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ENVIRONMENTAL PROTECTION FROM INDOOR RADON IN THE MEDICAL BUILDINGS

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Key words: Indoor radon, Radon pollution, Radiation protection, Radiological buildings.

حماية البيئة المغلقة من غاز الرادون فى المبانى الطبية الإشعاعية

نادية محمود سراج

خلاصــة

الرادون هو من الغازات المشعة طبيعياً ويوجد بكميات مختلفة فى جميع أنواع التربة والصخور. ومن المتفق عليه أن التعرض طويل الأمد لهذا الغاز يمكن أن يسبب سرطان الرئة. وهناك أدلة متزايدة على الخطر الناتج من تلك الغاز الذى وضعت قياسات مرجعية له لتكون ٢٠٠ بيكريل لكل متر مكعب كما أن أبسط الإجراءات الوقائية هى تهوية الأماكن المغلقة كذلك ينبغى النظر فى مستوى هذا الغاز فى الأماكن ذات الكثافات البشرية العالية والأماكن العلاجية مثل المستشفيات، لذلك وبموجب لوائح البناء، يجب على جميع المبانى الجديدة أن تتضمن تدابير الحماية من غاز الرادون.

وتعتبر المشكلة التى تواجهنا فى المبانى هى ظاهرة "المبانى المريضة" التى يعتقد أن وجود ملوثات الهواء عند مستويات مرتفعة فى أماكنها المغلقة هو السبب الرئيسى لهذه المشكلة. ويرجع ذلك أساساً إلى الاستخدام المكثف لمواد البناء والمعدات الحديثة، ومعظمها بمثابة المصدر الرئيسى للملوثات فى الأماكن المغلقة بالإضافة إلى أن أنظمة الحفاظ على الطاقة وعدم التهوية الكافية فى المبانى يساهم أيضاً فى هذه المشكلة.

وهذا البحث يهدف إلى مراجعة التوصيات التى تضمن جودة البيئة الداخلية ولها تأثير كبير على صحة الانسان والراحة والإنتاجية كذلك يهدف إلى ضرورة إجراء قياسات لغاز الرادون فى المبانى العامة ذات معدل إشغال عالى أو فترة إقامة طويلة مثل المستشفيات ومبانى البحوث الإشعاعية.

Accepted December 2014.

Radon can enter buildings via at least three common pathways:

- Migration from the soil into the basement through cracks and/or other openings in the foundation.
- Release of dissolved radon gas from the building on-site water supply.
- Release from building materials such as granite block foundation, some materials and floor or wall tiles.

Because the source of most radon in general buildings is the soil on which it is standing, radon is escaped from the soil then infiltrated to the building and because it heavier than air, higher indoor radon levels are more likely exist at the lower levels of the building.

In this study, two methods of measurements were investigated; long term and short term but the second method was preferred due to its accurate measurement. In addition, the study of typical and maximum activity concentrations in common building materials and industrial by-products used for building materials was carried out. On the basis of the measurement, devices have been proposed placements and two methods to reduce and get rid of radon were suggested.

Sources of radon in building:

Typical building materials, such as concrete block, brick, granite and sheet rock, contain some radium which are sources of indoor radon. Normally, these construction materials do not contribute significantly to elevated indoor radon levels. In rare cases, the building materials themselves have been the main source of radioactive gas i.e. building materials contaminated with uranium and uranium mill tailings were an important source of radon because they contained elevated concentrations of radium (tailings are the sand like material remaining after minerals removed from ore). Also, concrete made from phosphate slag and insulation made from radium-containing phosphate waste were found to emit high levels of radon.

METHODS OF MEASUREMENTS

Long term measurement:

Radon levels in hospitals or other buildings can vary significantly over time. In fact, the radon levels can change by a factor of 2 to 3 over a 1 day period and the variations from season to season can be larger. Higher radon levels are usually observed during winter months and as a result, the long term measurement will give a much better indication of the annual average of radon concentration than measurements of shorter duration. The long term measurements were carried out from 3 to 12 months in duration.

