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Radon Concentrations Assessment and Effective Dose Estimation in The Buildings of University of Technology/ Baghdad

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ABSTRACT:

The objective of the present work was to assess the distribution of radon in the University of Technology buildings, Baghdad - Iraq and to identify the effective dose of radon exposure to the staff using passive dosimeter (SSNTD) CR-39. One hundred CR-39 dosimeters were distributed over different buildings in the University campus according to the number of floors area. The exposure time started from December 2012, and the dosimeters were left inside buildings for 40 days. Only 93 dosimeters were collected, while the remaining 7 were considered lost. The average concentrations were calculated in units of Bqm^{-3}, for each sample in each building, and then are repeated after grouping in each floor of the same building. The average radon concentrations per building and at the university as a whole were also calculated.

Radon concentrations were found to vary from 80.1 to 416.7 Bqm^{-3}. The highest radon concentration with a mean value of 416.7 Bqm^{-3} was found atuniversity press section building, while the lowest radon concentration was found at the welding division 2 building with a mean value of 80.1 Bqm^{-3}. The average value of radon concentration at the university was found to have the value of 181.9 Bqm^{-3} which is less than the recommended value of 200 Bqm^{-3} UNSCEAR [18].

Dose rate (in µSv/h), annual dose rate (in mSv/y & WLM/y), cumulative dose (in mSv& WLM) and cancer risk were also calculated. It was found that the university staffs are exposed annually to 2.083 mSv which equal to 0.231 Working Level Month (WLM) from radon gas and its short-lived daughters. Hence, a person takes on the

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average an annual effective dose equivalent to 2.56and 1.84mSv according to average value considered by UNSCEAR [18] and ICRP [19], respectively. This implies an expected value for lung cancer probability of 0.0046.

Keywords: Indoor radon concentration; CR-39; Effective dose; Annual dose rate; cumulative dose; cancer risk; Baghdad, Iraq, University of Technology.

تقييم تراكيز الرادون والجرعة الفعالة في مباني الجامعة التكنولوجية- بغداد

الخلاصة:
هدف البحث الى تقييم تركيز الرادون في مباني الجامعة التكنلوجية, بغداد – العراق وكذلك حساب الجرعة الفعالة التي يتعرض لها العاملون في الجامعة باستخدام مجراع كاشف الاثر النووي CR-39. تم توزيع 100 مجراع في مباني الجامعة وتُركتلمدة 90 يوم ابتداءاً من كانون الاول 2012. بينت النتائج ان تركيز غاز الرادون يتراوح بين اوطأ قيمة له80.13 بيكريل/م^3 في مبنى شعبة اللحام الى اعلى قيمة له416.67 بيكريل/م^3 في مبنى مطبعة الجامعة. كما وجد ان متوسطمستوى الرادون في الجامعة 181.86 بيكريل/م^3 وهذه القيمة اقل من القيمة المسموح بها عالمياً.
كما تم في هذه الدراسة حساب معدل الجرعة ومعدل الجرعة السنوية والجرعة المتراكمة وكذلك نسبة خطر الاصابة بسرطان الرئة. وُجد ان العالمين في الجامعة يتعرضون سنوياً الى 2.083mSv من غاز الرادون ووليداتها وهي اقل من المعدلات المسموحة والمقترحة من(1982) UNSCEAR و ICRP . (1993)

INTRODUCTION:

Radon is an invisible, odorless, tasteless, radioactive gas, which is formed by the disintegration of radium, which is a decay product of uranium. Radon emits alpha particles and produces several solid radioactive products called radon daughters. Previous research papers show that ^{222}Rn, on average, in many countries contributes 50% radiation dose to the general public [1- 6].

Some amounts of radon gas and radon daughters are present everywhere in the soil, water, and air. Particularly high radon levels occur in regions where the soil or rock is materials. It can enter the indoor air where it and its decay products accumulate in poorly ventilated areas.

Harmful levels of radon and radon daughters can accumulate in confined air spaces, such as basements. Indoor radon concentrations are almost always higher than outdoor concentrations. Once inside a building, the radon cannot easily escape. Radon daughters are inhaled with air and deposit in the lungs. The lung absorbs alpha particles emitted by the radon daughters. The resulting radiation dose increases the risk of lung cancer.

Acceptable levels of radon in "dwellings" which includes homes or public buildings (schools, hospitals, offices …. etc.) is 200 Bq/m^3 based on the Government of Canada Radon Guideline[7].

