Available online at www.elixirpublishers.com (Elixir International Journal)

Nuclear and Radiation Physics

Elixir Nuclear & Radiation Phys. 81 (2015) 31911-31914

ISSN: 2229-712X

Measurement of indoor radon in a university environment in Nigeria using Solid State Nuclear Track Detector (CR-39)

Augustin Kolapo Ademola[1], Oluwasayo Peter Abodunrin[1], Moronfolu O. Olaoye[2], Mariam A. Oladapo[1] and Isreal Ayo Babalola[1]

[1]Department of Physical Sciences, Bells University of Technology, Ota, Nigeria.
[2]Physics Department of Physics, Lagos State University, Ojo, Lagos, Nigeria.

ARTICLE INFO

Article history:
Received: 31 January 2015;
Received in revised form:
10 April 2014;
Accepted: 21 April 2015;

Keywords
Indoor radon concentrations,
University campus,
CR-39 detector.

ABSTRACT

The concentration of radon has been investigated in a university campus in Nigeria to determine the health risk of the workers in the community. Seventy- eight offices were statistically selected for measurement from all the Colleges. Measurements were performed using a passive radon dosimeters comprising (CR-39) solid state nuclear track detector, for a period of six months. The detectors were chemically etched with 6.25 M solution of NaOH at 70^{o}C for 3 hours. The track were manually counted with microscope coupled with charged coupled digital (CCD) camera. Radon concentrations were statically determined. The mean radon concentration and the effective dose obtained in this work were 18.8 Bq m^{-3} and 0.02 mSv y^{-1} respectively. The mean value for excess lung cancer risk was estimated to be 0.08 (MPY)$^{-1}$. When compared with published data and international references, the results obtained in the current study were found to be within the safe limits. Our study also revealed that radon concentrations tend to be higher on the ground floor and reduced with height due air dilution.

Introduction

Radon according to World Health Organization (WHO, 1987) and United State Environmental Protection Agency (USEPA, 1987) is one of a very small number of substances which have been established to be human carcinogens on the basis of human studies. The naturally radioactive noble gas radon (^{222}Rn) originates from the decay of uranium in rocks and soils. It is tasteless, colorless and odorless. The presence of radon indoor may constitute a radioactive environment in homes and buildings and when it builds up to higher levels, and may cause the occupants to die of lung cancer many years later (UNSCEAR, 2000*)*. The radiation damage to the lungs, due to inhalation of radon and its radioactive progeny, may cause a significant increase in lung cancer risk to the population (Darby et al., 1998; ICRP, 2007). Risk projection indicated that radon and its progenies is the second leading cause of lung cancer after smoking (BEIR IV, 1999; Melloni et. al., 2000). It has also been recognized that an increase in radon concentration of 100 Bq m^{-3} is associated with approximately a 16% increased chance of contracting lung cancer (Darby et al., 2005) and that the risk coefficient for lung cancer is higher for children than that for adults (ICRP, 1993).

The level of exposure to radon in the building depends on ventilation in the building, local geology, and the content of the precursor nuclide ^{226}Ra (Canoba et al., 2001). The studies of radon's behaviour in the geological environment (Ball et al., 1991; Shirav and Vulkan, 1997) have indicated that there is a direct relationship between indoor radon levels and concentration of the gas in soil. As a result of this, many researchers from almost all around the world have measured radon concentration levels and its daughter elements inside dwellings, offices and in soil (Duranni and Illic, 1997). Several ways of reducing radon levels in dwellings were proposed by scientists but the most effective ways of reducing potential hazards posed to the occupants of a school environment will begin with investigation of radon concentrations in as many school and home sites as possible (Obed et al., 2011). Contribution of building materials to indoor radon is generally ranked second (UNSCEAR, 1977) and building materials made up of byproduct gypsum and concrete containing alum shale may contain higher radium concentrations which is the direct parent of radon in the decay series.

