

Measurements of Radon Concentrations and Dose Assessments in Physics Department-Science College- Al-Mustansiriyah University, Baghdad, Iraq

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ABSTRACT

Measurements of radon gas concentrations with their progeny and the annual effective dose indoor the building of Al-Mustansiriyah University College of Science-Physics Department have been carried out by using time-integrated passive radon dosimeters solid state nuclear track detector CR-39 technique. The detectors with 1cm x 1cm have been distributed over 70 places and suspended for sitting (1m) and standing (1.75m) positions in each location under study. The dosimetric measurements are made over a period of 90 days from 30 January 2014 to 30 April 2014. The calibration process has been done using radium-226 source with known activity radiation. It has found that the indoor radon gas concentrations varying from $37.488 \pm 6.123 \text{ Bq/m}^3$ to $58.670 \pm 7.660 \text{ Bq/m}^3$ with an average value $51.398 \pm 7.156 \text{ Bq/m}^3$ at 1m, and varying from $35.964 \pm 5.997 \text{ Bq/m}^3$ to $56.994 \pm 7.549 \text{ Bq/m}^3$ with an average value $47.057 \pm 6.847 \text{ Bq/m}^3$ at 1.75m which are within the worldwide limits 148 Bq/m^3 (EPA, 2003) and $200\text{-}300 \text{ Bq/m}^3$ (ICRP, 2009). The annual effective dose of the inhalation exposure to radon gas has been estimated and this vary from 0.394 mSv/y to 0.617 mSv/y with an average value 0.540 mSv/y at 1m, and varying from 0.378 mSv/y to 0.599 mSv/y with an average value 0.495 mSv/y at 1.75m which are within the worldwide permissible limit $3\text{-}10 \text{ mSv/y}$ (ICRP, 1993). The potential alpha energy concentration found to vary from 4.053 mWL to 6.343 mWL with an average value 5.557 mWL at 1m and vary from 3.888 mWL to 6.162 mWL with an average value 5.087 mWL at 1.75m which are less than the recommended value 53.33 mWL (UNSCEAR, 1993). The lung cancer cases per million person per year vary from 7.093 to 11.101 per million person per year with an average value 9.725 per million person per year at 1m and vary from 6.805 to 10.784 per million person per year with an average value 8.904 per million person per year which are less than the recommended range 170-230 per million person per year (ICRP, 1993). The number of decays per-minute using swabs measurements technique have been used for selected units within two swabs from building materials walls for each unite, with area of 100 cm^2 using Ludlum 3030, the average of three swabs measurements have been calculated. Hence, the effectiveness of emitted alpha particles from the walls has been calculated to be varied from 0.00000 to 0.02222 Bq/cm^2 with an average value 0.01169 Bq/cm^2 at 1m and 0.01015 Bq/cm^2 at 1.75m respectively which are within the permissible limit 0.04 Bq/cm^2 (Danial, 2010).

1. INTRODUCTION

Radon was the fifth radioactive natural element being found as a noble gas, that was discovered by the German Physicist Friedrich Ernst Dron in (1900), who called it Niton. It has been called radon since (1923). Its atomic number is 86 and mass number is 222 in the periodic table [1,2]. Radon is a gas that comes from the radioactive decay of either uranium-235 and 238 or thorium-232. All of the gaseous radon members of the three primordial series headed by U-235, U-238, and Th-232 which are common naturally occurring are radioactive alpha particle emitters[3]. The decay of radon, with uranium-238, goes through four intermediate states to form radium-226 which has a half-life 1600 years. radium-226 then decay to form radon-222 gas. Radon's half-life is 3.82 days, which provides sufficient time for it diffuse through soil and into homes, where it further

disintegrates to produce the more radiologically active radon progeny (radon daughters) [2]. The name radon is Rn-222 isotope in order to distinguish it from other two natural isotopes; called thoron Rn-220 (alpha emitter of 55.6s half. Life) and actinon Rn-219 (alpha emitter of 3.96 s half-Life) because they originate in the thorium and actinium series, respectively. Because of these properties the measurements of the alpha dose delivered from actinon Rn-219 and thoron Rn-220 would be the primary concern but so far these situations have been rare [2]. Because Rn-222 gas moves freely in the indoor environment, it becomes a human health hazard. If its concentration in indoor air becomes high, radon and its decay products can be inhaled and cause lung cancer. Many previous studies of indoor radon concentration have been performed with widely used of solid state nuclear track detectors (SSNTDs)[4,5,6,7,8,9,10]. However, in this work the indoor radon gas concentrations using CR-39 detectors have been measured in the department of physics in college of science of Al-Mustansiriyah University, at which a radioactive sources are usually used in their laboratories.

2. MATERIALS AND METHODS

2.1. Area of the Study

Baghdad city is located in the Middle of Iraq and it is the capital of the Republic of Iraq. Its location of latitude 33.316666 and longitude 44.416668 it is located about 34meters above sea level, with a total area nearly of 204.2 km² and a population nearly of 7665292 inhabitants, see fig. 1. Baghdad city has a desert climate characterized by extreme heat during the day, an abrupt drop in temperature at night, and slight, erratic rainfall. The temperature is moderate at 12°C in winter and 33°C in summer. Its lands are flat and leveled in areas linked to waters from the Degla River. AL-Mustansiriyah University is located in the Southern of Baghdad City, see fig. 2. The science college and their buildings are shown in fig. 3. The three figures are taken from google earth.

