Journal of Natural Sciences and Mathematics
Qassim University, Vol. 8, No. 2, pp 167-181 (July 2015/Ramadan 1436H.)

Indoor Radon Concentrations and Effective Dose Rates Estimation in Workplaces at Princess Nourah Bint AbdulRahman University

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Abstract. The main goal of the research was to mesure the Radon (^{222}Rn) concentration at indoor workplaces in different Colleges of Princess Nourah Bint Abdualrahman University (PNU), North of Riyadh, KSA, to estimate the effective dose to the worker from ^{222}Rn and its progeny. Measeurments were carried out for 105 workplaces by using a passive integrating ionization system with an E-perm® Electret ion champer technique. Radon concentrations measured in ground, first and second floors of workplaces. Also, the measurements have done in Winter and Summer seasons. For all measurements, Radon concentrations followed a log-normal distribution with an arithmetic mean of 27.86 ± 4.39 Bq/m^3. The effective dose rates from inhalation of radon and its decay products were estimated with a mean of 0.19 mSv/y. There was some variation found between Summer and Winter measeurments, however, radon concentrations measured in Ground floors were significantly higher than those measured in the first and second floors. The results were found to be within the reference levels recommended by WHO of 100 Bq.m^{-3}.

Keyword: Radon, Workplaces, E-perm electric, Effective Dose Rates, Princess Nourah bint abdualrahman University,Kingdom of Saudi Arabia.

1. Introduction

Radon is an inert radioactive gas, colorless, odorless gas at ordinary temperatures. The exposure of the general population to ionising radiation arises primarily from natural sources, which include radionuclides of terrestrialorigin and cosmic rays. The dominant contribution, amounting to half of the averagereceived dose, isderivedfrom inhalation of the naturally occurring radon (^{222}Rn) gas and its decay products[i]. Early studies have shown that the high incidence of lung cancer in miners was associated with exposure to elevated radon concentrations. Today, radon has been established as a major cause of lung cancer through epidemiological studies carried out in many countries [ii; iii]. Because radon occurs naturally, it is present every where in the atmosphere. Typically, exposure to radon represents (at least) one-half of the doses received by members of the public from all natural sources of ionizing radiation. The exposure risk associated with radon, was noticed as far back as the 1600s where high mortalityamongst underground miners was noted. In 1924 this increased risk was recognized as lung cancer and it was suggested that it was due to radon exposure [iv; v]. When inhaled, radon particles carrying daughters enter and stick onto the bronchial air passages, irradiating and damaging the surrounding cells. Based on national and worldwide investigations, several agencies have concluded that radon is a known cancer causing agent in humans and is the second most common cause of lung, skin, and leukemia cancers after smoking [vi]. An estimate of the risk leads to thousands of deaths per year from cancer caused by exposure to radon and its decay products. However, radon is a radiation risk, which we can do something to reduce at reasonable costs. To reach such a goal it is important that national authorities inform the public about the risks related to radon, and issue guidelines, which aim towards limiting exposure to radon, and taking measures against radon exposure where the risks are greatest. The International Commission on Radiological Protection (ICRP), the World Health Organization (WHO) and the International Atomic Energy Agency (IAEA) have repeatedly encouraged countries to create programs on radon [vii,viii, ix,x]. Exposure to radon and radon decay products in workplace constitutes one of the greatest risks from ionizing radiation. Workers are exposed to radon in several occupations. Certain mineral processing workers may also be exposed to significant levels. Exhalation of radon from ordinary rock and soils and from radon-rich water can cause significant radon concentrations in human living areas. Epidemiological studies of occupational exposures of miners and domestic exposures of public have provided strong and complementary evidence of risks associated to lung cancer following inhalation of radon and radon progeny [3, xi, xii,xiii, xiv, xv, xvi, xvii]. Scientests in Saudi Arabia have given an attention to measure the radon concentrations in several parts in the Kingdom. The first measurement was done by [xviii] through his survey which covered of 19 cities in Saudi Arabia. [xix] monitored radon in 1200 houses in four cities Hafr Al-Batin, Khafji, Madina and Taif. [xx] monitored radon in 2700 house and 98 school nine cities in Saudi Arabia seven in the eastern province Dammam, Abqaiq, Al Ahsa, Hafr Al Batin, Khafji, Qatif, and

Khobar and two in western province Madina and Taif. The lowest average radon concentration 8 Bq·m−3 was found in Ahsa while the highest average concentration 40 Bq·m−3 was found in Khafji. There are also other studies dealing with radon in Saudi Arabia cities [xxi]. In addition there are academic programs in Saudi universities concerned with the concentration of radon levels in areas in the Kingdom [xxii, xxiii,xxiv, xxv, xxvi, xxvii]. More investigations and surveys are still needed and are being carried out to add new building types and locations to the data base, and to review existing data using different instruments and methods.