The US EPA has set an action level of 4 pCi/L which is equivalent to 150Bqm^{-3}[8]. It is estimated that a reduction of radon levels to below 2 pCi/L nationwide would likely reduce the yearly lung cancer deaths attributed to radon by 50%. However, even with an action level of 2 pCi/L, the cancer risk presented by radon gas is still hundreds of times greater than the risks allowed for carcinogens in our food and water.A collective analysis of results from 13 European studies regarding relations between radon concentrations inhaled at home and lung cancer [9] showed that radon is responsible for 2% of deaths due to all neoplasms in Europe and approximately 9% of deaths due to lung cancer. The risk of lung cancer was observed to increase by 8.4% at the increase in concentration by 100 Bqm^{-3}[9]. There are also studies that undermine the causative relation between radon exposure and lung cancer [10 – 12].

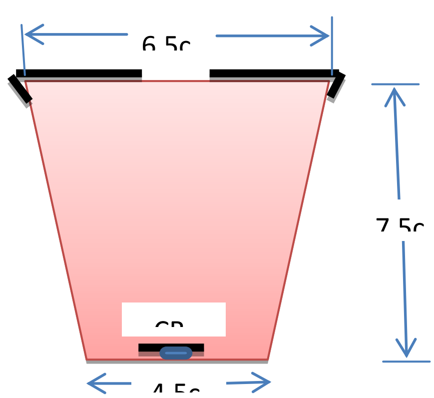
Indoor radon concentrations vary between regions and from building to building within individual towns and villages. The WHO has published a recent review of radon policies in 26 countries. The average radon concentrations of 26 countries are included in the WHO review [13].

WHO Handbook on Indoor Radon [14]: A Public Health Perspective indicates that radon exposure is a major and growing public health threat in homes and recommends that countries adopt reference levels of the gas of 100 Bqm^{-3} which is equivalent to 2.7 pCi/L.

The main aim of the present work is to estimate the mean annual radon progeny concentrations and effective inhalation radiation dose in the work offices of the University of Technology, Baghdad, Iraq.

Measuring Procedures

The measurement technique used in this work was the passive radon dosimeter[15, 16]. This technique is usually used for long-term measurements inside dwellings, where solid- state nuclear track detectors (CR-39) were used.They have been cut to (1x1.5) cm^2 size rectangles, and were fixed at the bottom of a plastic cup using double-sided tape (Figure 1). On the cover of the cup there is a hole sealed by a 5-mm thickness sponge. This set-up allows radon to diffuse inside the cup. The track density of alpha particles in the detectors provides information about the relative concentration of radon in the apartments surveyed.



Figure(1). Schematic diagram of the dosimeter used in the study.

Total of 100 dosimeters were prepared and distributed in the University of Technology buildings. Dosimeters were placed in different rooms of different floors in 28 buildings at a height of about 2 m above the floor. After 40 days of exposure, 93 dosimeters were collected, the rest were considered lost. The collected dosimeters were then chemically etched, using a 6.25N solution of NaOH at a temperature of 80^o C for five hours. An optical microscope with a magnification of 10x40 was used to count the number of tracks per cm^2 recorded on each detector.

The tracks for ten fields of view (FOV) (area$12.57x10^{-4}$ cm^2) were counted randomly all over the detector surface to obtain an average and representative value of track density for each dosimeter. The measured track densities formed on the analyzed NTDs were converted into radon concentrations (Bqm^{-3}) using the calibration factor of (0.00936tracks cm^{-2} per $Bqhm^{-3}$) [17] by adopting an exposure period of 40 days. The radon activity density C, in units of Bqm^{-3}, is then calculated using the following relation:

