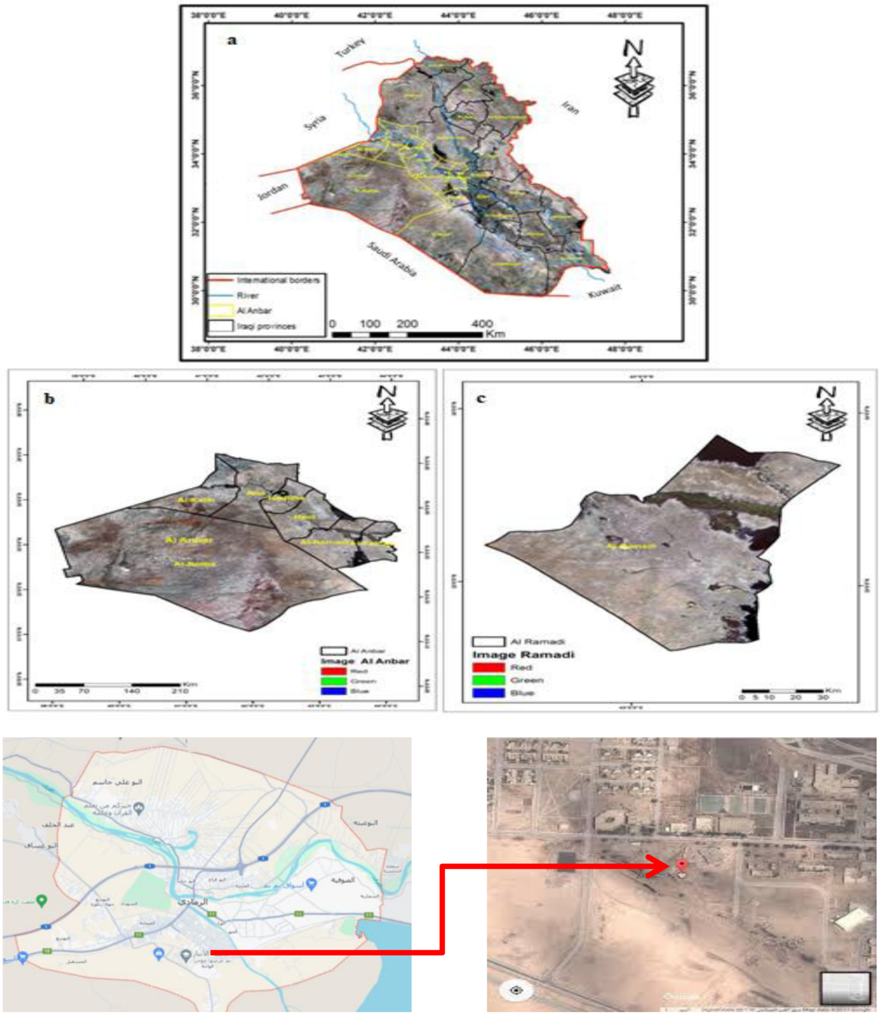

Fig. 1. The map of Iraq, the Anbar province and Al-Ramadi city by ArcGIS program. The selected study locations from Anbar University.

& Najam, 2015):

$$C_{rn}\left(Bq/m^3\right) = \left(C_o t_o/\rho_o\right)\left(\rho/t\right) = k\left(\rho/t\right) \quad (1)$$

The symbols in this equation are represented as follows: C_{rn} represents the Radon (^{222}Rn) concentration in this area, ρ_o is a constant value equal to 96768 ($track/cm^2$), the unit of this value is ($number\ of\ tacks/cm^2$), C_o is the activity concentration of the (^{226}Ra) is equal approximately 90000 (Bq/m), t_o is the calibrated dosimeters time of to ^{226}Ra, roughly 2 days, k is the calibration factor of these constants, ρ is track density ($number\ of\ tacks/cm^2$) and t is exposure time (in days) of detectors, roughly 40 days.

To determine the potential alpha energy concentration (PAEC) the following equation is used (Ismail & Jaafar, 2010; Kansal et al., 2012):

$$PAEC\ (mWL) = \left(F \times C_{rn}\right)/3700 \quad (2)$$

The symbols used in this equation can be defined as follow, F represented constant factor and equal is 0.4, C_{rn} represents the radon concentration in this area and its unit of measurement is ($nGy.h^{-1}$).

