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Radon Gas Potential Hazards Awareness among Undergraduate Students and Staff of a College of Health Sciences in South-East, Nigeria

Victor Kelechi Nwodo[1*], Innocent Chinweike Ezenma[1], Geofery Luntsi[1,2], Mathew Garba Abubakar[2], Maryrose Chiche Nwodo[1], Chiegwu Hyacenth Uche[1], Ezeigwe Chijioke Ogomegbuam E[3] and Charles Ugochukwu Nwodo[1]

***Corresponding author:** *Victor Kelechi Nwodo, Department of Radiography and Radiological Sciences, Faculty of Health Science and Technology, Nnamdi Azikiwe University, Nnewi Campus, Nigeria*

[1]*Department of Radiography and Radiological Sciences, Faculty of Health Science and Technology, Nnamdi Azikiwe University, Nnewi Campus, Nigeria*

[2]*Department of Medical Radiography, Faculty of Allied Health Sciences, University of Maiduguri, Borno State, Nigeria*

[3]*Department of Obstetrics and Gynaecology, College of Health Sciences, Nnamdi Azikiwe University, Nnewi Campus, Anambra State, Nigeria*

Abstract

Background: Radon is a noble radioactive gas that is considered one of the most significant indoor air pollutants associated with lung carcinoma when there is exponential dose inhalation and arithmetically depends on the concentration and duration of exposure. There is a paucity of documented research on knowledge and awareness of radon gas and associated potential radiological hazards among students and staff of the College of Health Sciences, Nnamdi Azikiwe University Awka, Nigeria. The aim of this study is therefore to assess the knowledge and awareness of Radon Gas and its potential radiation hazards among students and staff of the College of Health Sciences, Nnamdi Azikiwe University, Nnewi Campus, Nigeria.

Materials and methods: A cross-sectional study was conducted among students and staff of the College of Health Sciences, Nnamdi Azikiwe University, Nnewi Campus, Nigeria, using questionnaires. Twenty (20)-items semi-structured questionnaires were administered to 550 participants (undergraduate students, academic staff and non-academic staff) of the aforementioned faculty in the institution, from January 2022 to October 2022. Information on the demographic variables of the respondents, knowledge of radon Gas and radiological effects hazards were collected. The obtained data were analyzed using descriptive statistics.

Results: The majority of the participants were female 300 (54%). Most of the respondents 415 (75.5%) had no knowledge of Radon gas and have not even heard about it before this study. Only respondents 135 (24.5%) had knowledge of Radon gas before. Most of the respondents 448 (81.5%) were not aware that Radon gas is ionizing radiation of natural origin. Most participants 430 (78.2%) were not aware that Radon gas can cause serious health hazards to the Deoxyribonucleic acid (DNA) and can potentially cause lung cancer in the general population.

Conclusion: Poor knowledge and awareness of Radon gas and associated potential health hazards were eminent among students and staff of the College of Health Sciences, Nnamdi Azikiwe University, Nnewi Campus, Nigeria.

Keywords

Knowledge, Awareness, Radon, Radiation, Radiological hazards

Introduction

Radon is a naturally occurring noble radioactive gas formed by the disintegration of Radium, which is domiciliary in earth's crust, groundwater and building materials such as granites, and cement, among others [1]. Radon is a colourless, odourless, tasteless noble

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gas with a half-life of 3.8 days. It occurs naturally in minute quantities as an intermediate step in the normal radioactive decay chains through which thorium and uranium slowly decay into led and various short-lived radioactive elements; radon itself is the intermediate decay product of radium [2] and its short-lived daughter nuclei are hazardous to a respiratory organ such as the lungs. It can radiate inside our homes, offices, and classrooms through cracks in floors, walls, or building foundations and accumulate indoors. It can also radiate from the building materials or from groundwater obtained from wells that contain radon [3].

Radon levels can be higher in homes that are well insulated tightly sealed and/or built on soil rich in the elements such as uranium, thorium and radium. Basement and building first floors typically have the highest radon levels because of their proximity to the ground [1]. Radon escapes easily from the ground into the air, where it decays and produces further radioactive particles such as alpha particles. As we breathe, the particles are deposited in the cells, lining the airways, where they can damage DNA and potentially cause lung cancer. Therefore, health hazards from radon do not come primarily from radon itself, but rather from the radioactive product formed during the decay of radon [4,5]. The general effects of radon on human health are caused by its radioactivity and consequent risk of radiation-induced cancer. Radon is the most important cause of lung cancer after smoking. It is estimated that radon causes between 3-14% of all lung cancers, depending on the average radon level and the smoking prevalence. In fact, smokers are estimated to be 25 times more at risk from radon-induced health hazards than non-smokers [6].