$$C= \rho/t.CF \qquad \ldots(1)$$

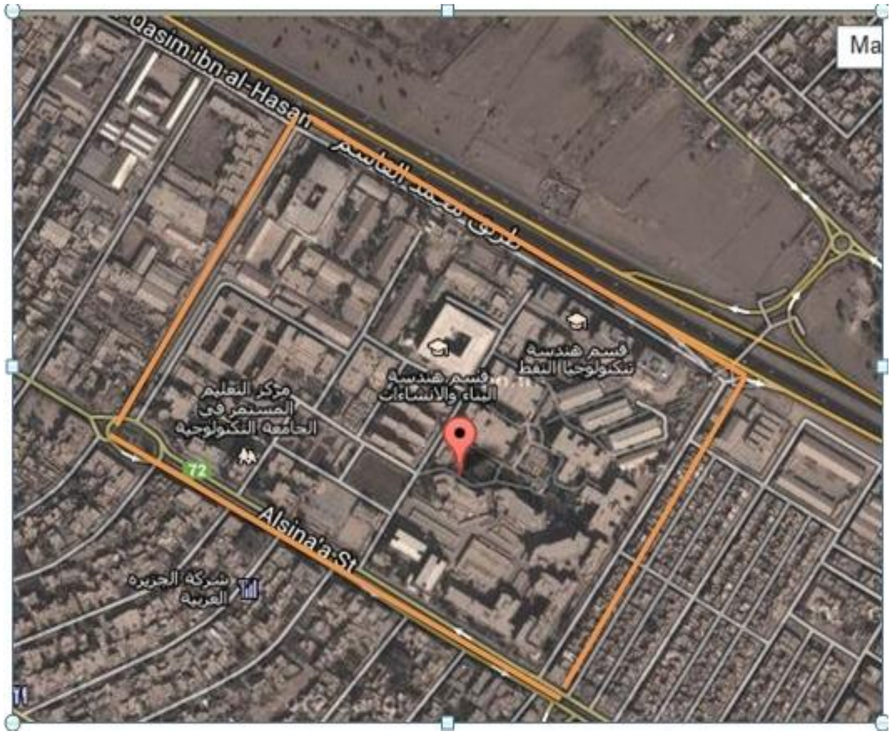
where ρ is the average track density per cm^2 on the CR-39 detectors that were inside our dosimeters used in this work, t is the exposure time of the distributed dosimeters in hrs and CF is the calibration factor in tracks/cm^2 Bqm^{-3}h.

Then dose rate in µSv/h, annual dose rate in mSv/y and in WLM/y, cumulative dose in units mSv and WLM and cancer risk were calculated for each building.

According to the suggestions made by UNSCEAR [18], the dose conversion factor is 0.061 mSv per Bqm-3, while according to ICRP 65 [19]dose conversion convention, the effective dose per unit of exposure at home is 4 mSv per working level month (WLM), which is based on a working month. It is defined as the amount of radioactive exposure an individual receives if he is exposed to 1 WL of radon for one working month (170 hours), considering the working time 2000h/y.

Region of Interest

University of Technology campus lies to the northwest of Baghdad, capital of Iraq, at the latitude of 33^o 18' 40” N and the longitude of 44^o 26' 51” E (Fig. 2). The university has an area of about 0.2 sq.km.it consists of 41 buildings and 4 metal buildings.



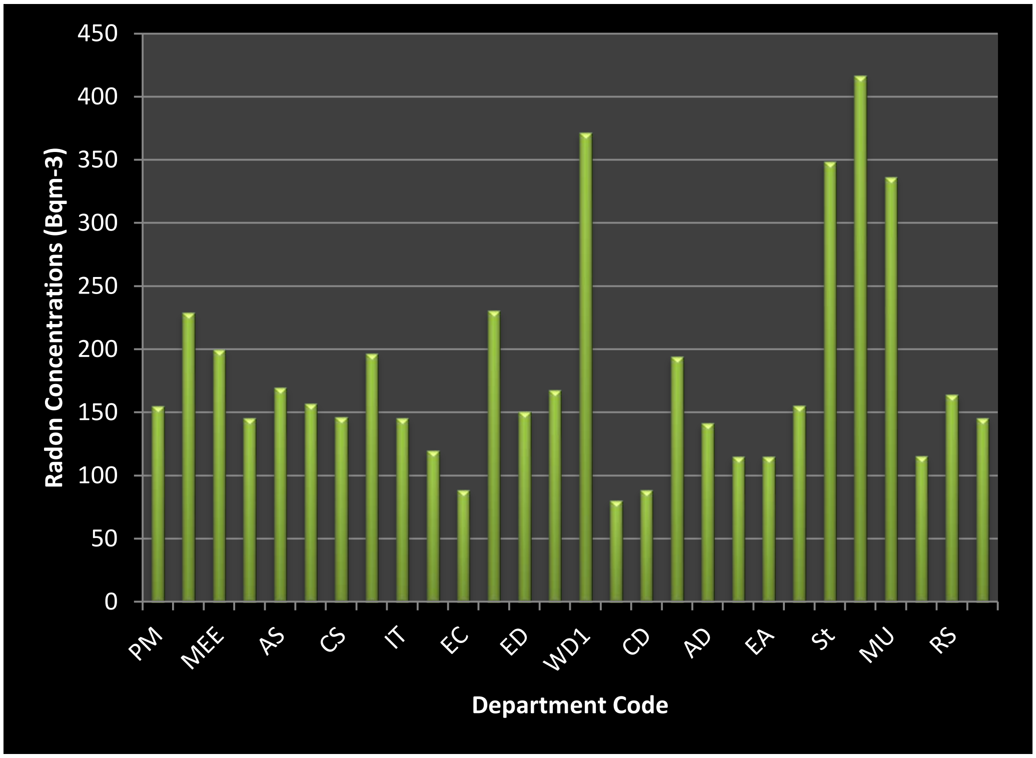
Figure(2). Satellite photo of the studied area.