In Nigeria, the level of public awareness and, sensitization on the knowledge of radon and its health hazards is low (Obed et al., 2011); this we also observed in the course of this study. Some studies have investigated radon levels in dwellings (Obed et al., 2012) while only few have been carried out in offices (Obed et al., 2010, 2011). The aim of this work was to determine the radon concentrations in some offices in a University environment in Nigeria using CR-39 track etch detectors. This study will add to the data available on the measurements of radon concentration levels in Nigeria.

Materials and Method

This study was carried out in a private university campus (Bells University of Technology) located in Ota industrial area, Nigeria. The university community is residential, hosting nearly 5,000 residents. All the buildings in the campus were built with red brick made from burnt clay. Seventy-eight offices were selected in all the six colleges in the campus. The average working hours in the offices selected is eight hours. All the offices surveyed have air-conditional, different dimension and not on the same level ground. So it is expected that activities in these offices vary.

Radon Measurements in Offices

Radon measurement in the offices was carried out using CR-39 (Pollyallydiglycol carbonate) Nuclear Track Detectors. The detectors were manufactured by Track Analysis Systems

Tele:
E-mail addresses: sayopeter@yahoo.co.uk

Ltd. (Bristol, UK). This passive radon dose meter geometry is a closed chamber into which radon diffuse. The NTDs use is a square of 10 mm x 10 mm x 1 mm^3 in size. These detectors were fixed by plasticine at the bottom of the cover of the dosimeter (5.5 cm height, 1.8 cm diameter). In each office, the detecting device was placed at ~2 m away from the ground as representative of breath height inside the office. The dosimeters were exposed for a minimum period of six (6) months. After exposure, the detectors were removed from each office, placed in the aluminum foil bag, sealed and taken to the Central Research Laboratory, Bells University of Technology, Ota, where they were chemically etched with 6.25 M solution of NaOH at 70^oC for 3 hours. The detectors were then washed thoroughly with running water and soaked in distilled water for about 10 and 15 minutes respectively. They were then allowed to dry in the laboratory overnight.

The tracks on the detectors were counted using a semi-automatic image analysis system consisting of a CCD camera connected to a personal computer and an optical microscope (40X). Radon readings from each detector were deduced as the mean value of readings from 10 optical fields. The minimum detection limit was found to be 2 Bq m^{-3}.

Results and Discussion

The frequency distribution of radon concentrations in all the offices surveyed is presented in Figure below. From the frequency distribution, the values ranged from 9.0 ±2.0 to 47.0±9.1 Bqm^{-3}, with an arithmetic mean of 18.8 ± 8.5 Bqm^{-3} in the offices.

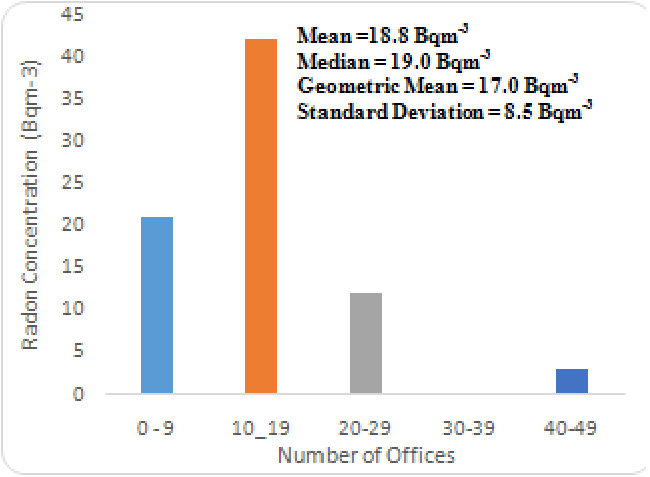

Figure. Frequency distribution of radon concentration in offices

The result of mean radon concentration in different blocks in the university is presented in Table 1. Highest concentration of radon (47.0 Bqm^{-3}) was obtained in an office very close to Chemistry Lab 1 in COLNAS while the least (9.0 Bqm^{-3}) was obtained in Registrar Office in the Administrative block. The highest mean radon concentrations in all the blocks surveyed were below the range of intervention level (200–600 Bq m^{-3}), as recommended by the International Commission on Radiological Protection (ICRP, 1993). It was found that all the offices monitored showed radon concentration between 0 and 50 Bqm^{-3}. The variation in indoor radon activity in different offices in the same campus may be due to different ventilation rates and the geological formation of the soil underneath the different offices.