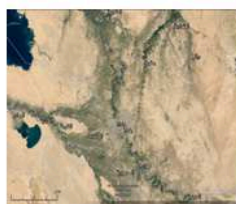


Fig. 1. Baghdad City.



Fig. 2. AL- Mustansiriyah University.



Fig. 3. The science college.

2.2. Measurement Technique

Radon concentrations are measured using 70 plastic cups (i.e. dosimeters) prepared with solid state nuclear track detectors CR-39 of 500μm thick, density 1.36 gm/cm³, UK issued, and 1x1 cm² area are distributed inside the rooms and laboratories of Department of Physics. 35 detectors of 70 are suspended at 1m and the others are suspended at 1.75m. Each dosimeter is to be made of a plastic cup of height 4.5cm, the diameter of the bottom is 3cm and that of the top is 4.5cm, with a circular hole of diameter 1cm in the center, fig. 4 shows the typical CR-39 track detectors. The hole is covered by a piece of sponge sealed into the interior surface of the lid. The detector CR-39 is fixed in the bottom of the dosimeter. The detectors are left for a period of three months from 30 January 2014 to 30 April 2014. The exposed detectors are collected from different locations and etched chemically in 6.5M NaOH solution at 60°C for 6 hours. The chemical etching process to the CR-39 detectors has been done in order to show the alpha-particles tracks from ²²²Rn. Optical microscope with magnification of 400X by an objective (4x, 10x, 40x and 100x) and two eye pieces (10x) with digital video camera of 5MB resolution and connected with a personal computer to show and counting the alpha damage tracks formed on the detectors.



Fig. 4 Typical CR-39 track detectors seen in the present work.

2.3. Ludlum3030

The Ludlum3030 alpha-beta counter is powered by main supply of AC voltage. The instrument features a built-in detector, ZnS (Ag) adhered to plastic cintillation material, tube 5.1cm (2inch) diameter, magnetically shielding photomultiplier, window 0.4mg/cm² aluminized mylar, active and open area 20.3cm², efficiency alpha 32% ²³⁰Th, 39% ²³⁸U, 37 % ²³⁹Pu, high-voltage power supply, adjustable count time periods, and a click-per-event audio with adjustable volume. A pulse height analyzer is employed to provide information to the two independent counters. Filter paper for qualitative analysis made in Germany by diameter 4.5cm, used to take samples from the walls of the Physics Department building of the College of Science.

2.4. Chemical Etching

For the preparation of etching solution, the weight of (NaOH) has been calculated as follows [11]:

$$W = W_{eq} \times N \times V \quad (1)$$

Where: W is the weight of NaOH needed to prepare for a given normality. W_{eq} is the equivalent weight of NaOH (i.e. the summation of the atomic weight of Na, O and H). i.e. $W_{eq} = 22.98977 + 15.9994 + 1.00794 = 39.99711 = 40$. N is the normality = 6.25. V is the volume of distilled water (1 liter). $W = 40 \times 6.25 \times 1 = 250$ gm of NaOH in 1 liter of distilled water.

2.5. Microscopic Viewing

After etching and drying process the detectors have a viewing by optical microscope so as to get on the alpha particles tracks by selecting right zoom (the ability of magnification is equal to 1000 related to objective lens and camera with magnification 100 and 10 respectively) and to count the tracks per unit area. Especially glass slide have been used to calibrate the dimensions of pictures. The camera has been connected with a microscope to photograph promised tracks. The camera is connected with the computer to show pictures effects on a computer screen. The calibration of software have been done to calculates the area of field view on a glass slide in front of the lens object-oriented and to calculate the length and width of the picture, then calculate the area and divides the average number of tracks (N_{ave}) for the (sample X) calculated on the area of field view per unit mm² (A) to get the track density. Ten attempts (pictures) have been taken for each sample, otherwise to calculate the average number of tracks obtained for each sample. The track density (ρ) has been calculated by using the following equation [12,13]:

$$\text{Track density } (\rho) = \frac{\text{average number of total tracks } (N_{ave})}{\text{area of field view } (A)} \quad (2)$$

2.6. Calibration of CR-39 Detector

The calibration of CR-39 detector has been carried out by using the standard source of radium ²²⁶Ra with radioactivity ($A=0.1\mu\text{Ci}=37000\text{Bq}$) at manufacturing data 1-03-1982, which emits radon gas ²²²Rn. After correction the activity to $A=36481.13\text{Bq}$ at 30-09-2013 and dose rate at 1cm is 63.611 $\mu\text{Sv/hr}$ using Rad Pro software. The CR-39 detector and the standard source of radium ²²⁶Ra were placed at the special container used in the present work with a cylinrical shape and volume 0.11m³ diameter 40cm and hight 85cm. The activity of radon gas (A_{Radon}) inside the container at any time can be calculated by using the following equation [14]:

$$A_{\text{Radon}} = A_{\text{Radium}} \times (1 - \exp(-\lambda_{\text{Radon}} \times t)) \quad (3)$$

