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Assessment of radiological risk due to radioactive contamination in the air for different types of laboratories in Ho Chi Minh City, Vietnam

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ABSTRACT

Background: The utilisation of radiation sources can increase radioactivity levels within radiation-applied laboratories, thereby affecting the health of individuals regularly working in such environments. This study aimed to assess the activity concentrations of radionuclides and dose rates across various research laboratories, including nuclear technique laboratories and others, in order to determine the effect of radiation sources on air quality. ***Materials and Methods:*** Dust particles in the air were collected and analysed using a low - background gamma spectrometer. The study was conducted in five distinct laboratories with varying frequencies of radioactive material usage. The differences in the activity concentrations of 40K, ^{232}Th, ^{238}U, ^{226}Ra/^{222}Rn, ^{228}Th/^{220}Rn, and ^{210}Po were compared between laboratories and with different periods of the month. To assess potential risks, the annual effective dose rate resulting from dust inhalation was estimated for two adult groups (male and female). ***Results:*** High activity levels were observed in lab 1 because of the presence of radioactive sources, standard samples, and diverse environmental samples. The radioactivity levels for various radioisotopes exhibited minimal changes between the weeks of the month. Lab 1 also recorded the highest estimated radiation dose with effective doses of 2300 μSv y^{-1} and 1886 μSv y^{-1} for men and women, respectively, surpassing the recommended ICRP value of 1 mSv y^{-1}. ***Conclusion:*** Assessment of the activity concentrations in airborne dust for different laboratory types showed that the health impacts of pollution are not significant. However, laboratories dealing with radioactive sources exhibited high radioactivity levels and should undergo frequent monitoring.

INTRODUCTION

Air pollution poses a serious health impact on both humans and the environment, emphasising the need to reduce its influence or prevent its occurrence. This type of pollution is caused by harmful substances present in the air, such as particulate matter, nitrogen oxides, sulfur oxides, ozone, and volatile organic compounds. Meanwhile, these pollutants can originate from different sources, including industrial activities, transportation, and natural sources like dust and wildfires. Breathing high levels of air-containing pollutants can lead to various health complications, including respiratory issues, cardiovascular diseases, and cancer [1-5].

Besides, airborne radioactive pollution may arise from the release of radioactive materials from natural environments, such as soil and atmosphere, or from artificial sources, such as nuclear power plants, mining activities, and nuclear weapons testing [6,7]. Radioactive particles can travel through the air and be inhaled by both humans and animals, potentially causing health issues like radiation sickness, cancer, and genetic mutations.

Different organisations have established regulatory standards for the permissible concentration of radioactive isotopes in environmental samples, including dust. In the United States (US), the Environmental Protection Agency (EPA) has defined a limit of 0.5 picocuries per gram (pCi g^{-1}) for the combined radium-226 and radium-228 in soil and dust samples obtained from residential properties [8]. This specified limit is intended to mitigate the risk of lung cancer resulting from the inhalation of radon gas, a byproduct produced by these radioactive isotopes.

In Canada, the Canadian Nuclear Safety Commission (CNSC) has established a limit of 20 becquerels per kilogram (Bq kg^{-1}) for gross alpha activity in outdoor dust samples and a limit of 50

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Bq kg^{-1} for gross beta activity in indoor dust samples [9]. These limits are intended to protect against the potential risk of radiation exposure from both natural and anthropogenic sources.

In the European Union (EU), the Euratom Directive 2013/59/Euratom established a limit of 1 millisievert per year (mSv y^{-1}) for the effective dose resulting from exposure to natural sources of radiation, including inhalation of radon and other radioactive isotopes in dust. Additionally, the reference level for indoor radon concentrations in workplaces mandated that the annual average activity concentration in the air should not surpass 300 Bq m^{-3} [10]. Member states are obligated to ensure that exposure does not exceed these specified limits.

Vietnam, as a member of the International Atomic Energy Agency (IAEA), adheres to the agency's safety standards and guidelines concerning radiation protection. The IAEA safety standards provide recommendations for controlling radiation exposure across diverse contexts, including environmental and occupational scenarios. The International Basic Safety Standards for Protection against ionizing radiation and for the Safety of Radiation Sources (BSS) serve as a framework for implementing a comprehensive system of radiation protection. It sets dose limits and outlines additional requirements aimed at safeguarding workers, the general public, and the environment from the effects of ionizing radiation. Furthermore, the BSS recommends a dose limit of 1 mSv y^{-1} for the general public and an average dose limit of 20 mSv y^{-1} over a 5 - year period for radiation workers [11]. These prescribed limits are designed to prevent exposure to ionizing radiation from posing unacceptable health risks.