When radon gas is inhaled, densely ionizing alpha particles emitted by deposited short-lived decay products of radon (Polonium-218 and Polonium-214) can interact with biological tissue in the lungs leading to DNA damage. Cancer is generally thought to require the occurrence of at least one mutation and the proliferation of intermediate cells that have sustained some degree of DNA damage can greatly increase the pool of cells available for the development of cancer. Since even a single alpha particle can cause major genetic damage to a cell, it is possible that radon-related DNA damage can occur at any level of exposure. Therefore, it is unlikely that there is a threshold concentration below which radon does not have the potential to cause lung cancer [4].

Out of the average annual radiation dose of 2.4 mSv from natural radiation sources to man, about 1.2 mSv comes from inhaling radioactively contaminated particles in the air and radon gas [7]. Although the adverse effects of radon gas are known to vary according to the dose and duration of exposure, it is assumed that there is actually no safe dose of ionizing radiation. The focal point for radiation safety based on this assumption is 'the ALARA concept'. This entails that radiation exposure be reduced to 'As Low As Reasonably Achievable (ALARA)' but not exceeding the limit on effective dose recommended by International Commission on Radiological Protection [8].

In a study carried out at Obafemi Awolowo University (OAU), Ile-Ife, it was revealed that there were poor awareness and knowledge of Radon gas among the Staff of the studied institution [9]. In another related study carried out at the same OAU among lecturers. It also revealed a low knowledge about Radon among respondents and a poor/negative perception of radon risk [10].

The College of Health Sciences, Nnamdi Azikiwe University, Nnewi Campus has geographically located at latitude 5.970191 and longitude 6.944716 coordinates and hosts a significant number of staff and students who spend about eight hours (8:00 am to 4:00 pm) daily in and around the school, offices, classrooms and around school buildings and the rest at their respective homes. This population may have little or no knowledge and awareness of radon gas as well as potential radiological hazards associated with it. Assessment of this possible knowledge gap will aid the Government through the Ministry of Health in mapping out a blueprint for public healthcare policymaking. Therefore this study is aimed at assessing the knowledge and awareness of Radon gas and potential radiation hazard among students and staff of the College of Health Sciences, Nnamdi Azikiwe University, Nnewi Campus, and Anambra State, Nigeria.

Materials and Methods

A cross-sectional study was conducted among the undergraduate students, academic staff and non-academic staff of the College of Health Sciences, Nnamdi Azikiwe University Nnewi campus, using a questionnaire. A 20 items semi-structured questionnaire written in the English language were administered to 550 participants (undergraduate students, academic staff and non-academic staff) from the aforementioned area who were informed about the study prior to the commencement of data collection from January to October 2022. A convenient sampling technique was used in this study. Ethical approval was obtained from the Ministry of Health, Anambra State for this study. A test re-test study was conducted among Twenty-four (24) subjects prior to the full commencement of the study and the Cornbrach alpha reliability test was carried out. The questionnaire had an acceptable internal consistency (Cronbach's alpha-0.81). Only students and staff of the studied area were allowed to participate and those that did not consent to participate in the study were excluded. The questionnaires were administered to the participants using the one-on-one method of administering the questionnaire. All completed questionnaires were retrieved by the researcher and the research assistant.

Information on the demographic variables of the respondents, knowledge of radon Gas, its sources and radiological hazards were collated. The obtained data were processed using the statistical package for social sciences (SPSS) version 21 IBM SPSS, United States, 2012) and analyzed using descriptive statistics.