Where: $t_{1/2}(^{222}\text{Rn}) = 3.8253$ day. $A_{\text{Radium}} = 36481.1\text{Bq}$ is the activity of radium-226 as a standard source. λ_{Radon} is the decay constant of radon-222 $= 0.1812 \text{ day}^{-1}$. t is the exposure time in day. The exposure time of detectors was with different times (0.25, 0.5, 0.7, and 1 day), then the radon exposure determined by [15]:

$$E_s(\text{Bq.day/m}^3) = [A_{\text{Radon}}(\text{Bq})/V(\text{m}^3)] \times t(\text{day}) \quad (4)$$

Where E_s is the radon gas exposure (i.e. concentration) in standard source. A_{Radon} is the radioactivity of ^{222}Rn calculated by equation (3). V is the container volume in m^3 ; t is the exposure time in day. Fig. 5 shows the relation between the track density (ρ_s) and the radon exposure (E_s).

$$\text{Slope} = \rho_s / E_s \quad (5)$$

Where ρ_s is the track density of standard source (tracks/ mm^2). E_s is the radon exposure of standard source (Bq/m^3).days = (Bq/m^3) by multiplying with (0.25, 0.5, 0.75, and 1 day).

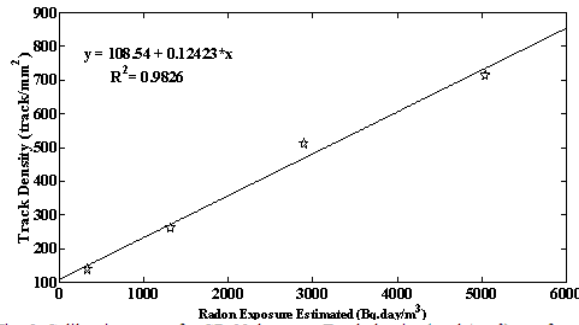


Fig. 5. Calibration curve for CR-39 detector. Track density (track/ mm^2) as a function of Radon exposure (Bq.day/m^3).

2.7. Calculation of Radon Exposure

After microscopic viewing process has been done to calculate the track density. Radon gas ^{222}Rn concentration indoor has been measured by comparison between track densities on the detector around the unknown sample and that of the standard calibration source, from the following relation [15]:

$$E_x(\text{sample})/\rho_x(\text{sample}) = E_s(\text{standard})/\rho_s(\text{standard}) \quad (6)$$

i.e. $E_x = E_s(\rho_x/\rho_s)$. where E_x is the radon gas exposure in unknown sample (Bq/m^3 .day). ρ_x is the track density of unknown sample (tracks/ mm^2). Therefore, from the slope $= \rho_s/E_s$, E_x can be estimated as:

$$E_x = \rho_x / \text{Slope} \quad (7)$$

2.8. Determination of Radon Concentration

Radon concentration in surrounding air is measured in terms of Bq/m^3 , since the most regulate reference levels are specified in this unit. Determinations of radon concentration indoor buildings of the Department of Physics-College of Science are carried out by the following equation [16,17]:

$$C_{\text{Rn}}(\text{Bq/m}^3) = \frac{E_x(\text{Bq.day/m}^3)}{\rho_x} \left(\frac{\rho}{t} \right) \quad (8)$$

Where ρ is the track density (number of track / mm^2) of distributed detectors. t is the exposure time (days) of distributed detectors. Comparable method is also obtained for track detectors techniques to determine the calibration constant (factor). This is obtained by dividing the track density by the total exposure of radon source. Then equation (8) of radon exposure becomes [18,19]:

$$C(\text{Bq/m}^3) = \frac{1}{\text{slope}} \left(\frac{\rho}{t} \right)_{\text{det}} \quad (9)$$

$$\text{Since } \frac{1}{\text{slope}} = \frac{E_s(\text{Bq.d/m}^3)}{\rho_s(\text{track/mm}^2)}; \text{slope} = \frac{\rho_s(\text{track/mm}^2)}{E_s(\text{Bq.d/m}^3)} \quad (10)$$

Where the slope is the calibration factor in terms of (track. mm^2 / Bq.day.m^3).

2.9. Dose Assessment Indoor Radon

2.9.1. The annual effective dose

The annual effective dose, H_E , due to radon inhalation, which corresponds to the values of indoor air radon concentrations, was calculated according to the following expression [20]:

$$H_E = C_{Rn} \times E_q \times T \times 9nSv(Bq.h.m^{-3})^{-1} \quad (11)$$

Where C_{Rn} is the average indoor air radon concentration, in Bq/m^3 . E_q is the indoor equilibrium factor between radon and its progeny ($=0.4$) (Wahl, 2007) [20]. T is the exposure time to this concentration, in hours, and $9nSv (Bq.h.m^3)^{-1}$ is the dose conversion factor.

2.9.2. Potential Alpha Energy Concentration

The Potential Alpha Energy Concentration (PAEC) in terms of (WL) units was obtained using the relation [8,21]:

$$PAEC(WL) = E_q \times C_{Rn}/3700 \quad (12)$$

2.9.3. Lung Cancer Cases per Year per Million Person

The lung cancer cases per year per million person (CPPP), was obtained using the relation [4,21,22]:

$$(CPPP) = H_E \times (18 \times 10^{-6} mSv^{-1}.y) \quad (13)$$

Where $18 \times 10^{-6} mSv^{-1}.y$ is conversion factor.