Laboratories worldwide are used for many subjects, such as physics, biology, geology, and chemistry. Some of these contain radioactive sources or materials, presenting potential risks to laboratory staff. Therefore, routinely measuring the background radiation in laboratories is a crucial task to maintain a safe and clean environment for research activities. However, there are few studies investigating the radiation background in small university laboratories. In particular, no such study has been conducted in certain laboratories within Vietnam National University, Ho Chi Minh City, Vietnam.

The current work was carried out in four laboratories at the University of Science, Vietnam National University, Ho Chi Minh City (VNU-HCM), Vietnam [12]. Within these laboratories, radioactive materials may exist in the form of radiation sources, geological samples, or environmental samples at various levels, posing risks to the laboratory staff. Hence, it is imperative to determine the radionuclide levels in these laboratories. Analytical techniques employed for this purpose include alpha spectroscopy, low background alpha/beta counting system, energy dispersive X-ray fluorescence (EDXRF) spectroscopy, and low-level gamma-ray spectroscopy using a Hyper Pure Germanium (HPGe) detector. To conduct the necessary analyses, the samples undergo a processing procedure, requiring laboratory staff to operate in the sample processing room. Moreover, a designated area is available for the storage of both the standard and analysed samples. To facilitate the assessment and regular monitoring of radioactivity concentrations of the isotopes in the air, the dust and radioactivity concentrations were analysed on a weekly basis. For this purpose, dust samples were collected using four filters over 24 h at 7-day intervals during June 2022. In addition, the activity concentrations of these radionuclides were used to assess the annual effective dose due to inhalation for employees and students working here.

MATERIALS AND METHODS

Sample collection and preparation

Airborne particulates were collected from five laboratories at the University of Science, VNU-HCM, Vietnam. Table 1 provides details on the purpose, usable area, and pollution sources of each laboratory. Specifically, lab 1 served as the sample processing room for the Nuclear Technique Laboratory, containing radioactive materials such as calibration sources and standard samples. Lab 2 was dedicated to gamma-scattering experiments and contained numerous radioactive sources, including some with high levels of radiation. On the other hand, labs 3 and 5 were general physics laboratories where a variety of standard experiments were carried out, and no radioactive materials were present in these spaces. Lastly, lab 4 was used for the geological research, containing many geological samples of radioactive materials. Notably, a high-volume air pump was employed to collect the dust samples, drawing air through the cellulose filter at a total volume of approximately 5000 m^3 for 24 h. The collected dust was kept on four high-efficiency glass-fired filters with a gas collection efficiency of 99.99%, covering a pore size range of 0.6 μm in diameter and larger [13,14]. These samples were stored and sealed for approximately one month to attain radioactive secular equilibrium (> 7 half-lives of ^{222}Rn and ^{220}Rn) before undergoing a 3-day measurement on a gamma spectrometer.

Analysis of radionuclides in the samples

Next, the dust density (C) in mg m^{-3} was determined by calculating the difference between the weights of the blank filter and the filter with dust, using Eq. (1) [15-17]:

$$C = \frac{(W_2 - W_1) - (B_2 - B_1)}{V} \quad (1)$$

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where W1 and W2 represent the mass of the filter before and after dust sampling (mg), respectively; B1 and B2 denote the mean mass of the blank filters and sampling filters (mg), respectively; and V stands for the collected volume corrected to standard conditions (m^3).

Table 1. Information about the investigated laboratories used for assessment.

Laboratory ID. (Name)	Properties
Lab 1: Nuclear Technique Laboratory: Sample processing room	- Radioactive sources: Standard samples for instrument calibration - Materials that contain radioisotopes: high radioactivity samples and environmental samples such as soil, water, and instruction materials. - Human: 5 technicians and 10 final-year students majoring in Nuclear Engineering (including 2 female technicians and 3 female students)
Lab 2: Nuclear Technique Laboratory: Room for Gamma scattering experiments	- Radioactive sources: Standard samples for instrument calibration, irradiation sources with high radioactivity. - Materials that contain radioisotopes: shielding materials, instruction materials such as stone, cement, and sand. - Human: 2 male technicians and 5 male final-year students in Nuclear Engineering
Lab 3: Laboratory of General Physics	- Radioactive sources: None - Materials that contain radioisotopes: None - Human: 4 lecturers and 100 freshmans working everyday
Lab 4: Laboratory of Geology	- Radioactive sources: None - Materials that contain radioisotopes: Many types of stone and soil are collected in the different regions. - Human: 2 male technicians and 4 male students in Geology
Lab 5: Laboratory of General Nuclear Physics	- Radioactive sources: Standard samples for instrument calibration and radioactive sources for general experiments. - Materials that contain radioisotopes: high radioactivity samples collected from the environment. - Human: 2 male technicians, 5 male students and 2 female students in Nuclear Physics