The main goal of the research was to measure the radon concentrations and its decay products in 105 (WP) workplace at different colleges in Princess Nourah Bin Abdualrahman University (PNU), North of Riyadh, KSA over one year using more than 150 detectors. The detector was a time-integrated passive device consisting of a disk detector (electret). Taking into account all the parameters that may effects to the exposure of radon such as the behavior of worker, the building materials and offices design, as well as the different climate. Also the different location of the workplaces (ground, first and second floors) as well. The results were used for evaluating effective doses from inhalation of radon and its decay products. This goal comply with the aims of the International Radon Project [xxviii] organized by the World Health Organization initiative to reduce the lung cancer risk around the world.

2. Material and methods

2.1. Workplaces (WP) at PNU description and sampling circumstances

(PNU) Princess Nourah bint Abdulrahman University is a public women's university located in north of Riyadh 24° 46′ 19.2″ N, 46° 43′ 30″ E 24.772, 46.725 , Kingdom of Saudi Arabia. On June 12, 2011, the new campus was opened . It is one of the ten largest universities in the world and the largest university for women in the world. It has over 42,000 students in 15 colleges. It is 8 million square meters in size. with a maximum capacity of 60,000 Students. The examined workplaces were distributed in eight detached, high-rise buildings and included various offices. Their construction, in the early 2008, was based on red brick and concrete block work, with concrete basement-floors and concrete roofs. All buildings have a central heating installation (HVAC: Heating, Ventilation And Air Conditioning System). The size of all the work places (under study) are around [16-20] m^2, and the floors that are made of Vinyl tiles and Ceramic. One of the walls of the room is made up of glass whilst the others are made up of two layers of gypsum slides that have a rock wool material in between that is used to block sound . The walls of all offices are painted with Plastic paint covering material. The ceiling of those rooms are made up of gypsum slides. Some of those offices have furniture and some have plants while others have opening windows for natural ventilation where other are complete closed with glass wall from one side. However, this study was performed for the indoor work places air where the temperature is controlled by air conditioning which dramatically reduces the seasonal or night–day variation in the temperature, and it is also known to have many strong dust storms. As we know, The climate in Riyadh is a hot arid desert with an average high temperature of 44 °C in the summer and a cold with an average temperature of 8 °C during winter. The day–night variation in outdoor temperature could be as high as 20–25 °C>. In this work, radon detectors were distributed to more than 105 work places at different colleges. All participants were recommended to place the detector 1 m above the ground, at least 30 cm from any objects, and at a similar distance from doors or windows or any voltage source. Furthermore, a brochure was provided to explain the significance of radon gas and its sources, as well as it shows how radon enters the buildings, health risks, and the detection system. The participants in the survey were instructed to record the time and date of the start and end of the measurement. To ensure a high quality of measurement, canisters were routinely checked for performance using a voltage reader and reference electret.

2.2. Radon measurements

The study was designed to record radon levels of 105 WP over one year using more

than 150 detectors [xxix]. The detector is a time-integrated passive device consisting of a disk detector

(electret) placed at the bottom of a plastic canister (ion chamber). Prior to deployment, the electret is kept covered by a spring-loaded screw cap. Once the cap is released, Radon gas enters the canister via passive diffusion through a filtered inlet [xxx, xxxi]. This filter will not allow the radon daughters products (RDP) to enter, such that all RDP are produced via radon decay inside the canister. When the disk is exposed, the positively charged electret collects the negative ions formed by the interaction of radiation emitted by radon and its daughters with the air inside the collection chamber. The resulting decrease in charge is related to the concentration of radon integrated over the period of measurement, according to equation (1) [30].

$$C = \frac{Vi - Vf}{Cf\ x\ t} - BKG \qquad (1)$$

where:

C is the average radon concentration in $Bq.m^{-3}$.