Results and Discussion

Figure (3) shows a block diagram of the radon concentrations in Bqm^{-3} for studied buildings at the university. Average radon concentrations in Bqm^{-3} for each studied building, mean value of radon concentration for the university buildings as a whole and the minimum and maximum values of radon concentration are shown in Table 1. The results indicate that the highest radon concentration is found in the University Press Section with value 416.7 Bqm^{-3} while the lowest value of 80.1 Bqm^{-3} was found in welding unit 2. Actually, about two thirds of the measured concentrations were below the action level (< 200 Bqm^{-3}) as reported by ICRP [19]. The observed variations of radon concentrations among various buildings can be attributed to many factors like the various types of building materials used for the construction of the dwellings, the heating systems, building age, location as well as the ventilation rates of the building[20].

Table (1): Average radon concentration in studied buildings of University of Technology.

Building Code	Department & Centers	Average Radon Conc. Bqm^{-3}
PM	Department of Production and Metallurgy Engineering	155.2±39.8
ME	Department of Materials Engineering	229.1±73.3
MEE	Department of Mechanics and Equipment Engineering	199.8±70.0
LE	Department of Laser Engineering and Electronic Optics	145.8±50.1
AS	Department of Applied Sciences	169.7±61.2
EE	Department of Electrical and Electronic Engineering	156.8±56.9
CS	Department of Computer Sciences	146.4±55.7
EC+EL+N	Environ. Res. Center +E. Language Center + Nanotech	196.7±62.8
IT	Information and Communication Technology Center	145.8±61.2
CE	Cultural Electronic Services Center	119.7±44.5
EC	Engineering Consulting office	88.7±44.5
TW	Training and Workshop Center	230.8±120.2
ED	Electricity division	150.6±32.3
PD	forming Division	167.7±71.2
WD1	Welding division 1	371.8±75.7
WD2	Welding division 2	80.1±20.0
DP	Casting Division	88.7±18.9
BS	Filing Division	194.4±55.6
AD	Automotive Division	141.7±59.4
WU	Workshop unit	115.0±55.6
EA	Department of Engineering Affairs	115.0±55.6
PE	Department of Physical Education and artistic activity	155.5±66.8
St	Stores	348.7±107.6
PC	University Press section	416.7±83.5
MU	Media Unit	336.5±66.8
SP	Security and Protection section of the university	115.4±44.5
RS	University Repairing section	164.0±50.1
CL	Central Library	145.8±55.6
AVE	Average	181.9±59.3
RNG	Range	80.1 - 416.7



Figure(3). Average radon concentration (Bqm^{-3}) in 28 studied buildings.

Mean radon concentrations at each floor level for each studied building with more than one floor are given in Table 2. Figure 4 shows the block diagram of these results. The results indicate that radon concentration in the buildings (EA, CS, LE and CL) decreases at higher floor levels. This difference can be related with radon density which is much higher than air density (almost nine fold than nitrogen), and hence will flow to lower floors by gravity. While in the rest buildings the radon concentration varies randomly between different floor levels in contrast with the previous results. This result is connected with many factors, among them the variation in room ventilation, the number of door opening per day, human population, the air exchange near the window and the convection currents inside the rooms. In other words, the air exchange near the windows reduces the radon concentration near them[21]. This case is clear in the buildings EC + EL + NT, results obtained in the third floor showed the lower value of radon concentration. The large number of students attend this floor (English language center) may cause the lowest radon concentration of 138.53 Bqm^{-3}.

Table(2).Average radon concentrations (Bqm^{-3}) at each floor level in each studied building.