Further, the radionuclides in the dust samples were analysed using a high-resolution gamma spectrometer. The system utilised an n-type HPGe detector, GMX35P4–70, manufactured by ORTEC. The detector was cooled using an X-Cooler III mechanical cooler and was housed in a low-background lead shielding to minimize the radiation background. The low-background gamma spectrometer can measure rays within the range of 3 keV and 10 MeV. It achieves a high level of resolution, with a full width at half maximum (FWHM) of 1.85 keV at 1332 keV, corresponding to the gamma radiation of ^{60}Co [18].

Later, the absolute method was utilised to ascertain activity levels, involving calibrations conducted using IAEA standard samples with known activity concentrations of radionuclides. The analysis of the desired radioisotopes involved using standard samples, namely IAEA-RGU1, IAEA-RGTh1, and IAEA-RGK, to calibrate the detector efficiencies for different gamma-ray energies. The standard samples containing the relevant radionuclides exhibit chemical compositions, geometries, and counting configurations similar to the real samples [14]. The efficiency curve for the real configuration was derived by accurately correcting the sample density using the angle 3 software.

The activity concentration (A, in Bq m^{-3}) of a radionuclide in the collected sample on the sample date (decay-corrected) for each energy of interest was calculated using Eq. (2) [18-20]:

$$A = \frac{S}{\varepsilon' \times y \times K_c \times K_w \times T_l \times V} \quad (2)$$

where S signifies the count on the peak area, ε' denotes the attenuation-corrected efficiency, y is the branching ratio of the peak energy, V represents the sample volume (m^3), Tl denotes the collection live time (s) of the collection, Kc implies the factor corrected for the tracer nuclide decay during spectrum acquisition, and Kw is the factor corrected for the tracer nuclide decay from the tracer reference date/time to the start of the spectrum acquired.

For radiation measurements with gamma spectroscopy, the accuracy of the analytical method was evaluated by determining the Minimum Detection Activity (MDA), which represents the minimum radioactivity value of a radioactive isotope that can be detected by spectroscopy. This is defined by the Currie MDA algorithm as Eq. (3) [18,19]:

$$MDA = \frac{L_D}{\varepsilon(E) \times m \times f \times t \times K_c \times K_w}$$
$$L_D = 2.71 + 3.29\sqrt{2B + \left(\frac{T_s}{T_b}\right) I + \left(\frac{T_s}{T_b}\right)^2 \sigma_I^2} \quad (3)$$

where, is the limit of detection (95% confidence interval), I denotes the net peak area of the background measurement, σI signifies the standard deviation of I, B represents the value of the continuum under the peak, Ts and Tb denote the live time of the sample and background measurements, respectively.

To assess the potential exposure and health risks associated with radioactivity concentrations, the inhalation annual effective radiation dose Ei (μSv y-1) of radioisotopes was calculated using Eq. (4) [21]:

$$E_i = A_i \times B \times d_i \times F_0 \quad (4)$$

where Ai denotes the radioactivity concentration of the radioisotope present in the dust of indoor air (Bq m^{-3}), B represents the human inhalation rate (m^3 y^{-1}), di is the dose per unit of intake from human inhalation or the conversion dose coefficient (Sv Bq^{-1}), and F0 stands for the indoor air occupancy factor.

Risk assessment

The annual effective dose rate due to the

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inhalation of dust was computed for two groups of adults (male and female). The calculations took into account the respective breathing rates and conversion dose coefficients for inhalation [21]. Considering employees working in laboratories, with an 8-hour work shift over a 40-hour work week and 51 weeks annually, the indoor occupancy factor (F0) was set to 0.23. According to UNSCEAR (2000), the respiratory rates for adults are 22.2 m^3 day^{-1} for males and 18.2 m^3 day^{-1} for females. The default modes of absorption for the isotopes relevant to adults (aged > 17 years) are summarised in table 2 [22], categorizing absorption rates into fast (F), moderate (M), and slow (S) in body fluids.