Short term measurement:

In rare cases, a more rapid indication of the radon concentration may be required. Under such circumstances, the short term measurement of duration less

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Short term measurement:

In rare cases, a more rapid indication of the radon concentration may be required. Under such circumstances, the short term measurement of duration less than 3 months (more typically 2 to 7 days) can be performed. However, the short term measurement should be used with caution according to the season. Testing durations of less than 2 days (48 hours) are never acceptable to determine radon concentrations for purposes of assessing the need for remedial actions. Since radon concentrations vary over time, it is strongly recommended that the result of any short term measurement should be confirmed with a follow-up long term measurement. The follow-up measurement should be made at the same location as the initial measurement and a single short term measurement is not sufficient for a decision to mitigate. In this case, a follow-up measurement is always necessary for mitigation decision making regardless of the initial measurement result.

Conditions for short term measurement:

The short term measurement must be made under closed building conditions to stabilize the radon concentrations and increase the validity of the annual radon concentration estimate. In addition to maintaining closed building conditions during the measurement, these conditions should be in place for 12 hours prior to the initiation of a measurement lasting less than 4 days, and are recommended prior to measurements lasting up to a week in duration. The closed building conditions involve ensuring that:

- Windows on all levels and external doors are kept closed for the duration of the test, except during normal entry and exit. Normal entry and exit include a brief opening and closing of a door but external doors should not be left open for more than few minutes.
- External-internal air exchange systems such as high volume, whole house and window fans should not operated. However, attic fans intended to control attic temperature or humidity may be operated. Combustion or furnace makeup air supplies must not be closed.
- Normal operation of permanently installed energy recovery ventilators (also known as heat recovery ventilators or air-to-air heat exchangers) may continue. In building where permanent radon mitigation systems have been installed, these systems should be functioning during the measurement period.
- Air conditioning systems that recycle interior air can be operated during the closed building conditions.

Table (1) shows the annual external gamma dose caused by building materials in four different hypothesizes of their activity concentrations. The dose is the excess to the average background originating from the earth's crust (50 nGy/h). The parameter values used for calculating the doses are given in table (1); the activity index. The specific dose rates are calculated with a computer program according to Radiation Protection 112 (1999).

Table (1): Typical and maximum activity concentrations in common building materials and industrial by-products used for building materials.

Material	Typical activity concentration (Bq kg^{-1})			Maximum activity concentration (Bq kg^{-1})		
Most common building materials (may include by-products)	^{226}Ra	^{232}Th	^{40}K	^{226}Ra	^{232}Th	^{40}K
Concrete	40	30	400	240	190	1600
Aerated and light-weight concrete	60	40	430	2600	190	1600
Clay (red) bricks	50	50	670	200	200	2000
Sand-lime bricks	10	10	330	25	30	700
Natural building stones	60	60	640	500	310	4000
Natural gypsum	10	10	80	70	100	200
Most common industrial by-products used in building materials						
By-product gypsum (Phosphogypsum)	390	20	60	1100	160	300
Blast furnace slag	270	70	240	2100	340	1000
Coal fly ash	180	100	650	1100	300	1500

It is important to classify the areas according to the override dose limits, access to the overall assessment of the areas, and the possibility exceeded 0.3 mSv or 1 mSv may be due to the use of certain building materials.

Table (2) shows the typical activity and concentrations determined by the treatment. The study of radon levels in building materials in the table lead up to design models proposed to study the dimensions of specific deliberate building materials and specific time.

As shown in table (3), radon levels were measured in the place of workers, therefore, several ways to treat and mitigate the ill effects of radon gas have proposed.

Ground contact test locations:

Detectors must be placed at least 20" (50 cm) above the floor. For large rooms or open areas, one detector was placed every 2000 square feet (186 square meters) (e.g. a square area with each side 45 feet (13.7 meters) in length), 3.0 where to test, including 3.6 choosing a location within a room.

Figure (1) shows ground contact test locations and this form is an example and not intended to prescribe all manners that may be desired or required for tracking.

Table (2): Parameter values used in calculating the dose given land in deriving.

