Available online at: www.basra-science-journal.org

ISSN –1817 –2695

Indoor Radon Concentration in the Basra Sport City, Basra, Iraq

Waleed H. Al-Mosuwi and Abdul Ridha H. Subber

Department of Physics College of Education for pure Science, University of Basra, Basra, Iraq

Received 30-6-2013 , Accepted 8-9-2013

Abstract

Radon from inside buildings, hotels under instruction and basement of the main stadiums in Basra Sport City (BSC), have been investigated. The measurements were carried out in 31 sites, using CR-39 and LR-115 solid state nuclear track detectors SSNTDs. The measurements were performed during winter and spring seasons of the year 2012, for a period of 100 days. The detectors were installed in underground basement areas of the stadium and hotels in BSC, selected randomly in the surveyed area. The results of indoor radon levels in these sites were found to vary from 233 Bq m^{-3} to 1091Bq m^{-3},for CR39 and 249 Bq/m^3 to 1225 in LR-115 detector with average value for both detectors 386.5 Bq m^{-3}. The radon annual effective dose ranged from 1.60 mSv y^{-1} to 9.12 mSv y^{-1} . The corresponding mean values of annual effective dose for the sites was 3.02 mSv y^{-1}, indicates that the basements, storage areas and tunnels are safe occupancies.

Keywords: Radon, CR-39, Bare LR-115 type II, Annual effective dose

Radon is a naturally-occurring radioactive gas, cannot be seen, smelled or tasted. It is produced from the radioactive breakdown of Ra-226, is found in soils, water just about everywhere and continually escapes from soils into the atmosphere. Although some radon can be found in virtually every building, under certain situations it builds up to high concentrations in indoor air, thereby constituting an important health hazard[1-4]. Radon gas is produced during a chain of radioactive disintegration reactions that begins when uranium-238 starts to break down. The uranium-238 is widely distributed in rocks and soils throughout the earth's crust [5].

Radioactive radon gas consists of three isotopes, namely: ^{222}Rn (called radon has half life 3.82 days, belongs to ^{238}U decay series); ^{220}Rn (called thoron with half life 55.6 s, belongs to ^{232}Th decay series) and ^{219}Rn (called actinon with half life 3.5 s, belongs to, ^{235}U decay series). The most abundant isotope of the element radon is

^{222}Rn isotope. Most kinds of rocks and soils have some uranium and thorium, but usually only a small amount [6] . At each stage in the radioactive decay series, one or more types of radiation is given off, and one radioactive element changes into another. There are eight different elements involved in the U-238 series. Eventually, a stable (non-radioactive) isotope of lead-206 is formed, and the sequence of reactions comes to an end. All of the elements in the chains of uranium and thorium are solids and tend to stay in place within the rocks except radon isotopes.

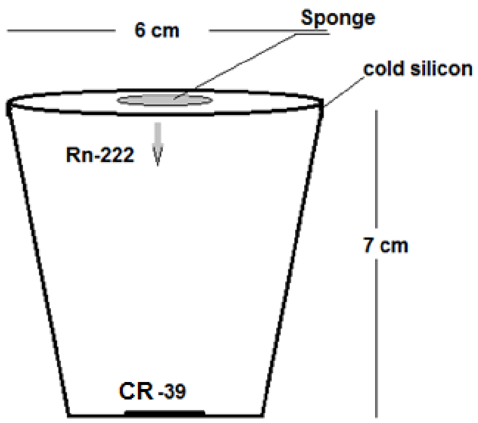
The EPA recommends 4 pCi/L (148 Bq/m^3) as an "action level" for radon in buildings. This action level is based partially on the study of cancer incidence in underground miners, partially on laboratory animal experiments, and partially on practicality. It is generally possible to reduce indoor concentrations to 4 pCi/L or below according to ALARA principal[7]. A person with lungs that are highly susceptible to lung damage from radon decay products might be at greater risk in a home with 4 pCi/L of radon than a very healthy individual living in a home with 10 pCi/L of radon. Radon radioactivity, at high concentrations, may be harmful to human. It could be considered as the second reason for lung cancer after cigarette smoking. Radon gas from natural sources can accumulate in buildings, especially in confined areas such as the basement. Variations of ^{222}Rn concentrations in the air influence seasonal and diurnal variations of the ambient dose equivalent rate depends on the intensity of ionizing radiation of radionuclides in the atmosphere and on the ground surface as well as on cosmic radiation. Measurements of indoor radon are important because the radiation dose to human population due to inhalation of radon and its progeny contribute more than 50% of the total dose from natural source. A large number of indoor radon surveys have been done covered most part of the world [8-9].