2.10. Alpha particles emitted of surfaces

Specific activities of various radionuclides, disintegrations per minute per 100 square centimeters (dpm/100 cm^2) used to measure alpha emitted of surfaces of an object, such as concrete or metal [23].

$$\text{Alpha emitted } (Bq/cm^2) = \text{dpm}/6000 \quad (14)$$

Where (dpm) is equal to ($Bq/60$). Table 1 tabulated the location name and the cods at 1m and 1.75m in the department of physics laboratories building. While Fig. 6 shows the block diagram for the physics department laboratories building.

Table 1 Department of physics laboratories building.

Sequence	Location Name	Coding at 1m	Coding at 1.75m
1	Department of Physics Secretary Room	Phy1a1	Phy1a2
2	Head of the Department of Physics	Phy2a1	Phy2a2
3	Rapporteur of the Department of Physics	Phy3a1	Phy3a2
4	Rapporteur of Higher Studies / Department of Physics	Phy4a1	Phy4a2
5	Scientific Affairs Room / Department of Physics	Phy5a1	Phy5a2
6	Computing Laboratory / Department of Physics	Phy6a1	Phy6a2
7	Laboratory of Theoretical Physics	Phy7a1	Phy7a2
8	Physics Department Store	Phy8a1	Phy8a2
9	Laboratory of Polymer Molecular	Phy9a1	Phy9a2
10	Laboratory of Spectra and Molecular1	Phy10a1	Phy10a2
11	Laboratory of Spectra and Molecular2	Phy11a1	Phy11a2
12	Teaching Staff Room No.5	Phy12a1	Phy12a2
13	Teaching Staff Room No.4	Phy13a1	Phy13a2
14	Atomic Physics Laboratory	Phy14a1	Phy14a2
15	Solid State Physics Laboratory	Phy15a1	Phy15a2
16	Teaching Staff Room No.13	Phy16a1	Phy16a2
17	Electronics Laboratory	Phy17a1	Phy17a2
18	Teaching Staff Room No.10	Phy18a1	Phy18a2
19	Teaching Staff Room No.11	Phy19a1	Phy19a2
20	Optical Physics Laboratory	Phy20a1	Phy20a2
21	Teaching Staff Room No.7	Phy21a1	Phy21a2
22	Solid Physics Laboratory of Higher Studies	Phy22a1	Phy22a2
23	Thermodynamic Laboratory	Phy23a1	Phy23a2
24	Teaching Staff Room No.8	Phy24a1	Phy24a2
25	Laboratory of Mechanics	Phy25a1	Phy25a2
26	Evaporation Laboratory of Higher Studies	Phy26a1	Phy26a2
27	Laboratory / Department of Physics	Phy27a1	Phy27a2
28	Nuclear Laboratory of Higher Studies	Phy28a1	Phy28a2
29	Solid State Laboratory of Higher Studies	Phy29a1	Phy29a2
30	Teaching Staff Room No.1	Lost	Lost
31	Teaching Staff Room No.2	Lost	Lost
32	Water Circuit for Men	Lost	Lost
33	Teaching Staff Room No.3	Lost	Lost
34	Water Circuit for Women	Lost	Lost
35	Teaching Staff Room No.6	Lost	Lost

Note: a1=1m, a2=1.75m

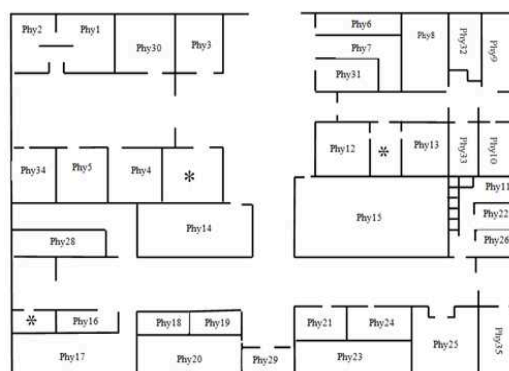


Fig. 6. Block diagram for the physics department.

* No suspended track.

3. RESULTS AND DISCUSSION

Radon exposure for such long time is necessary in order to obtain relatively a good number of tracks and to be counting statistically. The calibration factor used for conversion of track density (track/ $mm^2.day$) to radon concentrations in (Bq/m^3) is $0.12423 \text{ track} \cdot mm^{-2} \text{ per } Bq \cdot day \cdot m^{-3}$. The background has been calculated by calculating and subtracting from the track density of each track