To determine the Annual Effective Dose the following equation is used (Radiation, 2000):

$$E_p\left(WLMy^{-1}\right) = \left(T \times H \times F \times C_{rn}\right)/\left(3700 \times 120\right) \quad (3)$$

Where T is the number of hours per year which equal (8760), H is the occupancy factor in schools which is equal to (0.8), F is the equilibrium factor, it's equal is (0.4), 120 is the number of hours per working month., 1WL = 3.7 $Bq/L = 3700\ Bq/m^3$.

To determine the annual effective dose (AED) in air is calculated in units mSv/y, resulting from natural radionuclides of Radon (^{222}Rn) and Thoron (^{220}Rn). By the following formula (Farhan et al., 2020; Mowlavi

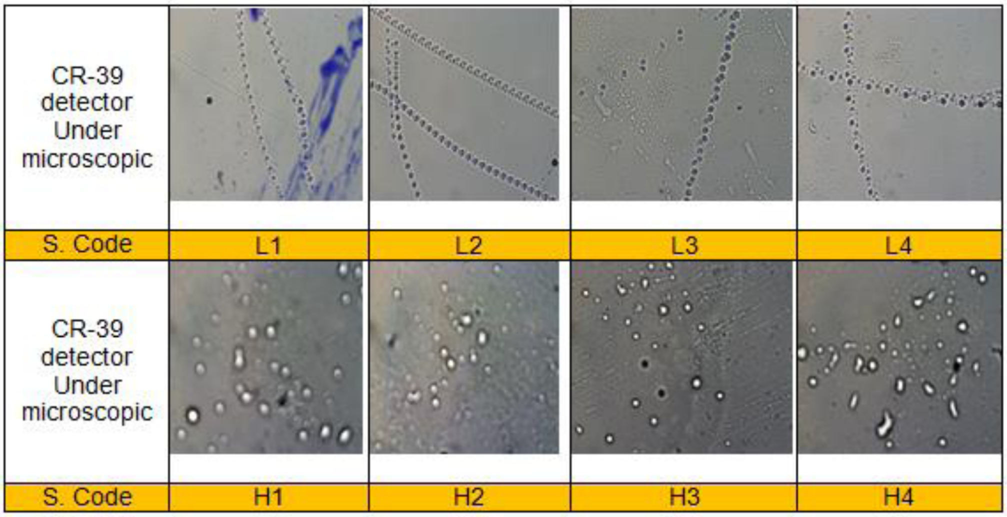

Fig. 2. The etched tracks observed under microscopic after treatment by NaOH solution 6N.

Table 1. Radon concentration (C_{rn}),The potential alpha energy concentration (PAEC), Effective Dose (EP), The annual effective dose (AED) and lung cancer cases per year per million people (CPPP) in Halls and laboratory of the Physics Department.

S. Code	S. Name	Mean of C_{rm} (Bq/m^3)	PAEC (mWL)	EP	AED	CPPP×10^6
L 1	Nuclear Lab.	104	0.0112	0.78792	2.623	47.22
L 2	Nano Lab.	82	0.0084	0.62124	2.068	37.32
L3	Electrical Lab.	78	0.0082	0.59094	1.967	35.42
L4	Mechanics Lab.	76	0.0082	0.57579	1.917	34.51
L5	Method Lab.	73	0.0073	0.55306	1.841	33.15
H1	First Hall	68	0.0071	0.51518	1.715	30.88
H2	Second Hall	66	0.0072	0.50029	1.665	29.97
H3	Third Hall	67	0.0072	0.50760	1.690	30.42
H4	Fourth Hall	69	0.0074	0.52275	1.740	31.33
H5	Teachers’ Hall	72	0.0011	0.59548	1.816	32.69
	Average	76.6	0.0087	0.58596	1.879	34.39
	Min	66	0.0071	0.5834	1.922	47.2
	Max	104	0.0112			29.97
	Worldwide average	200–300	53.33	2–1	370	55

et al., 2012):

$$AED\,(mSv/y) \;=\; C_{rn} \times F \times H \times T \times D, \tag{4}$$

The unit measuring of the absorbed dose rate (nGy h^{-1}), it’s represented by C_{rn}, the equilibrium factor represented by F in equation, it’s equal is (0.4), the indoor occupancy factor in building (H), it’s equal (0.2), it’s total equal (0.8), T represents the total occupancy time in hours over a year (8760 h), while D is the dose conversion factor, equal to $9 \times 10^{-6}\ mSv/(\frac{Bq}{m^3})$.