V_i is the beginning voltage on electret before exposure.

V_f is the final voltage on electret after exposure.

C_f is the calibration factor in Volts $Bq.m^{-3}\ d^{-1}$, which is calculated as

$C_f = 5.1\times10^{-2}+1.7\times10^{-5}\times$voltagemidpoint.

t is the exposure time in days.

BKG is the gamma background correction in $Bq.m^{-3}$ (8.7 $Bq.m^{-3}$ per $\mu Sv\ h^{-1}$).

In this study, the "S"-type size (210 mL) canister of Electret Passive Environmental

Radon Monitor (E-PERM) was used with The more sensitive short-term (ST) of electrets. The calibration of the electrets was done in the Rad Elec Inc. In addition, the electrets were divided into 5 groups according to their previous response. For each group, 3 electrets were selected and exposed to a ^{226}Ra radioactive standard which was placed at the bottom side of the top cover of a 3720 mL accumulator jar. The jar was covered by a radon leak-tight lid, and left for one month to ensure the secure equilibrium between the ^{226}Ra and its daughter ^{222}Rn. Moreover, 50 detectors were tested at the laboratory of the health and environmental center at KACST to ensure the quality assurance. The reader device was tested by using the reference package (RT) from Rad Elec Inc. The uncertainty ($\pm\sigma$) was estimated in all calibration measurement not to exceed 5% of the calculated values. By utilizing the appropriate electret, EICs can make integrated measurements from a few days up to one year. Based on preliminary lab trials and experiments, an optimum measurements period was estimated to be 19–20 days to achieve the highest practical measurements sensitivity for the ST electrets.

3. Results and Discussions

3.1. Idoor radon concentrations:

The radon concentrations levels measured in all work places (WP) during the year ranged from 11.15 ± 8.27 Bq/m^{-3} to 55.90 ± 9.17 Bq/m^{-3} with an arithmetic mean of 27.86 ± 4.39 Bq/m^{-3}, as shown in Figure.1.

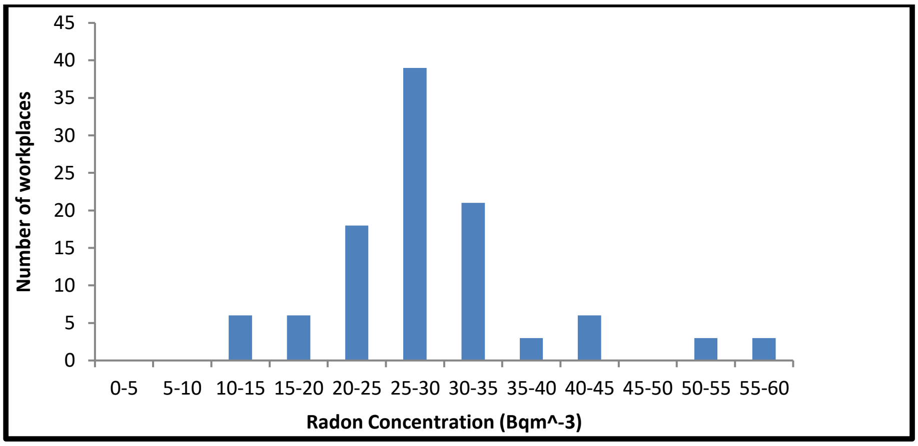


Figure.1: Distribution of radon concentrations measured in all work places (WP) during the year.

Seasonal variations in ^{222}Rn concentrations plotted as arithmetic mean in workplaces were similar to each other during the year (Figure.2). ^{222}Rn concentration were observed in every period (December-February for Winter and July-September for Summer). ^{222}Rn concentrations measured from July to September were generally lower than those in other period presumably because of increased ventilation by air conditioning and opening windows during the summer months. The higher results of radon concentration were found in the offices with complete closed with glass wall, no windows and no natural ventilation they have. Furthermore the central heating installation and ventilation were turnoff all the Winter period. Also, We noted that there was no impact for the furniture in the offices (carpet, curtain and natural or fake plants) for increase or decrease the radon concentrations.

