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Integrated Radon Measurements in King Saud University girl's Campus, Riyadh, Saudi Arabia

قياسات الرادون الجمعية في حرم جامعة الملك سعود النسائي في مدينة الرياض، المملكة العربية السعودية

سفر الغامدي، غاده خوقير، ميرزا رحمت بيك

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Abstract: This residential site consisting of three buildings was chosen because it is highly populated and in the center of the city of Riyadh. The dosimeters were kept in the buildings for a period of nine months from January to October, 2001. The radon average concentration per room in buildings one, two and three are found as (32 ± 2) Bqm^{-3}, (40 ± 3) Bqm^{-3} and (59 ± 6) Bqm^{-3} respectively. In this study a consistent trend of high radon concentration in small rooms than large ones may indicate poor ventilation in small rooms. The statistical analysis shows that 75 % of the values are equal or less than 50 Bqm^{-3}. It is also seen that 98% of the measured values are less than the safe limit of 148 Bqm^{-3} set by the Environmental Protection Agency of the U.S.A. It can therefore be concluded that these buildings may have no potential health hazard of Radon.

Keywords: Radon, girl's campus, small rooms, Saudi Arabia, dosimeters.

المستخلص: لقد أختير هذا الموقع لكثافته السكانيه ووقوعه في وسط مدينة الرياض. وضعت الكواشف لمدة تسعة أشهر من شهر يناير وحتى شهر اكتوبر عام 2001. وجد أن معدل تركيز الرادون لكل غرفة في البناية الاولى، الثانية والثالثة هو (32 ± 2) Bqm^{-3}، (40 ± 3) Bqm^{-3}، و(59 ± 6) Bqm^{-3} على التوالي. وجد في هذه الدراسة وبصوره مستمرة، أن التركيز في الغرف الصغيرة أعلى منه في الغرف الكبيره وهذا قد يدل على عدم كفاءة التهوية في الغرف الصغيرة. يدل التحليل الاحصائي للنتائج على أن 75 % من قيم التراكيز إما ان تكون مساوية او اقل من 50 Bqm^{-3}. وقد وجد ،كذلك، أن 98 ٪ من قيم التراكيز اقل من 148 Bqm^{-3} وهو الحد الامن المعتمد من هيئة حماية البيئة في الولايات المتحده (EPA) لذا يمكن القول بان هذه البنايات امنه.

كلمات مدخلية: الرادون، الرياض، الغرف الصغيرة، كفاءة التهوية.

Introduction

Radon is a radioactive gas that has been associated with adverse health effects. Radon daughters are of specific concern to health professionals since they can be inhaled and deposited in the lungs. The subsequent release of energy during the remaining decay steps can cause damage to the surrounding tissue and may lead to lung cancer (Unanimous, 1981).

Measurement of indoor radon concentration is vital since the dose received by the human population from radon and its daughters is more than 50% of that received from natural sources (UNSCEAR, 1988).

The radon concentration is dependent on many factors such as geological site, seasons, and environmental conditions. It is transferred to the environment through soil, water and building materials (Nazaroff and Nero, 1988; Nazaroff and Doyle, 1983; Durrani and Ilic, 1997; Abujarad and Fremlin, 1983).

According to most studies, soil surrounding foundations is usually the most important source of radon. It has been reported that different soils have different radium contents (Eaton and Scot, 1984). Ventilation is a contributory factor that affects the concentration of radon in residential buildings (Abujarad and Fremlin, 1980). The decrease in ventilation causes an increase in the concentration of radon and good ventilation decreases the radon level.

The track etch technique is recognized as the most suitable technique for integrated and long term measurement of radon concentrations (Allen and Flesher, 1981; Frank and Benton, 1979).

Radon concentrations are measured in three buildings, each building contained two room sizes, small which is used by one student and the large is used by more than one student.

This residential site was chosen because it is highly populated. The dosimeters were kept in these buildings for a period of nine months, from January to October, 2001.

Experimental methods

1. Preparation of Dosimeters

The CR-39 dosimeter are cut, using fine blade, into square pieces of 2 cmx2 cm from the original sheet of dimensions (10"x8"x0.5 mm), supplied by the Page Mouldings Ltd U.K (Page mouldings, UK). The known can technique was used in this project where the dosimeter is fixed at the bottom of a plastic cup using double sided tape. At the center of the cup's lid a hole of diameter equal to 1.5 cm is cut and covered with a sponge to allow radon gas in and prevents dust particles which may carry other radioactive nuclei to enter in the cavity of the dosimeter (Abujarad and Fremlin, 1980).

The dosimeters were made over a period of two days to minimize background radiation received by the detectors and were kept in airtight containers to minimize background radiation. These precautions were taken during the periods prior to their distribution and collection up to the time the detectors were chemically etched.

The collected detectors were etched, in groups of 60, using etching bath and a sample holder at a temperature of 70 ^{o}C, in 6 normal solution of sodium hydroxide for three hours. The detectors are then washed in water, using ultrasonic bath, to insure the removal of the etching liquid to protect the objective lens of the microscope from a possible damage. They were then dried with soft tissue paper making them ready for counting under the microscope.