detector which was exposure to a period of measurement. The radiological risk associated with indoor radon exposure and relevant regulation have been evaluated. Regulations vary greatly between countries. The United States of America (USA) use a reference level of 148Bq/m^3 for dwellings and 400Bq/m^3 for workplaces (USEPA, 2004) [24]. The European Union (EU) accepts the recommended action level, the radiation level above which preventive action must be taken, included in the International Commission on Radiological Protection (ICRP, 1965) [25] of between 500 and 1500Bq/m^3 given by Kavasi et al., 2006 [26], and ICRP, 2009 [27] has identified the limit of radon concentration for the population to be $(200\text{-}300\text{Bq/m}^3)$ (ICRP, 2009) [27]. In the United Kingdom (UK) the Health and Safety Executive (HSE) given by Kendall et al., 2005 [28] has adopted a radon action level of 400Bq/m^3 for workplaces. Also the limit is populated to be (148Bq/m^3) in Environmental Protection Agency (EPA) (EPA, 2003) [29]. In Hungary the action level for workplaces is 1000Bq/m^3 (Kendall et al., 2005) [28]. While Israel uses a reference level between 40 and 200Bq/m^3 (Akerblom, 1999) [30]. There are no specific regulations in Iraq for indoor radon levels in either dwellings or workplaces. Department of Physics Building consists of several unites including laboratories preliminary studies and laboratories graduate addition to the private rooms of the masters. Among 70 suspended detectors, 12 have been lost. The results of the measurements at 1m and 1.75m for the department of physics are as follows:

3.1. Measurements at 1 meter for Department of Physics

Figs. 7, 8, 9, and 10 show the measured radon concentrations, the annual effective dose, potential alpha energy concentrations, and the lung cancer per year million person for different locations in the building of department of physics at 1m. The minimum radon concentration is recorded at location (Phy21a1), teaching Staff room no.7, with a value $37.488 \pm 6.123\text{Bq/m}^3$, and the maximum value of radon concentration recorded at location (Phy11a1), Laboratory of Spectra and Molecular2, with a value of $58.670 \pm 7.66\text{Bq/m}^3$, with an average value $51.398 \pm 7.156\text{Bq/m}^3$. The results are less than the limits $(200\text{-}300\text{Bq/m}^3)$ (ICRP, 2009) [27], and (148Bq/m^3) (EPA, 2003) [29]. The measurements of radon concentrations from 30Bq/m^3 to 40Bq/m^3 are at locations: Ph21a1=37.488, and Phy23a1=37.640 Bq/m^3 . The measurements of radon concentrations from 40Bq/m^3 to 50Bq/m^3 are at locations: Phy2a1=49.679, Phy3a1=47.241, Phy7a1=46.174, Phy14a1=43.583, Phy16a1=46.783, Phy19a1=48.003, Phy20a1=43.736, Phy24=46.783, Phy27a1=45.107, and Phy29=46.936 Bq/m^3 . The measurements of radon concentrations from 50Bq/m^3 to 60Bq/m^3 are at locations: Phy1a1=53.641, Phy4a1=58.213, Phy5a1=53.64, Phy6a1=55.927, Phy8a1=57.298, Phy9a1=56.536, Phy20a1=55.165, Phy11a1=58.670, Phy12a1=57.603, Phy13a1=57.756, Phy15a1=58.518, Phy17a1=53.031, Phy18a1=56.994, Phy22a1=52.574, Phy25a1=53.793, Phy26a1=55.470, and Phy28=56.536 Bq/m^3 . The values of the indoor annual effective dose vary from 0.394mSv/y in (Phy21a1) to 0.617mSv/y in (Phy11a1) with an average value 0.540mSv/y which is less than the lower limit of the admissible range 3-10mSv/y (ICRP, 1993)[31]. The values of the potential alpha energy concentration were found to vary from 4.053mWL in (Phy21a1) to 6.343mWL in (Phy11a1) with an average value 5.557mWL which is less than the admissible value 53.33 mWL given by UNSCEAR, 1993 [3]. The values of lung cancer cases per million person per year vary from 7.093 in (Phy21a1) to 11.101 in (Phy11a1) with an average value 9.725 per million person which is less than the lower limit of the admissible range 170- 230 per million person per year (ICRP, 1993) [31].

3.2. The measurements at 1.75 meter for Department of Physics

Figs. 11, 12, 13 and 14 show the measured radon concentrations, the annual effective dose, potential alpha energy concentrations, and the lung cancer per million person per year for different locations in the department of physics building at 1.75m. The minimum radon concentration is recorded at location (Phy20a2), Optical Physics Laboratory, with a value $35.964 \pm 5.997\text{Bq/m}^3$, and the maximum radon concentration recorded at location (Phy12a2), teaching staff room no.5, with a value of $56.994 \pm 7.549\text{Bq/m}^3$, with an average value $47.057 \pm 6.847\text{Bq/m}^3$. All results are within the worldwide limits $200\text{-}300\text{Bq/m}^3$ (ICRP, 2009)[27], and 148Bq/m^3 (EPA, 2003)[29]. The measurement