Building Code	Departments & Centers	Floor level	Radon Concentration Bqm^{-3}
PM	Department of Production and MetallurgyEngineering	GF	88.7±28.9
		1st	123.9±32.3
		2nd	204.1±49.0
ME	Department of Materials Engineering	GF	257.0±72.9
		1st	114.3±±55.6
		2nd	164.0±65.7
		3rd	323.7±90.1
MEE	Department of Mechanics and Equipment Engineering	BS	177.4±78.0
		GF	150.1±66.8
		1st	345.1±66.8
		2nd	274.6±89.0
		3rd	150.8±61.2
LE	Department of Laser Engineering and Electronic Optics	GF	177.4±55.6
		2nd	167.7±55.6
		3rd	132.5±44.5
		4th	105.8±44.5
AS	Department of Applied Sciences	GF	100.4±44.5
		1st	243.1±50.3
		2nd	243.6±77.9
		3rd	80.1±55.6
		4th	163.5±55.6
		5th	177.4±55.6
EE	Department of Electrical and Electronic Engineering	GF	186.6±63.1
		1st	137.8±61.2
		2nd	115.4±44.5
		3rd	172.5±55.7
CL	Department of Computer Sciences	2nd	221.2±78.0
		3rd	98.3±44.5
		4th	177.4±66.8
		5th	88.7±33.4
EC+EL+NT	Environmental Research Center + English Language Center + Nanotechnology and Advanced Materials ResearchCenter	GF	164.0±61.2
		1st	194.4±55.7
		2nd	195.0±44.5
		3rd	138.5±52.0
		4th	283.5±74.2
		5th	274.6±111.3
EA	Department of Engineering Affairs	GF	194.5±55.6
		1st	159.2±55.6
CS	Cultural Electronic Services Center	1st	159.2±44.5
		2nd	80.1±44.5
CT	Information and Communication Technology Center	GF	123.93±66.8
		2nd	167.74±55.6
RS	University repairing section	GF	62.0±44.5
		1st	266.0±55.6
AD	Store of Automotive Division	GF	168.3±55.6
		1st	88.7±66.8

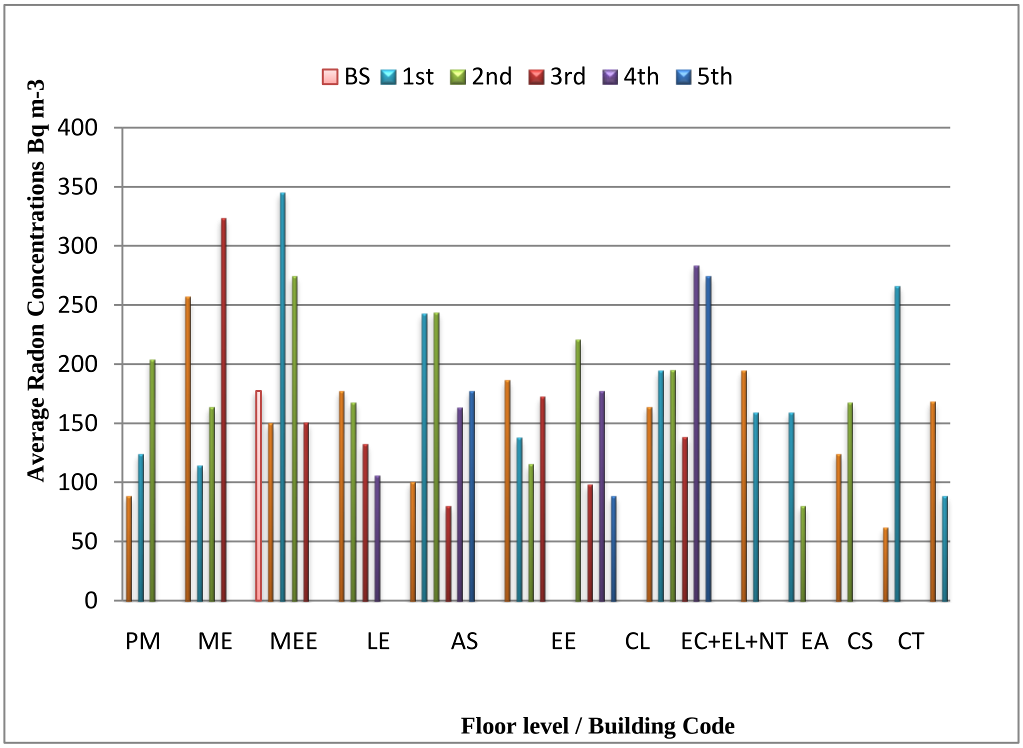


Figure.(4) Radon concentrations (Bqm^{-3}) at each floor level for each studied building.