Figure.3, shows arithmetic mean of radon concentration in offices by location. The results show that the radon concentration in the offices of the ground floor is higher than for the other floors above the ground floor. Because of the main source of Radon is the soil gas in the surroundings, and as we know, Radon is heavy gas and cannot go up to higher floors, So this could be attributed to the fact that the radon concentration results were higher in the Ground floors than the uppers. Table. 1, Summarized the radon concentration measurements from the present work.

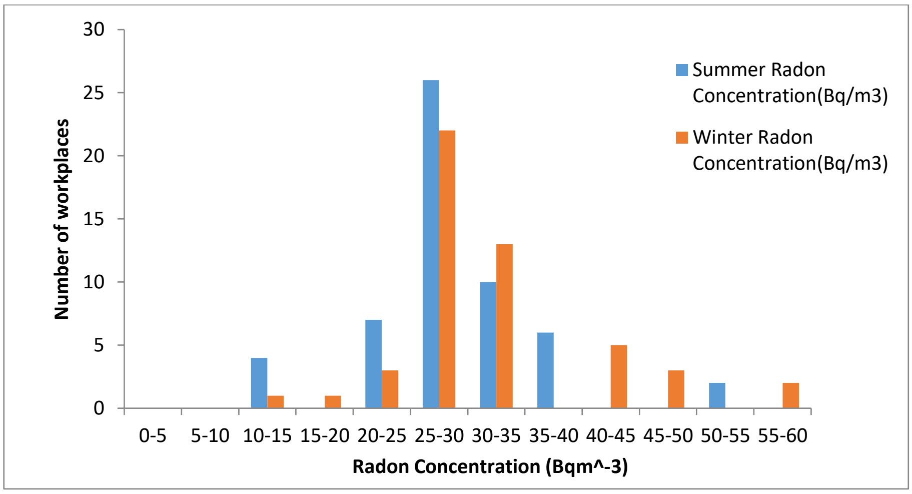


Figure.2: Radon concentration at work places.(Summer and Winter Season).

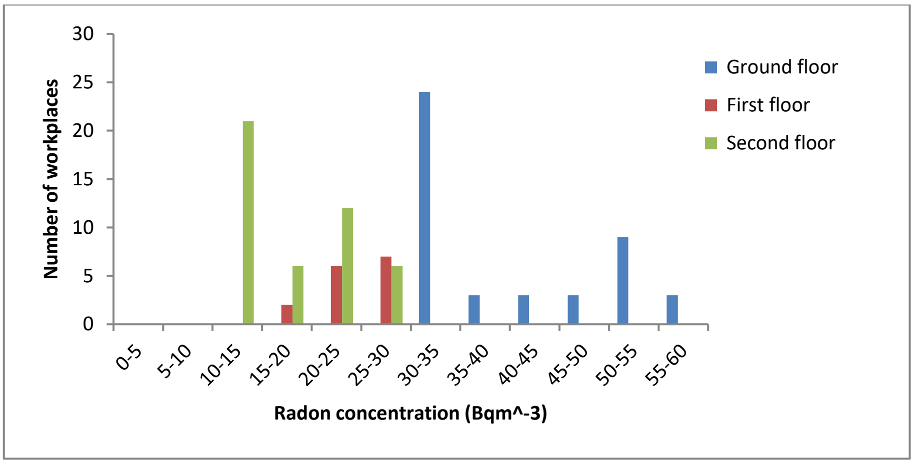


Figure.3.: Radon concentration at work places (Ground floor, First floor and Second floor)

Table.(1). Summary of radon concentration measuerments from the present work. N= number of sampling points, AM= Arithmatic mean, SD= Standard Dieviation

	N	AM ± SD (Bq/m3)	Range (Bq/m3
All measurements	105	27.86 ± 4.39	11.15-55.9
Summer	55	27.64 ± 8.43	11.15-50.82
Winter	50	29.40 ± 10.10	11.82-55.9

The mean radon concentrations in this study were compared with other studies from other countries. Table.2, shows that the radon concentration in this study are lower than those values reported in other worldwide excepte Japan and (Aljouf) in Saudia Arabia .

Table.2 compares the recent radon gas exposure studies from other countries with this research for work places (offices).