radon concentrations from 30Bq/m^3 to 40Bq/m^3 are at locations: Ph19a2=37.335, Phy20a2=35.964, and Phy21=39.012 Bq/m^3 . While the measurement radon concentrations from 40Bq/m^3 to 50Bq/m^3 are at locations: Phy1a2=46.479, Phy5a2=47.545, Phy6a2=49.069, Phy7a2=47.850, Phy8a2=42.669, Phy10a2=47.393, Phy13a2=41.145, Phy16a2=40.231, Phy17a2=42.212, Phy22=40.688, Phy23a2=43.126, and Phy24a2=43.736 Bq/m^3 ; and the measurement radon concentrations from 50Bq/m^3 to 60Bq/m^3 are at locations: Phy3a2=51.812, Phy4a2=55.775, Phy9a2=52.727, Phy11a2=53.336, Phy12a2=56.994, Phy14a2=50.288, Phy15a2=51.669, Phy18a1=581.812, Phy26a2=53.946, Phy27a2=53.336, Phy28a1=51.660, and Phy29a2=50.441 Bq/m^3 . Fig. 15 shows the radon concentrations at 1m and 1.75m for different locations in the laboratories building of the physics department. The minimum value recorded at location (Phy20a2) with a value of $35.964 \pm 5.997\text{Bq/m}^3$ and the maximum value recorded at location (Phy11a1) with a value $58.670 \pm 7.660\text{Bq/m}^3$. All results are within acceptable limits $200\text{--}300\text{Bq/m}^3$ (ICRP, 2009) [27], and 148Bq/m^3 (EPA, 2003) [29]. The indoor annual effective dose vary from 0.378mSv/y in (Phy20a2) to 0.599mSv/y in (Phy12a2) with an average value 0.495mSv/y which is less than the lower limit of the admissible range $3\text{--}10\text{mSv/y}$ (ICRP, 1993) [31]. The potential alpha energy concentration were found to vary from 3.888mWL in (Phy20a2) to 6.162mWL in (Phy12a2) with an average value 5.082mWL which is less than the admissible value 53.33 mWL given by UNSCEAR, 1993 [3]. The lung cancer cases per million person per year vary from 6.805 in (Phy20a2) to 10.784 in (Phy12a2) with an average value 8.904 per million person per year which is less than the lower limit of the admissible range ($170\text{--}230$) per million person per year (ICRP, 1993) [31].

3.3. Measurements of the Alpha particles emitted from wall surfaces

For this process, we need to use a filter paper which has specifically designed to take swabs from the surface of the walls inside rooms, since the walls consisting of building materials. The swabs have been taken from 58 swabs from the wall surfaces with squared area $(10 \times 10)\text{ cm}^2$ by scanning all this area with a filter paper. The measurements have been done by insert the filter in the Ludlum3030 device for a period of one minute. This procedure will be repeated three times for each filter respectively, to take the average value then using equation (14) to calculate the emitted alpha particles. Fig. 16 shows the results of measurements of alpha particles emitted from the wall surfaces in the physics department building by using Ludlum3030. The minimum value is 0.000Bq/cm^2 recorded at locations (Phy27a2, Phy28a1, and Phy28a2), library department of physics, and nuclear laboratory of higher studies respectively. While the maximum value is 0.02222Bq/cm^2 which is recorded at locations (Phy13a1, Phy17a1, and Phy21a2), teaching staff room no.4, electronics laboratory, and teaching staff room no.7 respectively. The average value is 0.01169Bq/cm^2 for sitting position and 0.01015Bq/m^2 for standing position. Therefore, all results are lower than the recommended limit 0.04 Bq/cm^2 given by Daniel, 2011 [32].

4. CONCLUSIONS

The maximum recorded values of higher radon concentrations in the laboratory building of Physics Department are at (Phy11a1) is $58.670 \pm 7.660\text{Bq/m}^3$ for sitting position, at laboratory of spectra and molecular2, and at (Phy12a2) is $56.994 \pm 7.549\text{Bq/m}^3$ for standing position, at teaching staff room no.5. While the measured value of radon concentrations in the head of the department of physics room Phy2a1 is $49.679 \pm 7.048\text{Bq/m}^3$ for sitting position, and Phy2a2 is $42.212 \pm 6.497\text{Bq/m}^3$ for standing position. The results are lower than the recommended worldwide ($200\text{--}300\text{Bq/m}^3$) (ICRP, 2009), and (148Bq/m^3) (EPA, 2003). The maximum indoor annual effective dose, potential alpha energy concentration, and lung cancer cases per million person per year are 0.617mSv/y , 6.343mWL , and 11.101 in (Phy11a1) the laboratory of spectra and molecular2, for sitting position and are 0.599mSv/y , 6.162mWL , and 10.784 in (Phy12a2) the teaching staff room no.5, for standing position which are less than the lower limit of the admissible limit range $3\text{--}10\text{mSv/y}$ (ICRP, 1993), 53.33 mWL given by (UNSCEAR, 1993), and the admissible limit range $170\text{--}230$ per million per person per year (ICRP, 1993) respectively. The maximum measured alpha particles

emitted values from the wall surfaces are 0.02222Bq/cm^2 at (phy13a1) the teaching staff room no.4, and at and (phy17a1) the electronics laboratory for sitting position, and 0.02222Bq/cm^2 at (phy21a2) the teaching staff room no.7, and (phy17a1) the electronics laboratory. The results are lower than the recommended worldwide limit(0.04Bq/cm^2). All results are within the worldwide acceptable limits and there are no health risks.