In the present study indoor radon concentration measurements have been carried out in basements and under stadiums field of newly built Basra Sport City.

2. <u>Materials and Methods</u>

2.1.Measurement with CR-39 detector

The Basra Sport City (BSC) is the largest architectural project of its kind in Iraq, located in the southern west of Basra Governorate . The city is still under its final construction and it is consists of a main stadium (fully equip), secondary stadium, eight hotels for hosting the ethylic and other accessories. The dosimeters, Figure 1, were mounted in the basements and tunnels of those facilities. The dosimeters were solid state nuclear track detectors(SSNTs) CR-39 in the cup mode and LR-115 type II, bare mode [10,11].



F

Figure 1 Cup Technique

Thirty one dosimeters, were prepared and distributed inside the underground levels of the BSC facilities region. These locations are chosen to be representative of the whole region. Our sampling strategy was to distribute the dosimeters in places located at different geographic parts of the city. The detectors were placed in a places so as to avoid contribution of ^{220}Rn and its progeny, where the occupants of the employer spend some of their time. The detectors were left in the basement for a period of 100 days. The collected detectors were chemically etched using a 6.25N solution of NaOH, at a temperature of 70°C, for 7 h, for CR-39. The detectors immersed in the etching solution, in a small container inside a water bath. At the end of the etching process, the detectors were washed thoroughly with distilled water and then left to dry. Each detector was counted visually using an optical microscope with power of (40×10).

The calibration process for the CR-39 dosimeters, we used in this survey, two dosimeters were exposed to ^{226}Ra (Radon source) of activity concentration 185 kBq for 48, 96 days. The calibration factor was used as 0.0961 ± 0.0089 $\frac{T}{cm^2.d}$ $per\ 1\ Bq\ m^{-3}$ taken from previous study [12], the overall uncertainty in this calibration was estimated to be ±10%. However, Al-Jarallah et al [10] used the same technique (cup technique) with calibration factor as 0.192 ± 0.005 $\frac{T}{cm^2.d}$ $per\ 1\ Bq\ m^{-3}$ and this is may be due to the detector properties and manufacture. Radon and its daughter's concentrations (C) throughout present work are determined by the following equation [13-15].

$$C\left(\frac{Bq}{m^3}\right) = \frac{C_0\left(\frac{Bq.d}{m^3.}\right)}{\rho_o}\frac{\rho}{t} \qquad (1)$$

C_0=the total exposure of ^{226}Ra (Radon source) in term Bq.d/m^3,

ρ_0=track density number of tracks/cm^2 of detectors exposed to ^{226}Ra,

ρ=track density (number of tracks/cm^2) of distributed detectors,

t= exposure time (days) of distributed detectors.

2.2. Bare LR-115 type II measurements

A small strip of LR-115 type-II solid-state nuclear tracks detector film of size 1.5 × 1.5 cm fixed on a thick flat card was exposed in "bare mode". Several detectors were mounted at different locations in the basement and under stadiums for a period of 100 days, at a height of more than 2.75 meters above the ground level and about 25 cm below the ceilings and away from the walls. Detectors were mounted vertical and locations were so selected that dust collection on the detectors to be minimum. After an exposure time of 100 days, detectors were removed and etched using 2.5N NaOH solution at 60^0 C for 120 min. in a constant temperature water bath. Then, these SSNTDs were washed, dried and scanned under a binocular microscope with a magnification of 400× for track density measurements. All α-particles that reach the LR-115 type-II SSNTDs with a residual energy fits with detector window (0.7 MeV to 4.5 MeV) are registered as bright track holes. The track density on the detector is related to the potential alpha energy concentration expressed in Working Level (WL) units. The track density registered in the bare detector will, therefore, be a function of radon gas progeny concentration in air. The radon gas concentration in (Bq m^{-3}) is calculated using the following relation [16,17];

$$C\left(\frac{Bq}{m^3}\right) = \frac{WL \times 3700}{F} \qquad (2)$$

where, F is the equilibrium factor for radon taken as 0.4 as suggested by UNSCEAR[18] . To obtain the Potential Alpha Energy Concentration (PAEC) of radon progeny in WLM, it is essential to use calibration factor for bare LR-115 type-II detector films measured under the conditions almost similar to the present work. For this purpose, we used the calibrated factor 442 tracks $cm^{-2}d^{-1}$ per WL, which is estimated by the Environmental Assessment Division of Bhabha Atomic Research Centre, Mumbai [19,20]. The effective dose equivalent to the occupant of the location estimated from PAEC levels. The estimation based on the conversion factor of 4mSv/WLM recommended by ICRP [21] for indoor exposure condition based on epidemiological approach.