To calculate the annual lung cancer cases per million people (CPPP) (Lecomte, 2015; Nor et al., 2023), the following equation was used.

$$(CPPP) = AED \times 18 \times 10^{-6}\ mSv/y, \tag{5}$$

3. Results and discussion

The image is displaying Fig. 2. it’s for tracks produced by Radon (^{222}Rn) and Thoron (^{220}Rn) in the CR-39 detector are taken by the camera of microscopic. By analyzing these tracks that formed on the surface of detector, we can calculate the concentrations of Radon on the halls, rooms, and laboratories.

In this present work, indoor C_{rn} were measured in the halls, rooms, and laboratories at the physics department building in Anbar University, located in the center of Anbar province. Table 1 displays the nuclear track densities for identified locations.

According to Fig. 2, the highest radon concentration is after the nuclear lab. was found in the Nano laboratory, with a mean of 82 Bq/m^3, due to the nature of the materials stored in this laboratory. The concentrations in other laboratories ranged from 78 to 73

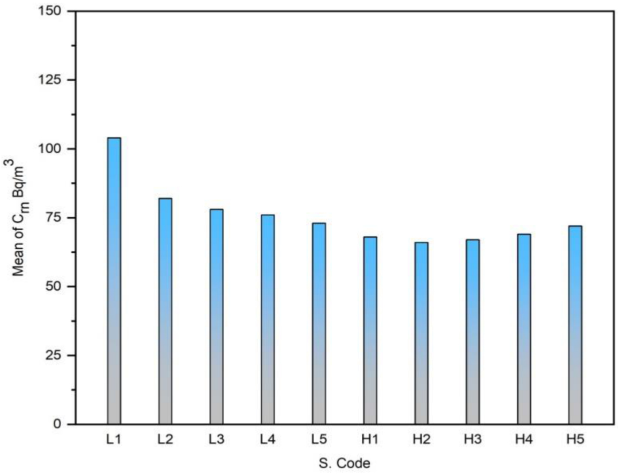

Fig. 3. The ratio of concentration of radon according to regions study.

Bq/m^3, attributed to the presence of electrical devices and chemical materials that degrade over time and can release radon. In the halls, the average concentrations ranged from 66 to 72 Bq/m^3, depending on their proximity to the laboratories and the ventilation conditions. However, all concentrations were below the global level in the study units. The Nuclear Lab (L1) had the highest potential alpha energy concentration (PAEC) at (0.01124 mWL), while the lowest value was found in First Hall (H1) at (0.0071 mWL). These results indicate these values are lower than the recommended value of (53.33 mWL).

Fig. 3. The mean radon concentrations show that the highest level was found in the Nuclear Lab (L1), while the lowest was in the Second Hall (H2). The high concentration of radon in the nuclear laboratory (L1) is mainly due to the presence of radioactive elements stored for practical experiments, and the types of materials used in the building. Additionally, some materials were used in the experiment in the fourth-stage physics department, which led to an increase in the emission of radon particles. This is a natural result of the radioactive decay of these elements over time. The radon concentration is below the recommended average, which ranges from 200 to 300 Bq/m^3. Other contributing factors include the quality and age of the building materials, as well as the materials inside the labs. The equilibrium factor is 0.4. The low radon concentration in the Second Hall (H2) is primarily due to the quality of materials and the high level of ventilation in these buildings. Another reason is the absence of radioactive elements near these halls. Consequently, the radon concentration in the halls is lower than in the laboratories of the department.