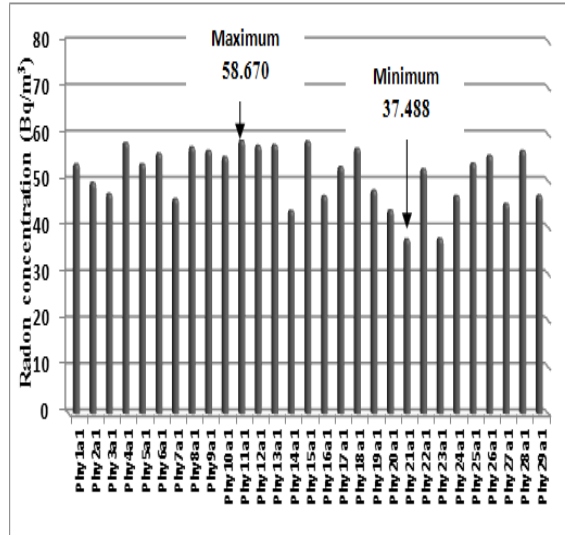


Fig. 7. Radon concentrations at 1m for different locations at department of physics.

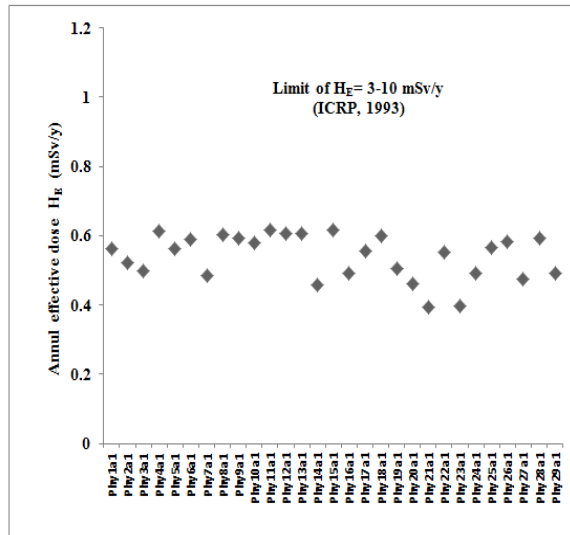


Fig. 8. Annual effective dose at 1m for different locations at department of physics.

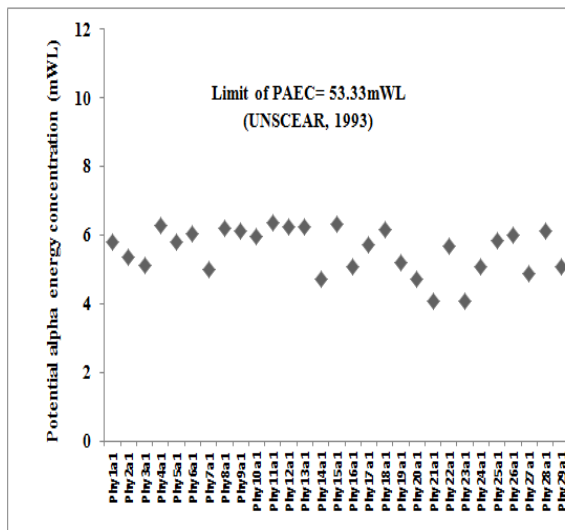


Fig. 9. Potential alpha energy concentration at 1m for different locations at department of physics.

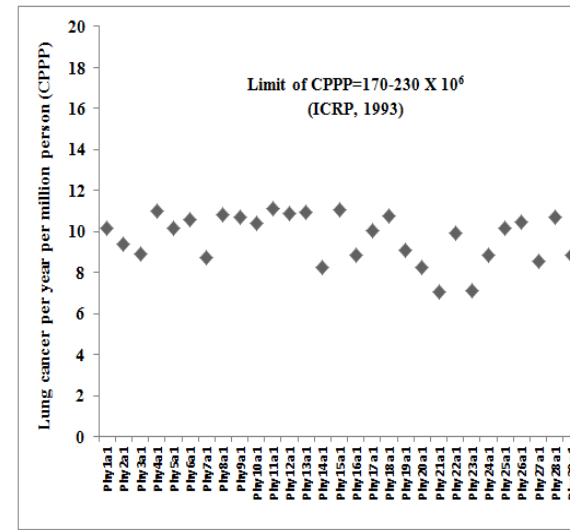


Fig. 10. Lung cancer cases per year per million person at 1m for different locations at department of physics.

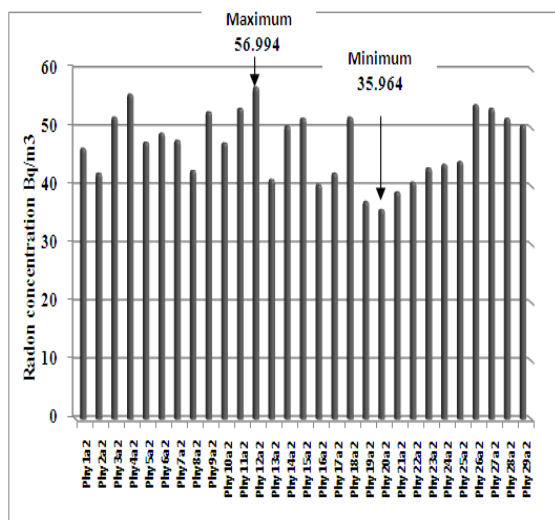


Fig. 11. Radon concentrations at 1.75m for different locations at department of physics.