Table 2. Committed effective doses per unit intake by inhalation of radionuclides di (μSv Bq^{-1}).

Isotopes	^{40}K	^{232}Th	^{238}U	$^{226}Ra/^{222}Rn$	$^{228}Th/^{220}Rn$	^{210}Pb
Type	F	M	M	M	S	M
di	0.0021	2.6	2.9	3.5	40	1.1

Statistical analysis

Gamma spectrum analysis was carried out using MAESTRO (Multichannel Analyzer Emulation Software), which is supported by ORTEC. Analysis of the experimental data was performed using Microsoft Excel in Office 365. It was confirmed that all data exhibited a normal distribution ($p < 0.05$) or had a confidence interval of 95%.

RESULTS

Table 3 presents the dust concentrations in the air based on the samples collected from the laboratories of a university in the year 2021. A total of five samples from five corresponding laboratories were collected for analysis, with details regarding the investigated laboratories provided in table 1. Notably, table 3 shows that the total dust concentration ranged from 7–37.6 μg m^{-3}, with a mean mass concentration of dust samples reported as 16.9 ± 1.6 μg m^{-3}. Importantly, the highest dust concentration was found in lab 1. All the recorded values fell below the workplace exposure limit (WEL) for 8-hour time-weighted averages of 8 mg m^{-3} for total dust and 4 mg m^{-3} for inhalable dust [23].

Table 3. Total dust concentration at the labs.

Site	Mass of dust stored on filters Δm^{-} ($\times 10^{-4}$ g)	The collected volume V^{-} (m^3)	Total dust concentration C^{-} (μg m^{-3})
Lab 1	1543 ± 2	4100 ± 300	37.6 ± 2.8
Lab 2	277 ± 2	4000 ± 200	7.0 ± 0.4
Lab 3	408 ± 2	4200 ± 300	11.7 ± 0.9
Lab 4	455 ± 2	3900 ± 700	15 ± 3.4
Lab 5	570 ± 2	4400 ± 500	13.1 ± 1.4

Furthermore, using gamma spectrometry, the concentrations of natural radioactivity (^{40}K, ^{232}Th, ^{238}U, $^{226}Ra/^{222}Rn$, $^{228}Th/^{220}Rn$, and ^{210}Pb) in the dust samples collected from the laboratories were calculated using Eq (2) and the results are presented in table 4. The table further shows the effective annual radiation doses due to inhalation for different radioisotopes at various survey sites. The values were separated by gender (male and female) and are expressed in units of 10−5 for ^{40}K. Noticeably, Lab 1 exhibited the highest effective annual radiation dose due to inhalation, ranging from 1886 to 2300 μSv y^{-1}, while lab 3 demonstrated the lowest effective annual radiation dose, with a value of 0.20 μSv y^{-1} for females. The activity concentrations of different radionuclides in the dust samples varied significantly among the different laboratories. In some instances, certain radionuclides fell below the limit of the measurement instrument, indicating exceptionally low concentrations. All values of radioactivity in the air measured at five laboratories for ^{238}U, ^{40}K, and ^{232}Th were lower than MDA, with the exception of lab 1 for ^{232}Th and ^{238}U.

Table 4. Radioactivity concentrations at the Labs in units of μBq m^{-3}.

Site	^{40}K	^{232}Th	^{238}U	$^{226}Ra/^{222}Rn$	$^{228}Th/^{220}Rn$	^{210}Pb
Lab 1	<MDA	75±45	292±83	1236±105	30328±1238	<MDA
Lab 2	<MDA	<MDA	<MDA	37±21	16±7	236±114
Lab 3	<MDA	<MDA	<MDA	114±43	<MDA	114±43
Lab 4	12.3±0.1	<MDA	<MDA	83±28	15±7	259±133
Lab 5	<MDA	35±23	<MDA	50±20	9±6	260±97

Table 5 shows the effective annual radiation dose due to inhalation for different radioisotopes at various survey sites. The values were categorised by gender (male and female) and are presented in units of 10−5 for ^{40}K.