Results

A total of 550 respondents participated in the study, amongst which 250 (45.5%) respondents were males, while 300 (54%) were females. Participants within the age range 15-25 years had the modal class with 300 (54.5%), while the age range of 56-65 years had the least number of respondents 15 (2.7%). A total of 370 (67.3%) of the participants were students, 94 (17.1%) were academic staff and 86 (18.6%) non-academic. The 200 Level students had the modal class of respondents with 160 (29.1%), while 400-level students had the least with 30 (5.5%). The majority of the student participants were from the Anatomy department with 370 (15.4%) while the least were students from the Environmental Sciences department 20 (5.4%). The majority of the staff participants were from the Anatomy department with 30 (16.7%), while the least was from the Medicine department 8 (4.4%). The majority of the study participants reside off-campus 530 (96.4%), and only 5 (0.9%) and 15 (2.7%) reside within the staff quarters and the dormitory respectively, as shown in Table 1.

Table 1: Socio-demographic characteristics of the participants.

Gender	**Frequency**		**Percent**	
MALE	250		45.5	
FEMALE	300		54.5	
Total	550		100.0	
Age	Frequency		Percent	
15-25	300		54.5	
26-35	150		27.3	
36-45	40		7.3	
46-55	45		8.2	
56-65	15		2.7	
Total	550		100.0	
Designation	Frequency		Percent	
STUDENT	370		67.3	
ACADEMIC STAFF	94		17.1	
NON-ACADEMIC STAFF	86		15.6	
Total	550		100.0	
Educational Level	Frequency		Percent	
200LEVEL	160		29.1	
300LEVEL	100		18.2	
400LEVEL	30		5.5	
500LEVEL	80		14.5	
STAFF	180		32.7	
Total	550		100.0	
Departments	**Students**		**Staff**	
	Frequency	**Percent**	**Frequency**	**Percent**
MEDICINE	35	9.5	8	4.4
RADIOGRAPHY	55	14.9	20	11.1
NURSING	53	14.3	20	11.1
MEDICAL LAB SCIENCES	55	14.9	20	11.1
ANATOMY	57	15.4	30	16.7
MEDICAL REHABILITATION	55	14.9	15	8.3
PHYSIOLOGY	40	10.8	25	13.9
ENVIRONMENTAL SCIENCES	20	5.4	17	9.4
BIOCHEMISTRY	0	0.0	25	13.9
Total	370	100	180	100.0
Place of Residence	**Frequency**		**Percent**	
DORMITORY	15		2.7	
OFF CAMPUS	530		96.4	
STAFF QUARTERS	5		0.9	
Total	550		100.0	

On respondents' knowledge of Radon gas and its associated potential radiological hazards, the study revealed that 415 (75.5%) respondents had no knowledge of Radon gas when compared with 135 (24.5%) respondents who had knowledge of Radon gas. A total of 448 (81.5%) respondents were not aware that Radon gas is an important source of ionizing radiation of natural origin compared to 102 (18.5) participants who accepted were aware of Radon gas and its origin. The majority 328 (59.6%) of the participants did not know that Radon gas is colourless, odourless and tasteless noble gas as against 98 (17.8%) who were aware. A significant majority of 550 (69.5%) did not know that Radon gas could radiate into houses, offices and classrooms through cracks in the floors, on the walls and even accumulate indoors, while 85 (15.5%) knew about it. A total of 384 (69.8%) respondents were not aware that Radon gas was present in soil, water and building materials such as granite, bricks, cement, and tiles, among others, while 80 (14.5%) of the respondents were aware. The majority of the respondents 404 (73.5%) were not aware that Radon gas levels can be higher in homes that are tightly sealed, while 68 (12.4%) know about it. A total of 423 (79.9%) respondents were not aware that basements and first floors potentially have the highest Radon gas levels because of their proximity to the ground, while 52 (9.5%) of the respondents were aware of it. A total of 475 (86.4%) respondents were not aware that Radon gas escapes easily from the ground into the air where it decays and produces further radioactive particles, while 75 (13.6%) knew about it. A significant majority of 499 (90.7%) of the participants were not aware that Radon gas can be routinely checked using a Radon survey meter or Radon test kit as against 51 (9.3%) who were aware of it, as shown in Table 2.

Table 2: Knowledge and awareness of radon gas among the studied participants.