There are many cases leading to lung cancer, and radon is second only to smoking. It causes cytotoxic and genotoxic effects that can damage the respiratory epithelium and DNA, potentially leading to lung cancer. The graphic below compares EPA estimates of annual radon-related lung cancer deaths to those of other selected cancers. Lung cancer is the leading cause of cancer-related deaths in the EU and the USA. In the EU, it is responsible for approximately 19.5% of all cancer deaths, while in the USA, it accounts for about 11.4% of all cancer deaths. Worldwide, lung cancer is estimated to be responsible for around 14.5% of all cancer deaths (Ismail & Jaafar, 2010; Pawel & Puskin, 2004).

Fig. 5 shows the relationship between radon concentration and the annual number of lung cancer cases per million people, finding a linear connection where higher radon concentration corresponds

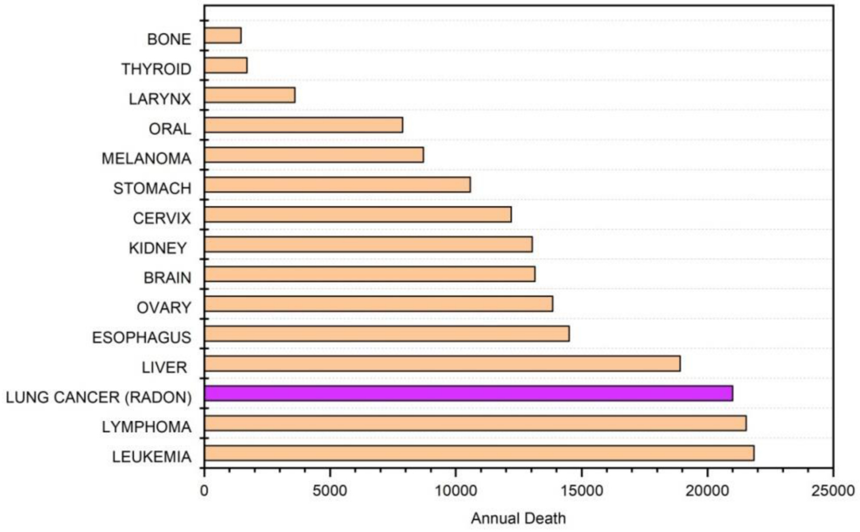

Fig. 4. EPA estimates of annual radon-related lung cancer deaths to those of other selected cancers.

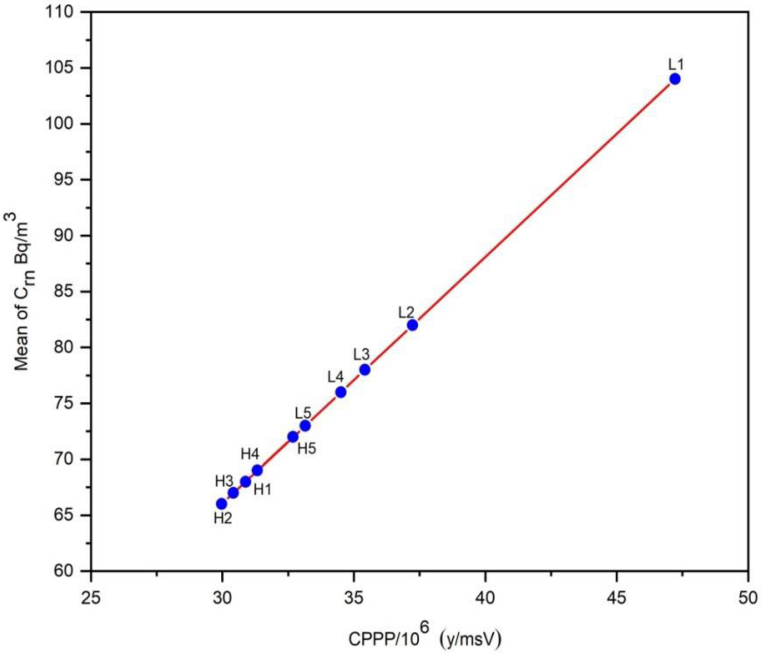

Fig. 5. The correlation between radon concentration and lung cancer cases per million people per year.