2. Measurement of Radon Concentration

Using a microscope, the track density is determined on each detector by counting the tracks for a number of fields of view (FOV). The number of tracks in ?m? is then, converted in number of tracks per cm^2 using a calibration factor equal to $9.61x10^{-4}$ cm^2 per FOV. The resulting number has to be converted into radon concentration units (Bqm^{-3}). This step is taken once the detectors are calibrated. The detectors were calibrated at the laboratory of the National Radiological Protection Board (NRPB) in the U.K. Each calibration point was obtained using a group of dosimeters (improved statistics). The tracks density for each irradiated group of detectors was determined after subtracting the background (NRPB, UK). The calibration factor was found to be 0.0052 $Tracks/cm^2.Bq.m^{-3}h$. Each measured radon concentration ($Bq.m^{-3}$) was calculated using this factor.

Results and analysis

One hundred and one detectors were collected (fifty eight were lost). The radon average concentration variation with height and room size was studied in each building. Each room is cooled by window type air conditioning unit. The rooms were randomly distributed on all floors and in all buildings.

1. Average concentration dependence on height.

The dependence of concentration on room size was studied using measurements in both room's sizes, (Fig. 1a,b,c).

In building one, the radon concentration average value, in the small rooms, is highest on the ground floor goes down on floor two and then goes up on floor three (Fig. 1a). The value in the large rooms starts high on the ground floor goes down on the second floor but reach its highest value on floor three.

In building two, the radon average concentration values in both room types start low on the ground floor and reach their maximum on the second floor. (Fig. 1b).

In building three, the radon average concentration value, in the small rooms, is lower on the ground floor than that on the second floor (Fig. 1c). In the large rooms, it starts low on the ground floor and then goes up on the second floor.

The average radon concentration values are found to vary randomly in all buildings suggesting strong contribution from soil and building materials. The values in the small rooms are higher than that in the large rooms which might be due to poorer ventilation in the small rooms.

In buildings one and two the average concentration values for both room types follow the same pattern in their variation with height. Based on this observation one may assume that the ventilation rates in buildings one and two have constant values (although not necessary equal) in each of the two buildings with that of the small rooms being lower.

If this conclusion is right then one may conclude that the soil contribution to radon concentration is relatively high on the ground floor and the material contribution is significant on floor three of building one. In building two, one may conclude that the soil contribution is low on the ground floor but the building material contribution is significant on the second floor.

In building three the pattern of average concentration values in one room type is opposite that of the other, hence no conclusion can be made on the possible stability of the ventilation rate. This renders our measurements of radon concentrations in building three open to interpretations.

Since it has been established that the ventilation in the large room type is more efficient than that in the small room type, it may be possible to study the difference in the contribution to radon concentration due to soil and building materials using the radon concentration values measured in the large rooms only, (Fig. 1a,b,c). Applying the previous assumption that the ventilation rate is constant in each building, one may conclude that since the soil contribution on the ground floor in all of the buildings is always lower than the respective value on the top floor of each building then the building material contribution to the radon average concentration is more significant than the soil contribution. The contribution of building materials in all of the rooms on all of the floors, including the ground floor is present. This may explain the randomness of the average concentration values on the ground floor (when values measured in the same room type are compared) and may also allow the assumption that the soil contribution is less significant than that previously assumed and is constant in all of the buildings. This view may be supported by the small to large room ratios of the concentration values on the ground floor which are 4.7, 5.5 and 4.7 in buildings one, two and three respectively. This, 'almost' constant ratio supports the assumption of constant ventilation efficiency and hence support the lower soil contribution conclusion. The randomness of building materials contribution to the concentration values may also explain the difference between building two ratio and those of buildings one and three.

The pattern of the radon concentration values for each building is analyzed using the measurements in each room type, ignoring floor number.

The concentration values in the three buildings are compared using this average for each room type.

2. Average concentration dependence on room size

In this analysis the radon concentration level per building is calculated for each room size regardless of floor number. This may reveal any difference between the buildings and hence help labeling the buildings according to their radon level for each room type.

The average concentration values measured in large rooms for buildings one, two and three are 18, 21 and 28 $Bq.m^{-3}$ and those measured in small rooms are 61, 52 and 74 $Bq.m^{-3}$ respectively, (Fig. 2).

It is observed, that the radon average concentration value is highest in both room types in building three (Fig. 2). Based on our previous assumptions and conclusions of equal ventilation rate in each room type, low and constant soil contribution in all three buildings it may be concluded that the building material contribution in building three is most significant followed by building one and is lowest in building two (the difference in the large rooms values in building one and two is small and most likely insignificant).

Further to the previous analysis, the overall average may also be taken regardless of room type. This may help ordering the rooms according to their average concentration values.

3. Average concentration per building

In Saudi Arabia, large housing compounds (consisting of high rise flats and villa type accommodation) exist and hence indexing buildings according to their radon concentration levels might be necessary a step to take in creating a priority check (attention) list for housing departments in these compounds.