Estimation of the dose rate due to radon in units of µSv/h, the annual effective dose in units of mSv and WLM were determined and shown in Table 3. Cancer risk estimation, on the other hand, can be done by adopting a mean absolute risk factor of 5×10^{-4} per WLM [8]. Accordingly, the staffs of the University of Technology are exposed to an annual mean dose rate of 2.083mSv (0.231WLM). This exposure produces an annual effective dose equivalent to 2.56and 1.84mSv according to UNSCEAR [18] and ICRP 65 [19], respectively, with an average cancer risk of 0.0046 %.

Table (3): Dose rate µSv/h, Annual dose rate mSv/y (WLM/y), Cumulative dose mSv (WLM) and Cancer risk

Equilibrium Factor = 0.4 indoors/work, working time =2000h/y, Public's Dose Factor = 9 mSv/WLM for 40 years, Risk Factor=0.0005/ WLM(EPA 2003)				
Dept. Code	Dose rate µSv/h	Annual dose rate mSv/y (WLM/y)	Cumulative dose mSv (WLM)	Cancer risk x10^{-2}
PM	0.877	1.754(0.195)	70.18(7.798)	0.390%
ME	1.295	2.590 (0.288)	103.6 (11.51)	0.576%
MEE	1.129	2.259 (0.251)	90.36 (10.04)	0.502%
LE	0.824	1.648 (0.183)	65.95 (7.328)	0.366%
AS	0.959	1.918 (0.213)	76.74 (8.527)	0.426%
EE	0.886	1.772 (0.197)	70.91 (7.879)	0.394%
CS	0.827	1.654 (0.184)	66.19 (7.355)	0.368%
EC+EL+NT	1.111	2.223 (0.247)	88.94 (9.882)	0.494%
IT	0.824	1.648 (0.183)	65.95 (7.328)	0.366%
CE	0.676	1.352 (0.150)	54.11 (6.013)	0.301%
EC	0.501	1.002 (0.111)	40.10 (4.456)	0.223%
TW	1.304	2.609 (0.290)	104.3 (11.60)	0.580%
ED	0.851	1.703 (0.189)	68.12 (7.569)	0.378%
PD	0.948	1.896 (0.211)	75.86 (8.429)	0.421%
WD1	2.101	4.203 (0.467)	168.1 (18.68)	0.934%
WD2	0.453	0.9059 (0.101)	36.23 (4.026)	0.201%
DP	0.501	1.002 (0.111)	40.10 (4.456)	0.223%
BS	1.099	2.198 (0.244)	87.93 (9.770)	0.489%
AD	0.801	1.602 (0.178)	64.10 (7.122)	0.356%
WU	0.650	1.300 (0.145)	52.02 (5.780)	0.289%
EA	1.032	2.065 (0.229)	82.62 (9.180)	0.459%
PE	0.879	1.757 (0.195)	70.30 (7.811)	0.391%
St	1.970	3.941 (0.438)	157.6 (17.52)	0.876%
PC	2.355	4.711 (0.523)	188.4 (20.94)	1.047%
MU	1.902	3.805 (0.423)	152.2 (16.91)	0.846%
SP	0.652	1.304 (0.145)	52.18 (5.798)	0.290%
RS	0.927	1.854 (0.206)	74.17 (8.241)	0.412%
CL	0.824	1.648 (0.183)	65.95 (7.328)	0.366%
average	1.041	2.083(0.231)	83.329(9.26)	0.46%
Range	0.453-2.355	0.906 - 4.711 (0.101 - 0.523)	36.23 - 188.4 (4.03 – 20.94)	0.20% - 1.05%

CONCLUSIONS:

Radon gas concentration levels inside buildings of the University of Technology area were found to have an average value of 181.9 Bqm^{-3} during winter 2012. It was found that the average exposure of staffs in university area is annually 0.282 WLM due to radon gas and its short-lived daughters. This corresponds to an annual effective dose equivalent of 2.56mSv according to UNSCEAR[18] and 1.84mSv according to ICRP 65[19]. This also implies an expected value for lung cancer probability of 0.0046%, which means that 4.6 out of each 100,000 dwellers on the average become infected by lung cancer caused by radon inhalation. Even though this is not a high dose, but based on the ALARA principle (as low as reasonably achievable), it is advisable to reduce the dose. An increase in ventilation rate would probably reduce the concentration level. For future work, it is recommended to extend the survey during other periods of the year in order to have a better representative value for the annual average. Finally, it is also recommended to study the radon concentration levels in soil and water in the same region of this study.

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