Have you heard of radon gas?	**Frequency**	**Percent**
YES	135	24.5
NO	415	75.5
Total	550	100.0
Are you aware that radon gas is an important source of ionizing radiation of natural origin?	**Frequency**	**Percent**
YES	102	18.5
NO	448	81.5
Total	550	100.0
Radon gas is a colorless, odorless and tasteless noble gas?	**Frequency**	**Percent**
YES	98	17.8
NOT SURE	124	22.5
NO	328	59.6
Total	550	100.0
Radon gas can enter homes, offices, classrooms, through cracks in floors, walls or foundation and accumulate indoors?	**Frequency**	**Percent**
YES	85	15.5
NOT SURE	83	15.1
NO	382	69.5
Total	550	100.0
Radon gas is present in soil, water and building materials like block, cement, tiles etc.?	**Frequency**	**Percent**
YES	80	14.5
NOT SURE	86	15.6
NO	384	69.8
Total	550	100.0
Do you know radon gas can be released from building materials or water obtained from wells that contain radon?	**Frequency**	**Percent**
YES	72	13.1
NOT SURE	81	14.7
NO	397	72.2
Total	550	100.0
Are you aware that radon gas levels can be higher in homes that are tightly sealed?	**Frequency**	**Percent**

YES	68	12.4
NOT SURE	78	14.2
NO	404	73.5
Total	550	100.0
Basements and first floor typically have the highest radon gas levels because of their closeness to the ground?	**Frequency**	**Percent**
YES	52	9.5
NOT SURE	75	13.6
NO	423	79.9
Total	550	100.0
Do you know that radon gas escapes easily from the ground into the air where it decays and produces further radioactive particle?	**Frequency**	**Percent**
YES	75	13.6
NO	475	86.4
Total	550	100.0
Are you aware that radon gas can be routinely checked using radon survey meter or radon test kit?	**Frequency**	**Percent**
YES	51	9.3
NO	499	90.7
Total	550	100.0

Table 3: Knowledge of the radiological hazards from radon gas.

Do You Know That Radon Gas can Cause Serious Health Hazard That Can Damage DNA and Potentially Cause Lung Cancer in the General Population?	**Frequency**	**Percent**
YES	120	21.8
NO	430	78.2
Total	550	100.0
Are You Aware That Radon Gas is the Leading Cause of Cancer after Smoking?	Frequency	Percent
YES	68	12.4
NO	482	87.7
Total	550	100.0
Exposure to Indoor Radon Gas can Cause Risk of Lung Cancer in the General Population?	Frequency	Percent
YES	110	20
NO	440	80
Total	550	100.0
Do You Know that the Increased Risk of Developing Lung Cancer Depends on the Radon Concentration and Length of Exposure?	Frequency	Percent
YES	57	10.3
NO	493	89.6
Total	550	100.0

A total of 430 (78.2%) respondents were not aware that Radon gas can cause serious health hazards that can damage the DNA and potentially can cause lung cancer in the general population while 120 (21.8%) respondents were aware of it. A total of 482 (87.7%) of the respondents were not aware that Radon gas was the leading cause of lung cancer after smoking, while 68 (12.4%) were aware of it. A total of 440 (80%) of the respondents were not aware that exposure to indoor Radon gas can cause a risk of lung cancer in the general population, while 110 (20%) of the respondents knew about it. A total of 493 (89.6%) of the respondents do not know that the increased risk of developing lung cancer is dependent on the Radon concentration and length of exposure, however, 57 (10.3%) knew about it, as shown in Table 3.

Discussion

The majority of the participants in this study had poor knowledge of radon gas and its associated radiological hazards prior to this study. Similar findings were reported among academics in ObafemiAwolowo

University (OAU) [9-11] among University employees; Peterson and Howland in Boston University [12] and in Canada by the home protection centre, and in India by Niphadkar, et al. [13]. This perhaps could be due to poor public health awareness of the risk posed by indoor air pollution by Radon among others.

The majority of the respondents were not aware that Radon gas is an important source of ionizing radiation of natural origin, and they did not also know that Radon gas is a colourless, odourless and tasteless noble gas. Radon gas is a radioactive colourless, odourless and tasteless naturally occurring, it is a by-product of Uranium decay in the soil, water and rocks [14]. Radon is an important source of ionizing radiation because radioactive particles from radon decay such as alpha particle when inhaled, could get trapped in the lungs and possibly lead to lung cancer, especially when the radon concentration in houses are high, people spend a long time indoors and even severe in heavy smokers [14-16].