2.3 The indoor radon effective dose rate

In order to evaluate the indoors annual effective doses, one has to take into account the conversion factor from absorbed dose in air to effective dose and the indoor occupancy factor. In the UNSCEAR 2000 Report, a value of 9.0 *nSv* h^{-1} per Bq m^{-3} was used as a conversion parameter. The effective dose indoors in units of *m Sv* y^{-1} is calculated by the following relation;

$$H_{effective} = C_{Rn} . F . t . D \qquad (3)$$

where C_{Rn} is the measured ^{222}Rn concentration (in *Bq* m^{-3}), F is the ^{222}Rn equilibrium factor indoors (0.4), t is the indoor occupancy time (0.25 × 24 *h* ×365 = 2190 *h* y^{-1}), and D is the dose conversion factor, which convert activity concentration to effective dose rate, D= 9.0×10^{-6} *mSv* h^{-1} *per Bq* m^{-3} .

3. Results and discussions

An overview of the Radon (^{222}Rn) concentrations at BSC fields and athletics hotels basements are calculated and given in table 1. The minimum value was 233 ± 24 in the hotel basement number(1), maximum values of Radon concentrations was 1091± 112 Bq m^{-3} at a point under the secondary stadium and the average value of ^{222}Rn was 373.7 Bq m^{-3}. This value exceed the limit of WHO and more investigation is required plus ventilation.

Table 1. Radon (^{222}Rn) concentration measured by CR-39 track detector

Sample No	Location	^{222}Rn by CR-39 Bq/m^3
1	Main stadium	327 ± 34
2	Main Stadium	294 ± 27
3	Tunnel of main Stadium (1)	397 ± 34
4	Tunnel of main Stadium (2)	327 ± 34
5	Tunnel of main Stadium (3)	274 ± 28
6	Tunnel of main Stadium (4)	291 ± 30
7	Tunnel of main Stadium (5)	400 ± 41
8	Tunnel of main Stadium (6)	331 ± 34
9	Hotel No.1 basement	291 ± 30
10	Hotel No.2 basement	233 ± 24
11	Hotel No.3 basement	327 ± 34
12	Hotel No.4 basement	265 ± 27
13	Hotel No.5 basement	364 ± 37
14	Hotel No.6 basement	436 ± 45
15	Hotel No.7 basement	364 ± 37
16	Hotel No.8 basement	258 ± 27
17	Secondary Stadium	1091± 112
18	Tunnel under tracks(1)	472 ± 49
19	Tunnel under tracks (2)	300 ± 31
20	Tunnel under tracks (3)	278 ± 29

21	Tunnel under tracks (4)	368 ± 28
22	Tunnel under tracks (5)	374 ± 28
23	Tunnel of secondary Stadium (1)	698 ± 72
24	Tunnel of secondary Stadium (2)	262 ± 27
25	Tunnel of secondary Stadium (3)	268 ± 28
26	Tunnel of secondary Stadium (4)	333 ± 34
27	Tunnel of secondary Stadium (5)	582 ± 60
28	Tunnel of secondary Stadium (6)	287 ± 30
29	Tunnel of secondary Stadium (7)	327 ± 34
30	Tunnel of secondary Stadium (8)	368 ± 35
31	Tunnel of secondary Stadium (9)	399 ± 41

The bare LR-115 detector measured both radon and thoron isotopes of radon gas in air, the tracks recorded are for both of them. However tracks number belong to thoron are very small relatively and can be negleted. This due to the short lived isotope and limited energy range recorded. The results of radon cocnetration measured by LR-115 detector are listed in table 2. The radon gas concentration ranged from 249 ± 17 to 1225 ± 61 Bq m^{-3} and the average concentration 399.32, little more than the average concentration related to ^{222}Rn only which may be related to small amount of thoron.

Table 2. The radon gas activity cocntration in (Bq m^{-3})measured by bare LR-115 type II detectors.