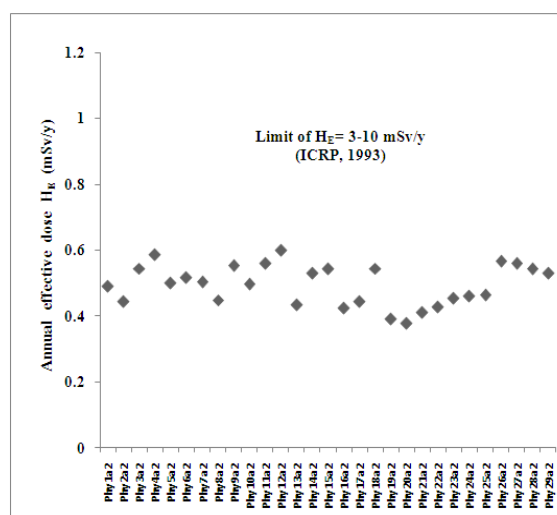


Fig. 12. Annual effective dose at 1.75m for different locations at department of physics.

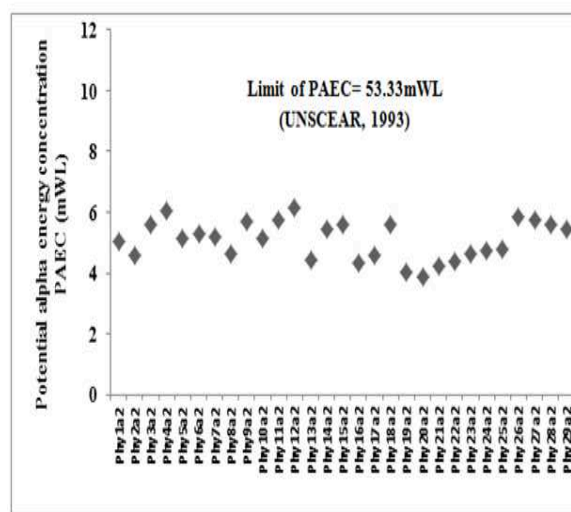


Fig. 13. Potential alpha energy concentration at 1.75m for different locations at department of physics.

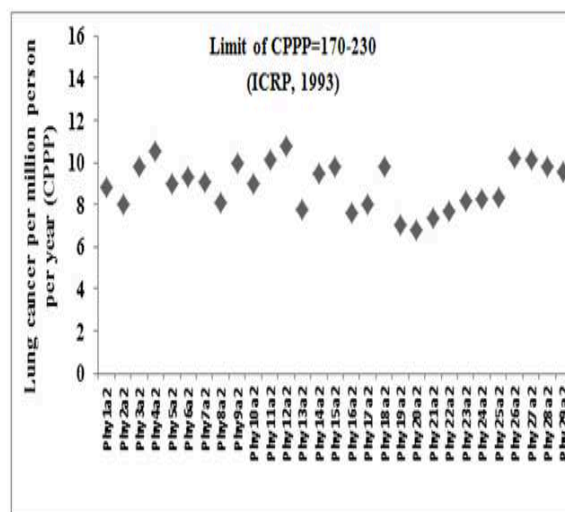


Fig. 14. Lung cancer cases per million person per year at 1.75m for different locations at department of physics.

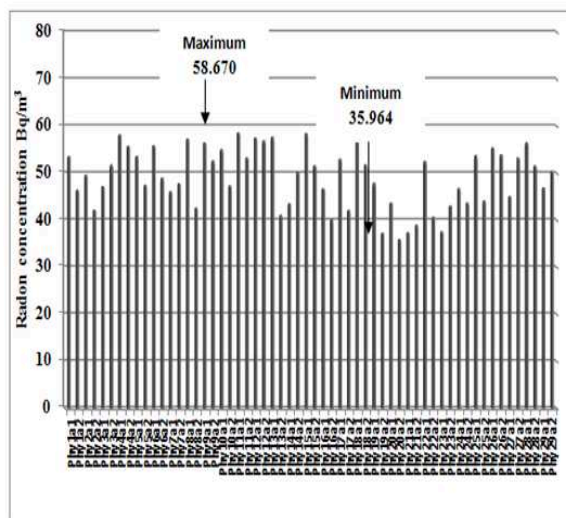


Fig. 15. Radon concentrations at 1m and 1.75m for different locations at department of physics.

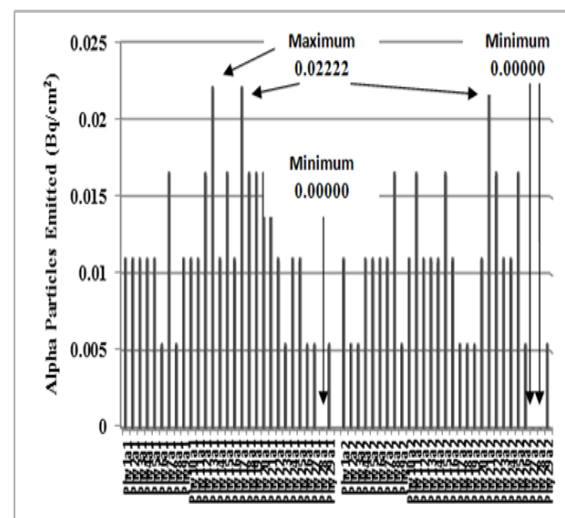


Fig. 16. Alpha particles emitted from surfaces in the department of physics at 1m and 1.75

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