Type of work places	Country	Year	Average of Radon Concentration (Bq/m^3)	Number of Office	Reference
Office	Present Study(PNU)	2015	27.86	105	Present Study(PNU)
	Japan	2006	22.6	287	[14]
	Hong Kong	2008	37	216	[xxxii]
	Pakistan	2009	64	107	[xxxiii]
	Greece	2010	95	42	[15]
	Turkey	2014	76	37	[xxxiv]
	Algeria	2014	92	43	[xxxv]
	Saudia Arabia(Aljouf)	2014	11.7	30	[24]

3.2. Effective dose rates from exposure to radon :

The Effective dose rate (mSv/y) was calculated as a result of exposure to radon and its daughter (Alpha particle), [1], By the following equation:

$$H = C \times F \times T \times E \times D \quad (2)$$

Where:
C is a concentration of radon in Bqm^{-3}
F is a coefficient of stay (This figure is computed on the assumption that less work hours for faculty members, teachers and students is equal to 20 hours per week, for a period of 26 weeks, which represents less than the duration of the academic year. As the hours stay to work varies from person to person, therefore it was determined the value of coefficient of stay equal to the maximum time possible to stay in the same place which is 8 hours per day for 5 days a week for 46 weeks per year)
E is a coefficient of equilibrium between radon and its daughter of alpha particles ICRP, 1994

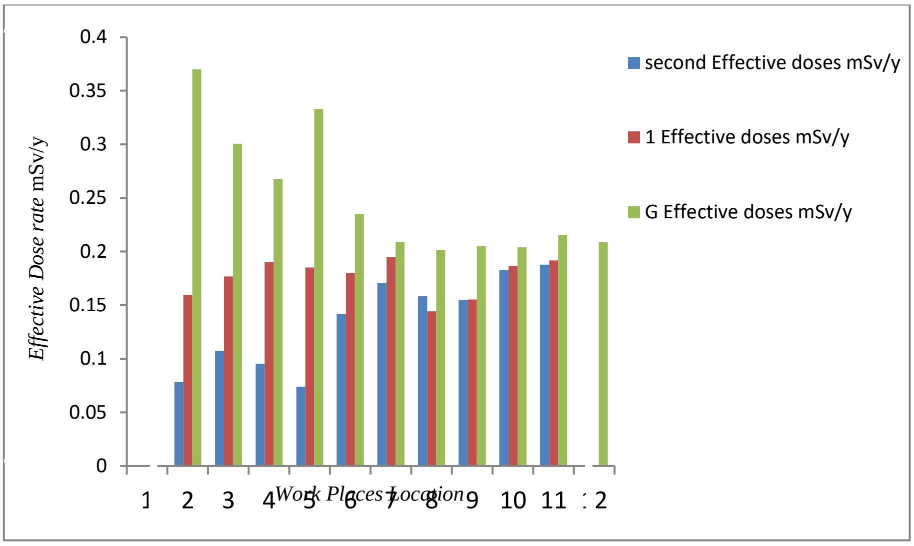
T is the time in hours.

D is a dose conversion factor and express D = 0.0000009 mSv per Bqm^{-3}.

Table.3, shows the effective dose rate to the worker from 222Rn. We found that the worker will be received effective dose in the range of 0.08 to 0.37 mSv/y with an average of 0.18 mSv/y and Both values were less than the ICRP recommended limit of 3-10 mSv/y. Figure.4 shows the effective dose rates from exposure to radon and its decay products. For each workplace, the average of Winter and Summer measurements is assumed to repesent radon concentration throughout the year.

Table 3: Effective dose rates from exposure to radon and its decay products.

	Radon Concentration (Bqm^{-3})		Effective dose rate ($mSvy^{-1}$)	
	AM	Range	M	Range
All work places (N=105)	27.86	11.5-55.90	0.18	0.08-0.37
Ground floor (N= 45)	38.78	30.45-55.90	0.26	0.20-0.37
First floor (N= 15)	25.16	19.23-29.41	0.17	0.13-0.19
Second floor (N=45)	11.34	11.15-27.6	0.12	0.08-0.18



Fiureg.4. Effective dose rates from exposure to radon and its decay product.

Conclusion

The Radon (^{222}Rn) concentration at 105 indoor workplaces at different Colleges of Princess Nourah Bin Abdualrahman University (PNU), North of Riyadh, KSA was measured by using a passive integrating ionization system with an E-perm® Electret ion champer tequnic with ST electret.