Sample No	Location	Radon LR 115 bare Bq/m^3	Effective dose received mSv/y
1	Main stadium	328 ± 16	2.58 ± 0.20
2	Main Stadium	328 ± 16	2.45 ± 0.17
3	Tunnel of main Stadium (1)	365 ± 18	3.0 ± 0.20
4	Tunnel of main Stadium (2)	359 ± 18	2.70 ± 0.20
5	Tunnel of main Stadium (3)	332 ± 17	1.60 ± 0.14
6	Tunnel of main Stadium (4)	249 ± 17	2.13 ± 0.19
7	Tunnel of main Stadium (5)	428 ± 22	3.26 ± 0.25
8	Tunnel of main Stadium (6)	410 ± 21	2.92 ± 0.22
9	Hotel No.1 basement	291 ± 15	2.29 ± 0.18
10	Hotel No.2 basement	288 ± 15	2.05 ± 0.16
11	Hotel No.3 basement	323 ± 16	2.56 ± 0.19
12	Hotel No.4 basement	330 ± 17	2.34 ± 0.17
13	Hotel No.5 basement	383 ± 19	2.94 ± 0.22
14	Hotel No.6 basement	408 ± 20	3.32 ± 0.26
15	Hotel No.7 basement	383 ± 19	2.94 ± 0.22
16	Hotel No.8 basement	319 ± 16	2.27 ± 0.17
17	Secondary Stadium	1225 ± 61	9.12 ± 0.68
18	Tunnel under tracks(1)	398 ± 20	3.43 ± 0.27
19	Tunnel under tracks (2)	372 ± 19	2.65 ± 0.20
20	Tunnel under tracks (3)	345 ± 18	2.46 ± 0.19
21	Tunnel under tracks (4)	333 ± 17	2.76 ± 0.18
22	Tunnel under tracks (5)	371 ± 19	2.94 ± 0.19
23	Tunnel of secondary Stadium (1)	653 ± 33	5.34 ± 0.41
24	Tunnel of secondary Stadium (2)	325 ± 16	2.31 ± 0.17
25	Tunnel of secondary Stadium (3)	332 ± 17	2.36 ± 0.18
26	Tunnel of secondary Stadium (4)	368 ± 18	2.76 ± 0.21
27	Tunnel of secondary Stadium (5)	566 ± 28	4.52 ± 0.35
28	Tunnel of secondary Stadium (6)	357 ± 18	2.54 ± 0.19
29	Tunnel of secondary Stadium (7)	342 ± 17	2.64 ± 0.21
30	Tunnel of secondary Stadium (8)	411 ± 21	3.07 ± 0.22
31	Tunnel of secondary Stadium (9)	457 ± 23	3.37 ± 0.25

To correlate the bare detector technique with the can technique a plot between the measurements has been prduced and presented in figur 2. As one see from the figure, that the correlation is excellent (R=0.963) and the slope of the fitting line is one, means there is a very small amount of thoron detected.

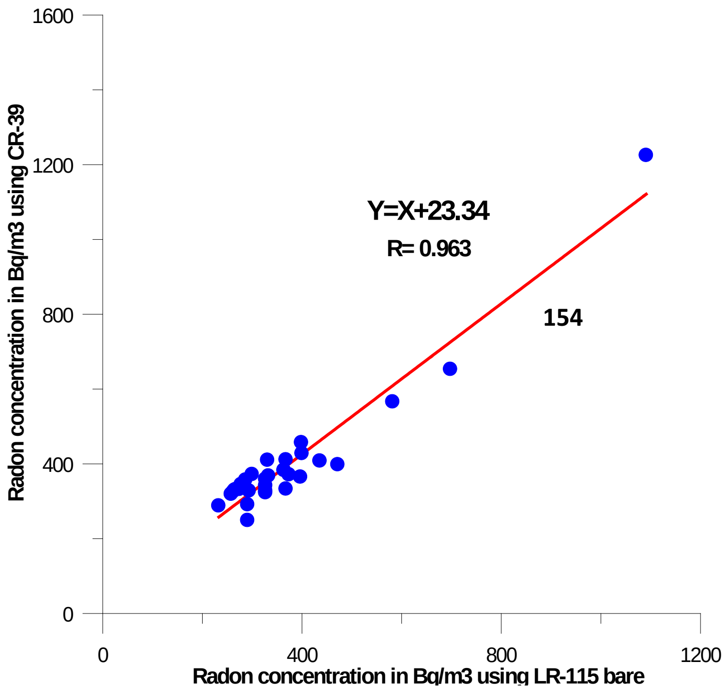


Figure 2. Correlation between Cr-39 and LR-115 type II measurement of radon concentration

The annual effective dose from the corresponding measured radon concentration has been calculated using equation (3), which varies from (1.6 to 9.12) mSv/y . The average annual effective dose received by occupier is 3.02 mSv/y, which is less than the range of action level (3-10 mSv/y) recommended by ICRP (1994).

4. Conclusion

The radon activity concentrations were measured in the underground and basements of Basra Sport City facilities. The detectors CR-39 and LR-115 type II were mounted for 100 days. The observed level of indoor radon activity concentration in the underground level and tunnels of BSC is within the recommended permissible level as set by monitoring by researchers in different countries. Consequently, the health hazard related to indoor exposure consider to be negligible. Workers using these facilities are therefore, relatively safe. However, It is suggested that improvement of ventilation in such compartment will reduce the radon concentration in air, according to the ALARA principal.