Radon in Different Floors

Radon activity levels tend to be higher at ground floors than upstairs because soil which is the main source of radon in indoor environment is closer to the ground floor and it enters from there. Therefore, it is necessary to investigate the concentrations of radon in different floors. The result of the concentration in the ground floor, the first floor and the second floor is presented in Table 2. The range of indoor radon concentration on the ground floor is between 9 and 47 Bqm^{-3} while it was found to be from 9 to 19 Bqm^{-3} in both the first floor and the second floor. The mean radon concentration on the ground floor was 19.3 Bqm^{-3} while on first and second floor it was 15.7 and 12.3 Bqm^{-3} respectively.

Table 1. Radon concentration levels in the blocks

Blocks	**Number of sites**	**Radon concentration (Bqm^{-3})**
Administrative block (ADMIN)	15	16.8
College of Management Science (COLMANS)	6	19.0
College of Natural Sciences (COLNAS)	24	17.5
College of Information and Computer Science (COLICT)	9	19.0
College of food sciences (COLFOOD)	6	19.0
College of Engineering (COLENG)	9	23.5
College of Environmental Sciences (COLENV)	6	9.0
Post-Graduate School (PG)	3	28.0

Table 2. Variation in radon concentrations with floor levels

Floor	**Number of sites**	**Radon concentration (Bqm^{-3})**	**Range (Bqm^{-3})**
Ground	60	19.3	9-47
First	9	15.7	9-19
Second	9	12.3	9-19

The high indoor radon concentration in the ground floor may be due to closeness of the ground floor to the soil which is the primary source of radon indoor and also to the fact that radon enters through a pressure driven flow through holes and pores in the soil. Hence the chance of it reaching the upper floors easily is very small.

Exposure Rates in Offices

The annual effective dose to the population in the offices due to exposure to radon and radon decay products was estimated using the expression given by UNSCEAR (2006):

$$E_{dose} = A_{Rn} \times F \times O \times DCF \dots\dots\dots\dots 1$$

where A_{Rn} is the ^{222}Rn concentration (Bq m^{-3}), F is an equilibrium factor (0.4), O is the occupancy factor (7,000 h) and DCF is the dose conversion factor (9.0 nSv Bq m^{-3} h^{-1}).

Excess lifetime cancer risk (ELCR) was estimated from effective dose using the following the formula in Equation 2:

$$ELCR = E \times DL \times RF \dots\dots\dots\dots\dots\dots\dots . 2$$

where DL is the duration of life (70 years), RF is the risk factor (0.055 Sv^{-1}) recommended by the ICRP, 2007.

The estimated annual effective doses estimated in the offices were found to vary from 0.01 to 0.06 mSv with a mean of 0.02 mSv y^{-1}. According to UNSCEAR (2006), the worldwide average dose due to inhalation of radon and its decay product is 1.15 mSv y^{-1}, while the internal and external exposure to all natural radiation sources amounts to 2.40 mSv y^{-1}. Therefore, the dose received by the occupants of the offices is about seven times lower than the world average. ICRP (1993) publication 65 recommended an action levels to be set between 3 and 10 mSv. Therefore, the dose received by the occupants of offices in the university investigated in Nigeria is below the lower limit in the action level.

The excess lung cancer risk obtained in the offices monitored ranged from 0.039 to 0.23 per million person year $(MPY)^{-1}$ with mean of 0.08 $(MPY)^{-1}$.