The results showed that:

- The average radon concentrations measured in all work places (WP) during the year ranged from 11.15 ± 8.27 Bq/m^{-3} to 55.90 ± 9.17 Bq/m^{-3} with an arithmetic mean of 27.86 ± 4.39 Bq/m^{-3} . This small numbers compared with the world's studies agreed that the structure and building material of PNU are high quality.

- Little seasonal variations in ^{222}Rn concentrations found, the arithmetic mean in workplaces were similar to each other during the year (December-February for Winter and July-September for Summer). However, ^{222}Rn concentrations measured from July to September were generally little bid lower than those in other period presumably because of increased ventilation by air conditioning and opening windows for those offices which has windows during the summer months.

- Radon concentrations measured in ground floor workplaces were significantly higher than those measured in the first and second floors.

- The differences in radon concentration mostly originate from the frequency of indoor air changes, ventilation and insulation factors of these buildings.
- The higher results of radon concentration were found in the offices with complete closed with glass wall, no windows and no natural ventilation they have.
- The cause of the differences is mostly from the ventilation system and the usage of
- Clearly, a better ventilation system has a big impact on decreasing the radon exposures in these offices.
- We noted that there was no impact for the furniture in the offices (carpet, curtain and natural or fake plants) for increase or decrease the radon concentrations.
- The estimated effective doses delivered to the workers due to the indoor radon were found to be less than the lower limit of ICRP recommended action levels of 1 mSv/y.

Acknowledgments: The author is thankful to the Deanship of Scientific Research at Princess Nourah Bint Abdualrahman University (PNU) for funding this research project Number(35-S-62). Staff members at the University of PNU kindly acknowledged for agreeing to have their offices tested. The author express her thanks to all the laboratory members in the physics department- Princess Nourah University. Special thanks to Alghamdi, A.S and the laboratory members at Institute of Atomic Energy Research, King Abdulaziz city for Science and Technology(KACST).

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حساب معدل تركيز غاز الرادون ومعدل الجرعة المكافئة للعاملين في أماكن العمل بجامعة الأميرة نورة بنت عبدالرحمن، شمال مدينة الرياض، المملكة العربية السعودية

K.S.Al Mugren

قسم الفيزياء/ كلية العلوم/ جامعة الأميرة نورة بنت عبدالرحمن/الرياض المملكة العربية السعودية

ملخص البحث. كان الهدف من الدراسة هو قياس معدل تركيز غاز الرادون داخل أماكن العمل المغلقة في كليات مختلفة في جامعة الأميرة نورة بنت عبدالرحمن (الواقعة شمال مدينة الرياض، في المملكة العربية السعودية) وذلك من أجل تقدير معدل الجرعة الفعالة التي يتعرض لها العاملين من غاز الرادون ووليداته. عُملت الدراسة على ١٠٥ مكاتب عمل باستخدام passive integrating ionization system with an E-perm® Electret ion champer technique تقنية "

قيس تركيز غاز الرادون في الطابق الأرضي والأول والثاني لأماكن العمل المختلفة، كما تم عمل القياسات في فصلي الصيف والشتاء. لجميع هذه القياسات، أعطى تركيز غاز الرادون توزيعاً لوغاريتمياً بمتوسط حسابي ٢٧,٨٦ ± ٤,٣٩ Bq/m3 ، وقدرت معدلات الجرعة الفعالة من جراء استنشاق غاز الرادون ووليداته بمتوسط 0.19 mSv/y.

وُجدت بعض الاختلافات في قياس تركيز غاز الرادون في فصلي الصيف والشتاء، ولكن الاختلاف الأكبر في القيم أتضح في الطابق الأرضي عنه في الطوابق الأعلى من ذلك. نتائج الدراسة التي حصلنا عليها تقع ضمن الحدود المسموحة التي أوصت عليها منظمة الصحة العالمية. (WHO) وهي ١٠٠ Bq.m -3

الكلمات الدالة: غاز الرادون، أماكن العمل، كواشف إي- بيرم، معدلات الجرعة المكافئة، جامعة الأميرة نورة بنت عبدالرحمن، المملكة العربية السعودية.