Table 5. Annual effective dose due to inhalation of radionuclides Ei (μSv y^{-1}) at the survey sites

Site	Sex	^{40}K (´10-5)	^{232}Th	^{238}U	$^{226}Ra/^{222}Rn$	$^{228}Th/^{220}Rn$	^{210}Pb	Total dose
Lab 1	Male	-	0.4± 0.2	1.6± 0.5	2.6± 0.7	2295± 94	-	2300± 95
	Female	-	0.3± 0.2	1.3± 0.4	2.1± 0.6	1882± 77	-	1886± 78
Lab 2	Male	-	-	-	-	1.2±0.5	0.5± 0.2	1.8± 1.0
	Female	-	-	-	-	1.0±0.4	0.4± 0.2	1.5± 0.8
Lab 3	Male	-	-	-	-	-	0.24± 0.09	-
	Female	-	-	-	-	-	0.20± 0.07	-
Lab 4	Male	4.9± 0.1	-	-	-	1.2±0.5	0.5± 0.3	2.3± 1.9
	Female	4.0± 0.4	-	-	-	1.0±0.4	0.4± 0.2	1.9± 1.5
Lab 5	Male	-	0.2± 0.1	-	-	0.7±0.4	0.5± 0.2	1.5± 0.9

Upon receiving the results of the radiation concentration, lab 1 implemented several measures, and stringent regulations on radiation safety were enforced to ensure the health of students and staff working there. The increased concern and precautionary actions were primarily attributed to the presence of radioactive materials in the

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laboratory. In June 2022, the laboratory initiated a 24 -hour collection every Saturday as a part of a radiation concentration survey to verify the radioactivity concentration in the air. The results for both dust and radioactive concentrations are illustrated in tables 6 and 7. Moreover, table 7 provides the estimated radiation dose values due to inhalation for different radioisotopes based on four measurements conducted monthly in lab 1. Table 8 shows the monthly variation in the dose rates determined for lab 1. High doses were estimated for ^{228}Th and ^{220}Ra. The total dose rates ranged from 180 to 396 µSv y^{-1} in the male group and from 147 to 325 µSv y^{-1} for the female group.

Table 6. Total dust concentration $\bar{C}$ (µg m^{-3}), at the laboratories during June 2022.

Site	Mass of dust stored on filters (Δm)$^{-}$ (× 10^{-4} g)	The collected volume $\bar{V}$ (m^3)	Total dust concentration $\bar{C}$ (µg m^{-3})
Week1	829 ± 2	4800 ± 400	18 ± 2
Week2	667 ± 2	4800 ± 400	14.1 ± 1.2
Week3	524 ± 2	4900 ± 400	11.7 ± 0,8
Week4	562 ± 2	4800 ± 400	12.8 ± 0.8

Table 7. Radioactive levels in the air in units of µBq m-3.

	^{40}K	^{232}Th	^{238}U	^{226}Ra/ ^{222}Rn	^{228}Th/ ^{220}Rn	^{210}Pb
Week1	160 ± 40	<MDA	<MDA	182 ± 109	4269 ± 189	182 ± 109
Week2	< MDA	24 ± 20	<MDA	148 ± 84	2355 ± 111	148 ± 84
Week3	< MDA	<MDA	<MDA	202 ± 105	3279 ± 157	202 ± 105
Week4	< MDA	<MDA	<MDA	99 ± 88	5221 ± 214	99 ± 88

Table 8. Effective annual dose due to inhalation of radioisotopes.

	Sex	^{40}K (×10^{-5})	^{232}Th	^{238}U	^{226}Ra/ ^{222}Rn	^{228}Th/ ^{220}Rn	^{210}Pb	Total dose
Week 1	Male	65 ± 46	-	-	1.21 ± 0.72	323 ± 14	0.4 ± 0.2	325 ± 16
	Female	53 ± 37	-	-	0.99 ± 0.59	265 ± 12	0.3 ± 0.2	266 ± 13
Week 2	Male	-	0.12 ± 0.10	-	0.98 ± 0.56	178 ± 8	0.3 ± 0.2	180 ± 9
	Female	-	0.10 ± 0.08	-	0.8 ± 0.46	146 ± 7	0.25 ± 0.14	147 ± 8
Week 3	Male	-	-	-	1.33 ± 0.69	248 ± 12	0.42 ± 0.22	250 ± 13
	Female	-	-	-	1.09 ± 0.57	203 ± 10	0.34 ± 0.18	205 ± 11
Week 4	Male	-	-	-	0.66 ± 0.59	395 ± 16	0.21 ± 0.18	396 ± 17
	Female	-	-	-	0.54 ± 0.48	324 ± 13	0.17 ± 0.15	325 ± 14