The mean concentration of the radon level obtained from the present work was compared with the results of similar studies in literature and is presented in Table 3. From the table, the mean radon concentration obtained in this study is lower than previous studies in Nigeria; Ibadan (Obed et al., 2010) and Oke-Ogun (Obed et al., 2011) but higher than similar study in Kuwait (Maged, 2006). However, studies in Japan (Oikawa et al., 2006), Pakistan (Rahman et al., 2010), Italy (Giovani et al., 2002), Spain (Hermandez et al., 2007) and Slovenia (Vaupotic et al., 2000) in Table 3 (row 4 to 8) recorded higher values than the result obtained in this study.

Table 3. Global Indoor Radon Levels in Schools

Location		**Mean Radon concentration (Bq.m^{-3})**	**Reference**
Nigeria	Ota	18.8	Current study
	Ibadan	293.3	Obed et al. (2010)
	Oke-Ogun	45	Obed et al. (2011)
Kuwait		17	Maged (2006)
Japan		28.8	Oikawa et al. (2006)
Pakistan		52	Rahman et al. (2010)
Italy		100	Giovani et al. (2002)
Spain		130	Hermandez et al. (2007)
Slovenia		170	Vaopotic et al. (2000)

Conclusion

Radon concentrations in 78 offices in Bells University of Technology were measured using Solid State Nuclear Track Detectors (CR-39). Radon concentrations were found to range from 9 to 47 Bqm^{-3} with mean values of 18.8 Bqm^{-3}. The dose received by the occupants of the offices lie below the lower limit of the action level. Occupants are therefore relatively safe from the health effects of radon and its decay products. Our study also revealed that radon concentrations tend to be higher on the ground floor and reduced with height due air dilution.

Acknowledgement

The authors fondly acknowledge the contribution of late Mrs. Alabi O. F. for her contribution to the success of this work. Thanks to all members of staff and management, especially those who willingly welcome the detectors in their office.

References

Ball T. K., Camoron D. G., Colman T. B. and Roberts P. D. Behavior of radon in the geological environment: a review. Q. J. Eng. Geol. 24, 169e182, 1991.

BEIR (Biological Effects of Ionizing Radiation) VI Report. Health Effects of Exposure to Radon. National Academy Press, Washington, D.C. 1999.

Canoba, A., Lopez, F.O., Arnaud, M.I., Oliveria, A.A., Neman, R.S., Hadler, J.C., Iunes, P.J., Paulo, S.R., Osorio, A.M., Apaarecido, R., Rodriguez, C., Moreno, V., Vasquez, R., Espinosa, G., Golzarri, J.I., Martinez, T., Navarrete, M., Cabrera, I., Segovia, N., Penaa, P., Tamez, E., Pereyra, P., Lopez-Herrera, M.E. and Sajo-Bohus, L. Indoor radon measurements and methodologies in Latin American Countries. Radiat. Meas. 34, 483-486, (2001).

Darby, S., Whiteley, E. and Silcock, P. Risk of lung cancer associated with residential radon exposure in South-West England: a case control study. Br. J. Cancer 78, 394-408, (1998).

Darby, S., Hill, D., Auvinen, A., Barros-Dios, J.M., Baysson, H., Bochicchio, F., Deo, H., Falk, R., Forastiere, F., Hakama, M., Heid, I., Kreienbrock, L., Kreuzer, M., Lagarde, F., Mäkeläinen, I., Muirhead, C., Oberaigner, W., Pershagen, G., Ruano- Ravina, A., Ruosteenoja, E., Schaffrath Rosario, A., Tirmarche, M., Tomásek, L., Whitley, E., Wichmann, H.E., Doll, R. Radon in homes and risk of lung cancer: collaborative analysis of individual data from 13 European case-control studies. BMJ 330, 223-228, 2005.