The building can be indexed by a single radon concentration average value which is done by calculating the concentration level in each building regardless of room type, (Fig. 3). The figure , clearly shows that building three has the highest average concentration value followed by building two and the lowest average is obtained for building one. It can be seen that the radon concentration levels in building one was higher in the small rooms than that in building two by about 9 Bqm^{-3} but the value in the large rooms is higher in building two than that in building one but only by 2 Bqm^{-3}. When the overall average is taken, building two radon's concentration value exceeded that of building one. This is due to the fact that larger number of small room measurements was taken in building two than that in building one. This emphasizes the importance of taken large number of measurements as well as taken equal or near equal number of measurements for each measurement category for best comparison.

Although the average concentration values measured in this site remained below the safe level value of 148 $Bq.m^{-3}h$ set by the environmental protection agency (EPA), one may conclude that the relative average concentration values showed, consistently, higher radon gas content in the small rooms than the large rooms indicating poor ventilation in the small rooms. With low contribution to the radon concentration from soil, the random variation of the average concentration values with height indicates some contribution from building materials which may be the most significant contribution in these buildings.

4. Statistical distribution of radon concentration values

Another form of measurements representation is a distribution graph, figure 4 which may be used to give an overall picture for the radon concentrations values distribution. Such a distribution may be used to compare different sites with each other in terms of a number of statistical parameters such as the average radon concentration value, maximum, minimum as well as quartile values. These parameters can help ranking sites according to their concentration levels.

Ninety seven measurements are included in Fig. 4 with class width of 5 Bqm^{-3}.The values of statistical parameters obtained are those for the actual data points (real concentration values). When all the data points are included, the mean value of this distribution is 39 Bqm^{-3} (standard error of the mean = 3.7 Bqm^{-3}), its maximum value is 235 and the minimum is 5 Bqm^{-3}. The 1^{st}, 2^{nd} and 3^{rd} quartiles are 17, 29 and 50 Bqm^{-3} respectively, which shows that, 75% of the concentration levels are equal or less than 50 Bqm^{-3}. It is also found that 98% of the values are equal or less than safe limit of 148 Bqm^{-3}. If Chauvenet's criterion is applied to eliminate the outliers (extreme values) then the data would give slightly modified statistical parameters after discarding two measurements (173 and 235 Bqm^{-3}). The new average is 33 Bqm^{-3} (standard error of the mean = 2.4 Bqm^{-3}). The 1^{st}, 2^{nd} and 3^{rd} quartiles are 17, 29 and 44 Bqm^{-3} respectively and all the measurements values fall within the safe limit 148 Bqm^{-3}. The values of the mean and 2^{nd} quartile indicate that the distribution is skewed to the right.

To sum up, the soil contribution to radon levels in all of the buildings is relatively low and may be assumed constant. The average radon concentration values are found to be higher in the small rooms than that in the large rooms indicating poorer ventilation in the small rooms. The average concentration values are found to vary randomly with height in both room sizes and in all buildings indicating relatively strong contribution from the building materials. The overall average is found to be higher in building three followed by building two and is lowest in building one. This ranking should not be taken seriously since it is dependent on the number of measurements taken in each room type. If this difference is real then it may be due to building materials, considering that the ventilation rate is likely to be the same in each room type and the soil contribution is low and constant in all building.

The campus site could be labeled by the statistical factors calculated for the distribution with an average value of 33 Bqm^{-3} and the 2^{nd} quartiles 29 Bqm^{-3} indicating that the distribution is skewed towards the right but by inspecting the data points one finds that two points exceeded the safe limit of 148 Bqm^{-3} set by the EPA.

Discussion

The average concentration per room in buildings one, two and three were 32 ± 2 Bqm^{-3}, 40 ± 3 Bqm^{-3} and 59 ± 6 Bqm^{-3} respectively.

Out of one hundred and one measured concentration levels only two values, 235 ±38 Bqm^{-3} and 177 ± 33 Bqm^{-3}, exceeded the acceptable limit set by the EPA within the standard error. Other concentrations average values remained not only within the acceptable level but also far below this limit with the highest value being 147 Bqm^{-3}.

Ventilation is a main factor that affects the concentration of radon in residential buildings where low ventilation causes an increase in the concentration of radon (Abu-Jarad and Fremlin, 1989). In this study, It appears that small sized rooms have relatively high concentration than the large rooms which may be due to poor ventilation.

Building material usually contains traces of uranium which can contribute to higher radon's levels. The contribution, usually, varies from building to building and from room to room (Garawi, *et. al* ., 2004), hence the randomness of the values measured in this site. The soil contribution may be assumed low in this site and hence the building materials may be assumed to have relatively stronger contribution to the radon concentration values.

In the three buildings, no indication of high levels of radon concentration were observed and hence one could argue that the contribution from soil and building material is not significant, however the ventilation is found to be inefficient at least in the small size rooms in all of the buildings and should be improved.

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