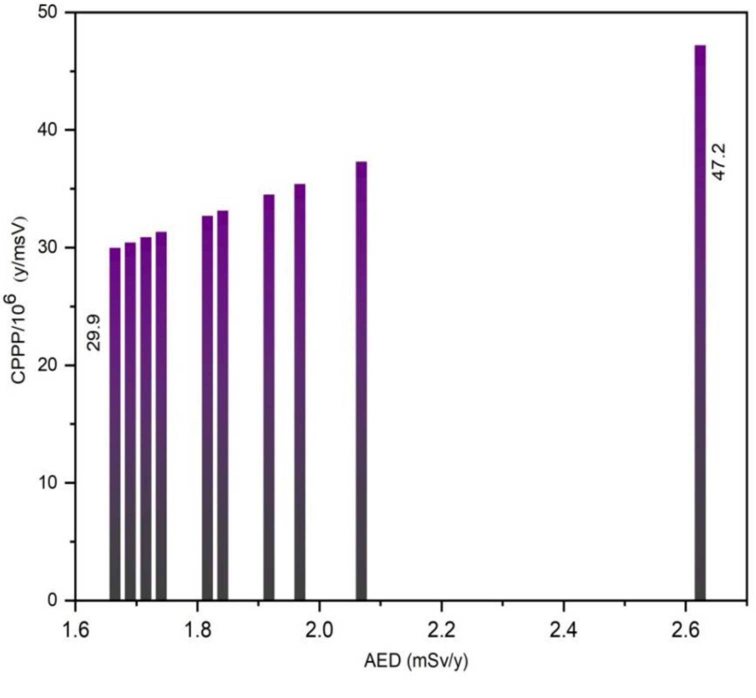

Fig. 6. The relationship between the number of lung cancer cases per year per million people and the annual effective dose (AED).

to more cases of lung cancer. Table 1 shows that the nuclear laboratory L1 had the highest radon concentration. Fig. 1 also indicates that the people most at risk of being affected are those working in the nuclear laboratory due to its high radon concentration, while the lowest concentration was found in the second hall H2. We can see that the highest number of lung cancer cases was found in the Nuclear Lab (L1), totaling 47.22. while, the lowest number was found in the Second Hall (H2), amounting to 29.97. The probability of the number of people with lung cancer cases per year per million people (CPPP) is lower in halls than in laboratories. The average value for all locations of 34.39 is lower than the recommended range of 55.

The annual effective dose (AED) was calculated. Table 1 shows that Nuclear Lab (L1) has the highest value at 2.623 mSv/y. While the Second Hall (H2) has the lowest value at 1.665 mSv/y. On average, the annual effective dose (AED) for the selected locations is 1.879 mSv/y, significantly lower than the recommended limit of 370 mSv/y.

Fig. 6 shows the relationship between the number of lung cancer cases per year per million people and the annual effective dose (AED). A higher effective dose corresponds with a higher incidence of lung cancer, these results agree with Table 1. This is due to the high concentration of radon in specific locations, leading to an increase in the effective annual dose (AED) for workers in these areas. Consequently, this elevated exposure results in a higher number of lung cancer cases per year. It has been observed that the highest probability of people getting infected in laboratories with high radon concentrations is around 47 people per year. On the other hand, the lowest value in the halls compared to the laboratories. The lowest probability of infection is in the second hall, with about 30 people, which is less than the recommended range internationally.

4. Conclusion

The results of measuring radon gas in various locations showed that radon concentrations varied depending on the area sampled. The average radon concentrations in CR39 detectors ranged from 67 Bq/m^3 to 104 Bq/m^3, with an overall average of 76.6 Bq/m^3. Radon concentrations in laboratories were higher in the halls within the same building. This was attributed to factors such as the quality and age of the building materials, as well as Fig. 6. The relationship between the number of lung cancer cases per year per million people and the annual effective dose (AED). The chemical materials are present in the labs. All samples were found to be within the recommended range. The concentration of radon gas radiation in the Physics Department was within permissible limits for study. Additionally, both the annual effective dose and the risk factor for cancer associated with chronological age were lower than the recommended limit.

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Author contribution

Ahmed O. Frhan, Omar Abboosh, Sabah S. Farhan, and Mazin H. Hasan and Dhafar Th. Altaan contributed equally to this work and approved the final manuscript version.

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