Durrani, S.A and Ilic, R. Radon Measurements by Etched Track Detectors: Applications in Radiation Protection, Earth Sciences and the Environment. World Scientific Publishing Co. Pte. Ltd. 1997.

Giovani, C., Cappelletto, C., Garavaglia, M., Villalta, R., Radon concentration survey in schools of Friuli-Venezia Giulia region, north east Italy. In: Proceedings of Seventh International Symposium "Natural Radiation Environment (NRE VII). Rodi (GR), pp. 20e24, pp. 985e996, 2002.

Hernández, F., Gonzalez-Manrique, S., Karlsson, L., Hernández-Armas, J., Aparicio, A., Counting radon tracks in Makrofol detectors with the "image reduction and analysis facility" (IRAF) software package. Radiat. Meas. 42, 496e504, 2007.

ICRP Publication 65, International Commission on Radiological Protection Protection against radon at home and work. Oxford: Pergamon Press; Annals of ICRP 23 (2), 1993.

ICRP Publication 103, The 2007 Recommendations of the International Commission on Radiological Protection. Oxford and New York: Ann, ICRP 37, Pergamon Press; 2007.

Maged, A. F., Radon concentrations in elementary schools in Kuwait. Health Phys. 90, 258e262, 2006.

Melloni, B., Vergnenegra, A., Lagrange, P. and Bonnaud, F. Radon and domestic exposure. Rev. Mal. Respir. 17, 1061 – 1071, 2000.

Obed, R.I., Lateef, H.T. and Ademola, A.K. Indoor radon survey in a University campus of Nigeria. J.Med. Phys. 35, 242-246, 2010.

Obed, R.I, Ademola, A.K, Vascotto, M and Giannini, G., Radon measurements by nuclear track detectors in secondary schools in Oke-Ogun region, Nigeria. Journal of Environmental Radioactivity 102:1012-1017, 2011.

Obed, R. I., Ademola, A. K. and Ogundare, F. O., Radon measurements by nuclear track detectors in dwellings in Oke-Ogun area, South-western, Nigeria. Radiat. Prot. Dosim. 148(4): 475-481, 2012.

Oikawa, S., Kanno, N., Sanada, T., Abukawa, J., Higuchi, H., A survey of indoor workplace radon concentration in Japan. J. Environ. Radioact 87, 239e245, 2006.

Rahman, S.U., Matiullah, Anwar, J., Jabbar, A., Rafique, M., Indoor radon survey in 120 schools situated in four districts of the Punjab Province e Pakistan. Indoor Built Environ. 19, 214e220, 2010.

Shirav, M. and Vulkan, U., Mapping radon-prone areas; a geophysical approach. Environ. Geol. 31, 167-173, (1997).

UNSCEAR United Nations Scientific Committee on the Effects of Atomic Radiation (1977). Sources and effects of ionizing radiation, United Nations ed., New York, E.77.IX.1.

UNSCEAR United Nations Scientific Committee on the Effects of Atomic Radiation (2000). Sources and Effects of Ionizing Radiation. Report of the United Nations Scientific Committee on the Effects of Atomic Radiation to the General Assembly. Vol.1, Annex B. New York: United Nation.

UNSCEAR United Nations Scientific Committee on the Effects of Atomic Radiation, (2006). Effects of Ionizing Radiation: UNSCEAR 2006 Report. In: Report to the General Assembly Scientific Annexes A and B: Report to the General Assembly Scientific Annexes A and B, Vol. 1. United Nations, New York.

USEPA U.S. Environmental Protection Agency. Technical support document for the1992. Citizen guide to radon, office of radiation programs, EPA 400-R-92-011.

Vaupoti_c, J., Sikovec, M. and Kobal, I., Systematic indoor radon and Gamma-ray measurements in Slovenian schools. Health Phys. 78, 559e562, 2000.

WHO World Health Organization 1987. Air quality guidelines for Europe, WHO Regional Publications, European Series No.23, Copenhagen.