DISCUSSION

The permissible limit for total dust concentration in indoor workplace air varies depending on the specific country or region. For instance, Wagner *et al.* (2009) identified a particle mass concentration of 20 –150 µg m^{-3} in Portugal [24], while over 82% of the Chinese population lives in an environment with particulate matter concentrations exceeding 75 µg m−3 [25]. In contrast, the dust concentrations measured in the laboratories were minimal and did not surpass the recommended threshold [26]. Here, total dust refers to all airborne particles, regardless of their chemical composition or size. The International Labour Organisation (ILO) has issued guidelines specifying occupational exposure limits for various types of dust, including total dust. These guidelines recommend exposure limits lower than those established by some countries and organisations. Different countries and organisations have instituted guidelines and regulations for exposure limits for total dust in the workplace. For example, the Occupational Safety and Health Administration (OSHA) in the US has set a permissible exposure limit of 15 mg m^{-3} of air for total dust in general industrial workplaces [8]. The Health and Safety Executive (HSE) in the UK and the EU have both set a WEL of 10 mg m^{-3} for total inhalable dust and 4 mg m^{-3} for respirable dust [27, 28]. Meanwhile, the National Technical Regulation on Dust in Vietnam has set a WEL for 8-hour time-weighted averages of 8 mg m^{-3} for total dust and 4 mg m^{-3} for inhalable dust.

The total effective inhaled radiation dose from the isotopes of interest was notably highest in lab 1, nearly 1000 times higher than in the other laboratories. Specifically, the total dose at Lab 1 reached 2300 µSv y^{-1} for men and 1886 µSv y^{-1} for women, significantly surpassing the one-year effective dose level for the general public, which should not exceed 1 mSv y^{-1}. However, these are still lower than the one-year effective dose limits for apprentices and students aged 16 to 18 years (with a limit of 6 mSv y^{-1}), as well as radiation workers (20 mSv y^{-1}). Besides, the mean effective dose attributed to gamma radiation in the indoor air across over 360 sites in Ondo State, Nigeria, was recorded as 1.56 mSv y^{-1} [29]. The range of annual effective doses around the ten major hospitals in the central and western regions of Bangladesh varied from 0.021 to 0.622 mSv y^{-1} [30]. Additionally, in the indoor air of Ho Chi Minh City, Vu *et al.* (2020) found the annual effective doses resulting from exposure to natural radionuclides ranged from 0.23 to 0.57 mSv y^{-1} [32]. A global average value of 0.48 mSv y^{-1} was documented by UNSCEAR [31].

High radioactivity levels were observed in the dust samples collected from lab 1, which could be ascribed to the presence of radioactive sources, standard samples, and environmental samples such as soil, water, and instructional materials [33,34]. Moreover, several human activities usually occur in this room during sample preparation. Thus, the radioisotope measurements were carried out four

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times a month to determine the monthly variation in radioactivity levels, with the results presented in table 7. It was noted that the activity values for ^{40}K fell within the normal background range, while those for ^{232}Th and ^{238}U were below the MDA. In addition, the radioactivity values for ^{226}Ra/^{222}Rn, ^{228}Th/^{220}Rn, and ^{210}Po remained detectable but showed a significant decrease compared to previous results. The variability of radioactivity levels between different periods of the month is not clearly defined. According to the literature, there is typically no noticeable difference in radioactivity levels over a short period (such as a month or a year) in the absence of a specific influencing factor [35,36]. Considering the outcomes of the radioactivity concentration and effective annual radiation dose due to inhalation, the radiation levels at lab 1 were generally within safe limits. Nevertheless, it is important to note that despite being within safe limits, continuous monitoring and strict regulations on radiation safety should be implemented to ensure the health and safety of both staff and students working in the laboratory.

CONCLUSION

As part of routine procedures, the activity concentrations of ^{40}K, ^{232}Th, ^{238}U, ^{210}Po, ^{226}Ra/^{222}Rn, and ^{228}Th/^{220}Rn were monitored in five distinct laboratories. According to the obtained results, it was identified that the ^{228}Th/^{220}Rn ratio constituted the main component present in the indoor air. Meanwhile, particle concentrations were found to be within the recommended level of 75 μg m^{-3}). Notably, high radioactivity levels were estimated for lab 1, primarily due to the presence of radiation and radioactive materials. Although the highest radiation doses were calculated for lab 1, the values remained within acceptable limits. It is recommended to conduct regular measurements for this laboratory type to ensure continuous monitoring and safety.

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