	Activity concentrations, Bq kg^{-1}			
	Low activity material	**Average concrete**	**Upper level of normality**	**Enhanced concentrations**
^{226}Ra	10	40	100	200
^{232}Th	10	30	100	200
^{40}K	300	400	1000	1500
Structures in a building causing the irradiation:	Annual excess dose			
Floor, ceiling and walls (all structures)	less than dose from background	0.25 mSv	1.1 mSv	2.3 mSv
Floor and walls (e.g. wooden ceiling)	less than dose from background	0.10 mSv	0.74 mSv	1.6 mSv
Floor only (e.g. wooden house with concrete floor)	less than dose from background	less than dose from background	0.11 mSv	0.41 mSv

Table (3): Measured radon levels in model design.

Dimensions of the model room	4 m x 5 m x 2.8 m		
Thickness and density of the structures	20 cm, 2350 kg m^{-3} (concrete)		
Annual exposure time	7000 hours		
Dose conversion	0.7 Sv Gy^{-1}		
Background	50 nGy h^{-1}		
	Specific dose rate, nGy h^{-1} per Bq kg^{-1}		
Structures in a building causing the irradiation	^{226}Ra	^{232}Th	^{40}K
Floor, ceiling and walls (all structures)	0.92	1.1	0.080
Floor and walls (wooden ceiling)	0.67	0.78	0.057
Floor only (wooden house with concrete floor)	0.24	0.28	0.020
Superficial material: tile or stone on all walls (thickness 3 cm, density 2600 kg m^{-3})	0.12	0.14	0.0096

Table (4): General evaluation on the possibility of exceeding 0.3 mSv or 1 mSv because of the use of certain building materials. See table (1) for typical activity concentrations.

Building material	Exposure above 0.3 mSv / circumstances or explanation	Exposure above 1 mSv / circumstances or explanation
Concrete	POSSIBLE/almost anywhere where bulk amounts are used	POSSIBLE/ if bulk amounts are used and the concrete contains large amounts of blast furnace slag, fly ash or natural sand or rock rich in natural radionclides
Aerated and light-weight concrete	POSSIBLE/if blast furnace slag, fly ash or natural materials rich in natural radionuclides is used.	NOT LIKELY/used only in walls
Clay bricks	POSSIBLE/if clay rich in natural radionuclides is used	NOT LIKELY/used only in walls
Sand-lime bricks	NOT LIKELY / low activity concentrations, limited use (only walls)	NOT LIKELY / low activity concentrations, used only in walls
Natural building stones	NOT LIKELY/ superficial or other minor use	NOT LIKELY/superficial or other minor use
	POSSIBLE/if used in bulk amounts	POSSIBLE/if used in bulk amounts
Gypsum boards or blocks	NOT LIKELY/Natural gypsum POSSIBLE/ if radium rich by-product gypsum is used	NOT LIKELY/ superficial use or used only in walls

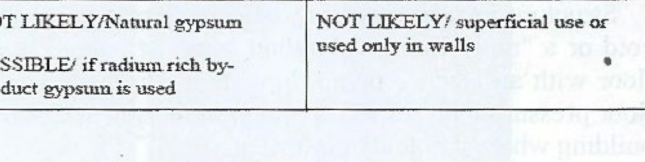

Fig. (1): Ground contact test locations.

Required closed building conditions:

- Closed building conditions must be maintained for 12 hours prior to the initiation of the test and during the test.
- All windows in all levels and external doors must be kept closed (except for momentary events such as normal entry and exit) before and during the test period.
- Heating and cooling systems must be set to normal occupied operating temperatures and their fan/blower controls must be set to normal intermittent activity unless continuous activity is a permanent setting. Window air conditioning units must only be operated in a recirculation mode. Only by measuring actual radon or progeny levels, we can know whether they are being exposed to excessive levels of radon or not.