References

1. Al-Jundi, J., W.B. Li, M. Abusini J. Tschiersch C. Hoeschen and U. Oeh,. Inhalation dose assessment of indoor radon progeny using biokinetic and dosimetric modeling and its application to Jordanian population., J. Environ. Radioactiv., 102: 574-580. 2011.
2. WHO,. Handbook on Indoor Radon: A Public Health Perspective, ISBN 9789241547673 World Health Organization. 2009
3. Chen, J., N.M. Rahman, I.A. Atiya. Radon exhalation from building materials for decorative use. J. Environ. Radioactiv., 101, 317-22, 2010.

4. Rafique, M., S. Ur. Rahman, T. Mahmood, S. Rahman, Matiullah S., Rehman,Ur. Radon exhalation rate from soil, sand,bricks, and sedimentary samples collected from Azad Kashmir, Pakistan. Russ. Geol. Geophys., 52, 450-457, 2011.
5. Singh, S., M. Kumar and R.K. Mahajan K. The study of indoor in dwellings of Bathinda district Punjab, India and its correlation with uranium and radon exhalation rate in soil. Radiation Measurement, 39, 535-542, 2005.
6. Florea, N. and Duliu, O.G. Eighteen years of continuous observation of Radon and Thoron progenies atmospheric activity. J. Environ. Radioactivity, 104, 14-23, 2012.
7. Chauhan R. P., Kant K., Sharma S. K., Chakarvarti S. K. Measurement of aplha radioactive air pollutants in fly ash brick dwellings. Radiation Measurements, 36, 533-536, , 2003.
8. Catalano R., Imme G., Mangano G., Morelli D., Rosselli Tazzer A. Indoor radon survey in eastern Sicily. Radiation measurements, 47, 105-110, 2012.
9. Kapdan E., altinsoy N. A comparative study of indoor radon concentrations between dwellings and schools. Radiation Physics and Chemistry, 81, 383-386, 2012.
10. Al-Jarallaha M.I., Fazal-ur-Rehmana B, Abu-Jaradb F, Al-Shukri A. Indoor radon measurements in dwellings of four Saudi Arabian cities. Radiation Measurements, 36, 445 – 448, 2003.
11. Chauhana, R.P., Kantb, K. , Sharmac, S.K., Chakarvartic, S.K. Measurement of alpha radioactive air pollutants in-yash brick dwellings. Radiation Measurements, 36, 533 – 536, 2005.
12. Al-Mosuwi W. H. and Subber Abdul Ridha H. Indoor radon survey in dwellings closed to Basrah Sport City (BSC), Basra, Iraq. University of Thiqar, College of Science, Physics department 1st conference, 2013.
13. Al-Kofahi M., Khader B., Lehlooh A., Kullab M., Abumurad K., and Al-Bataina B. Measurement of Radon-222 in Jordanian Dwellings, Nucl., Tracks Radiation Measurement, 20, 377-382, 1992
14. Khader B.Radon-222 Concentration in the Air of the Dwellings in Irbid Region- Jordan, Yarmouk Univ., Irbid M. Sc. Thesis, 1990.
15. Corporation T., Lane W., Creek W. and Fleischer R. Passive Integrating Radon Monitor for Environmental Monitoring, Health Phys., 40, 693-702, 1081
16. Mahur A. K., Kumar Rajesh, Mishra Meena, Azam Ameer and Prasad R. Indoor radon monitoring in some building surrounding the (NHPC), Indian J. Phys. 83, 8-18, 2009
17. Gupta Mamta, Mahur A.K., Sonkawade R.G. and Verma K.D. Indoor radon levels in some dwellings surrounding the National Thermal Power Corporations (NTPCs), India. Pelagia Research Library 2(5), 421-426, 2011.
18. UNSCEAR United Nations Scientific Committee on the Effect of Atomic Radiation. Annex A: Exposure from Natural Sources, United Nations, New, 2000.
19. Singh A. K., Khan A. J. and Prasad R. Study of radon concentrations in oil refinery premises and city dwellings. J. Radiat. Prot. Dosim. 74, 189-195, 1997.

20. Jojo P. J., Khan A. J., Tyagi R. K., Ramchandran T. V., SubbaRamu M. C. and Prasad R. Inter laboratory calibration of track-etch detector for the measurement of radon and radon daughter levels. Radiat. Meas. 23, 715-724. 1994.
21. ICRP, International Commission for Radiological Protection: Protection against radon at home and at work. Annals of ICRP, 65, 12, 1994.