Practical control of radon levels in buildings:

Radon enters a building primarily by airflow from the underlying ground, and protection measures for reducing levels inside workplaces are varied depending upon the severity of the problem and the type of building construction. The new buildings (fig. 2) can be protected during construction by installing a radon proof barrier membrane within the floor.

a- Radon proof barrier membrane:

Structure in more seriously affected, areas provision of a ventilated sub-floor void or a "radon sump". A radon sump is a small bucket sized cavity under the floor with an electric pump drawing air from it. This reduces the normal under floor pressure with respect to radon in the soil and vents the radon gas outside the building where it quickly dissipates.

In existing buildings, it is not possible to provide a radon proof barrier and so, alternative reduction measures are used depending upon the severity of the problem. Such measures include improved under floor and indoor ventilation in the area, sealing large gaps in floors and walls in contact with the ground, positive pressure ventilation of occupied areas, and installation of radon sumps and extraction pipe work. Descriptions of radon solutions are described on the BRE website in report BR 293. If it is necessary to reduce radon levels by engineered means, the employer should ensure that the radon levels in the area are pre-measured immediately after installation in order to verify its effectiveness.

b- Passive system:

The passive system is a minimal approach to radon reduction that relies on the convective flow of air upward in a vent pipe to exnaust the radon gas. Figure (3) shows that the state building code only requires a passive system to be installed. However, a fan may need to be added at a later date if radon levels are still high.

The active system offers maximum radon reduction through the use of a fan that continuously pulls radon-laden air from the soil and exhausts it outdoors. The active system can make a big difference in reducing radon exposure.

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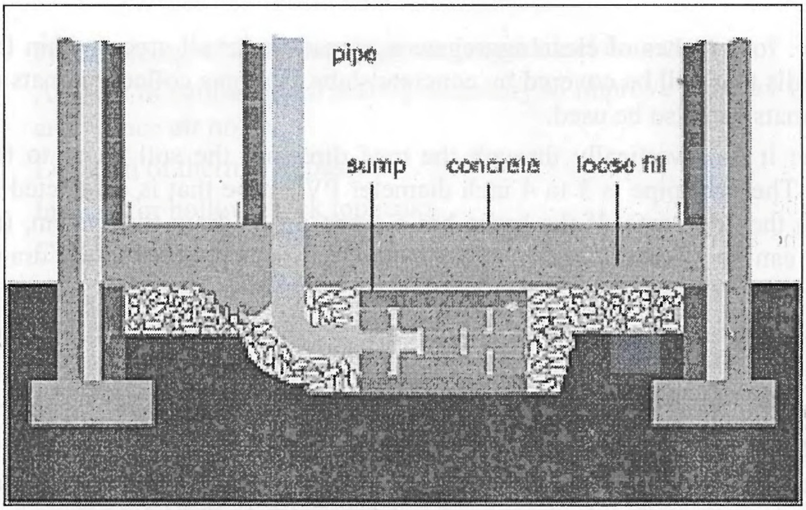

Fig. (2): The underlying ground and protection measures for reducing levels inside workplaces.

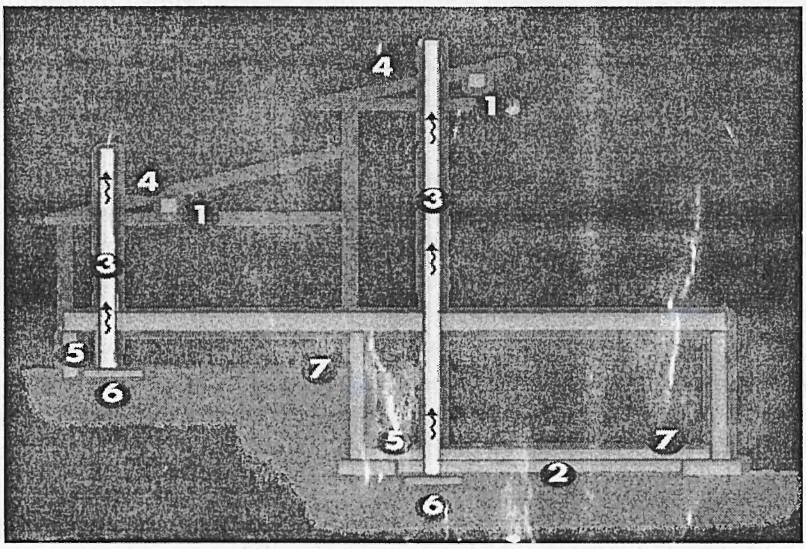

Fig. (3): Passive system that relies on the convective flow of air upward in a vent pipe to exhaust the radon gas.

Features of radon resistant construction:

1. Electrical junction box: it is roughed in the attic near the vent pipe. This power supply will be ready to use if the radon control system needs to be activated in the future.

2. Aggregate: four inches of clean aggregate is spread under all areas within the home's walls that will be covered by concrete slabs. Soil-gas collection mats or drainage mats can also be used.
3. Vent pipe: it runs vertically through the roof directing the soil gases to the outdoors. The vent pipe is 3 to 4 inch diameter PVC pipe that is connected to the "T" in the aggregate. If the home has a sump pit or drain-tile system, the vent pipe can be inserted directly into the sump pit or connected to the drain-tile loop.
4. Roof flashing: it must be installed around the vent pipe where it exits the roof to prevent leakage.
5. Sealing: all potential soil gas entry points are sealed with caulk or expanding foam. The sump baskets must have sealed cover.
6. Vent pipe (T): its fitting made of 3 to 4 inch diameter PVC pipe and inserted into the aggregate under the basement slab or under a crawl space's vapour barrier. The vent pipe allows soil gases to enter with little resistance and connects to the main vent pipe.
7. Soil-gas retarder: to help in keeping water/moisture in concrete so that, it fully cures with minimum cracking 6 mil thick polyethylene's sheeting. Overlapped 12 inches at the seams, fitted closely around all penetrations, is placed over the aggregate. In crawl spaces, the sheeting is sealed to the foundation walls and interior piers.

In radon resistant new construction, if you plan to build a new home, it should be radon resistant. It is much safer for your family and far more cost-effective to prevent radon from becoming a problem. Radon resistant construction combines common building techniques and materials to seal entry points and route the gases outdoors and helping to prevent radon from entering the home. If there is a way to test the soil before building, the test cannot predict what the radon levels will be once the building is completed. The impact that the site preparation will have radon pathways into the building and the extent of air pressure in the finished building car affect radon levels and exposure.

Recommendations

The purpose of sitting radioactivity controls of building materials is to limit the radiation exposure due to building materials with enhanced or elevated levels of natural radionuclides. Additionally, the doses to the members of the occupational and public should be kept as low as reasonably achievable. It is the most international recommendations.

The following recommendations are important to provide guidance for sitting radioactivity controls of building materials. Important information collected during the site investigation should include:

- Previous test results.

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The following recommendations are important to provide guidance for sitting radioactivity controls of building materials. Important information collected during the site investigation should include:

- Previous test results.

- Proper sizing of a radon mitigation fan and duct diameter.
- Amount of caulking and sealing necessary to improve pressure field extension and reduce air noise.
- Location of thermal bypasses.
- Inspect for hollow block top leaks.
- Check wall floor joint leaks.
- Check plumbing penetrations and all floor drains for water traps.
- Check all expansion joints in floors.
- Check footers or thickened slabs.
- Inspect sump pump for type (submersible or pedestal).
- Determine foundation material.
- Check crawl space for gravel and access.
- Check recently installed waterproofing.
- Check untapped air-conditioning condensate lines.

The above minimum information is needed to properly design any radon mitigation system. No one mitigation system fits all buildings (Hansen, 1991).

The levels of indoor radon in Egypt are far above the acceptable values for the population as prescribed by the Environmental Protection Agency (EPA) and European Union (EU) for residential radon concentrations, and a strong association between lung cancer and the exposure to domestic levels of radon was convincingly demonstrated especially for buildings with bad ventilation.

CONCLUSION

According to the present study, the recommendations for national case are the basic safety standards sets down a framework for controlling exposures to natural radiation sources arising from work activities. The directive applies to work activities within which the presence of natural radiation sources leads to a significant increase in the exposure of workers or members of the public.

In addition to increasing ventilation, radon control measures include sealing the foundation, sub-salt depressurization (creating negative pressure in the soil), pressurizing the building and using air cleaning devices. Methods of increasing ventilation include opening windows, ventilating basements and crawl spaces, ventilating sump-holes and floor drains to the outside of the house, and increasing air movement with ceiling fans. Ventilation must be modified properly because increased ventilation can depressurize the building in some cases causing an increase in soil gas enters to the building. Heat exchangers provide a way of bringing fresh air indoors without major heat loss but these must be properly balanced or can worsen the problem.

It was suggested that exposure assessment can be improved by considering time, design and materials at hospitals, special at radiotherapy and nuclear medicine units at which changes in building and ventilation conditions can affect radon concentration. This was confirmed by the present study which showed that indoor radon concentrations were significantly higher in buildings with bad ventilation as compared to buildings with good ventilation.

REFERENCES

Al-Jarallah, M.I., The Journal of Environmental Radioactivity, 1(53), L 1, 89-96, November (2000).

Al-Qhahtani, A.S., Subjective Assessment of Indoor Air Quality in Office Buildings, M. Sc. Thesis, King Fahd University of Petroleum and Minerals, Dhahran (1993).

Al-Zaharna, E.T., Objective and Subjective Assessment of Indoor Air Quality In KFUPM Buildings, M. Sc. Thesis, King Fahd University of Petroleum and Minerals, Dhahran (1996).

American Society of Heating, Refrigerating and Air Conditioning Engineers Inc. ASHRAE Standard 62, Ventilation for Acceptable Indoor Air Quality, Atlanta (1989).

Awbi, H.B., In: Ventilation of Buildings, 1st Edition, E and FN SPON (1991).

Brooks, B.O. and William, F.D., Understanding Indoor Air Quality, CRC Press Inc. (1992)

Comments and Sub-committee Consensus, 7/20/10 Protocol for Conducting Radon and Radon Decay Product Measurements In Multifamily Buildings (2010).

EPA, Citizen's Guide to Radon, USA (1992).

Guide for Radon Measurements in Public Buildings, Schools, Hospitals, Car Facilities and Detention Centres.

Hansen, S.J., Managing Indoor Air Quality, The Fairmont Press Inc. (1991).

Hays, S.M., Ronald, V.G. and Nicholas, R.G., Indoor Air Quality, Solution and Strategies, McGraw Hill Inc. (1995).

http://nlquery.epa.gov/epasearch/epasearch?querytext=radon&fld=&areaname=&typeofsearch=epa&areacontacts=http%3A%2F%2Fwww.epa.gov%2Fepahome%2Fcomments.htm&areasearchurl=&result_template=epafiles_default.xsl&filter=sample4filt.hts&x=4&y=8

http://www.epa.gov/In Multifamily Buildings.

http://www.radon-systems.com

Lubin, L. and Boice, I. Jr., Journal of the National Cancer Institute, 89(1), January (1997).

Meckler, M., Indoor Air Quality Design Guide Book, The Fairmont Press Inc. (1991).

Namiesnik, J. et al., Building and Environment, 27(3), 339-356 (1992).

Radiation Protection 112, Radiological Protection Principles Concerning the Natural Radioactivity of Building Materials Directorate General Environment (1999).

Sundell, J., ASHRAE Journal, 38(6), 51-57 (1996).

The American Heritage Abbreviations Dictionary, 3rd Edition, Copyright by Houghton Mifflin Company, Published by Houghton Mifflin Company (2005).

The Canadian Guidelines for Management of Naturally Occurring Radioactive Materials (NORM) and the Canada Labour Code.

US Department of Health and Human Services, Agency for Toxic Substances and Disease Registry, Division of Health Education and Promotion.

Wadden, R.A. and Peter, A.S., Indoor Air Pollution, Characterization, Prediction and Control, John Wiley and Sons Inc. (1983).

Yeung, Y.N. et al., Building and Environment, 26(4), 319-330 (1991).