A significant majority of the studied population was not aware that Radon gas could radiate into houses, offices and classrooms through cracks in the floors, on the walls and even from accumulated indoors. Radon gas enters houses, offices, and classrooms through cracks in the floors, walls and foundations, thus it builds up to high concentrations that could be dangerous when ingested or inhaled by humans. The risk of cancer developing from exposures to radon gas however depends on the measure of radon gas concentration (dose), the length of time that an individual spends in such a room (duration) and the smoking status of the individual exposed to radon gas [14,15,17].

A good majority of respondents were not aware that Radon gas was present in soil, water and building materials like bricks, cement, and tiles, among others. Most of the respondents were unaware that building basements and first floors often possess high Radon gas levels because of their proximity to the ground and that Radon gas escapes easily from the ground into the air where it decays and produces further radioactive particles. The primary routes through which the harmful gas gets into a man are through inhalation from the air and ingestion of water with dissolved radon, especially from underground well water [14,15], Cheng [18] recommended increasing under-floor ventilation, installing a radon pump system in the basement, improving the overall ventilation of the building, and sealing all cracks and holes in the floors and walls among others to minimize the spread of radon gas throughout the building. When these radioactive substances are inhaled/ingested, they tend to transfer their energy to the cells, thereby causing cellular changes which result in the formation of free radicals [19,20] and if the dose accumulates significantly, the damage may be irreversible, thus causing cell death or continued cellular proliferation which can result in various malignancies like the cancer of the lungs among others [21].

A significant majority of the participants were not aware that Radon gas can be routinely checked using a Radon survey meter or Radon test kit. Previous studies by Tammy, et al. [22] reported similar findings, where there was poor public health knowledge about radon gas and the methods used in detecting radon gas in homes. There is, therefore, a need for the government and healthcare professionals as well as regulatory bodies to intensify efforts in creating public health awareness of radiation hazards [23,24].

This study found a poor level of knowledge among the participants on the potential health hazards associated with exposure to Radon gas. Radon gas was labeled a human carcinogen by the International Agency for Research on Cancer.18 Majority of the participants were not aware that Radon gas was the second leading cause of lung cancer after smoking. The risk of lung cancer is reportedly multiplied ten times among smokers [25-28]. The lifetime risk of lung cancer from exposure to radon gas among smokers is 62 per 100 persons and 7 per 100 persons for non-smokers. Implying 8.86 times the increased tendency of developing lung cancer for a smoker if exposed to radon gas than a non-smoker in a lifetime [29]. Thus the recommended test for all homes by the U.S surgeon general and the United States Environmental Protection Agency [14,30,31] is to know the average levels of radon concentration and to implement appropriate recommendations when the findings are beyond the normal limits of 4 pCi/L. The testing is done by exposing the radon detector to air for up to four days in an enclosed house usually in the lowest inhabiting spaces of the house. If the screening test result is 4 pCi/L or even more, the homeowner is advised to take certain remedial actions [28,32,33]. It is also very important to note that DNA damage may occur at any level of exposure as no threshold values have been established, therefore, indoor residential radon concentration should be reduced to the barest minimum possible [20,31,34-39]. There is therefore an urgent need by the university management to intensify her awareness and enlighten campaign to the entire university community about radon gas and associated radiation hazards.

This study is however, limited in its sample size as only a handful of students and staff were willing and consented to participate in the study, a possible reason could be due to the industrial action (strike) embarked upon by the academic staff union of universities and the non-academic staff union of universities during the period of the study. Also, this was a single-institution study. We hope that subsequent research will be multicentric to expand the scope, get divergent views and get a larger sample size.

Conclusion

This study found poor knowledge and awareness of Radon gas and its associated potential health hazards

among students and staff of the College of Health Sciences, Nnamdi Azikiwe University, Nnewi Campus, Nigeria. Radon is a naturally occurring radioactive, colourless, odourless, tasteless gas formed by the disintegration of Radium, which is domiciliary in the earth's crust, groundwater and building materials such as granites, and cement, among others. It has a half-life of 3.8 days. Public health education through seminars, webinars, workshops, billboards, and print and electronic media, will go a long way in enlightenment and creating awareness to the general public about the potential hazards of radon gas, regular home and building radon testing as well as possible ways of ameliorating the potential health hazards associated with radon gas.

References

1. Akinremi OT, Ogo CN, Olutunde AO (2011) Review of prostate cancer research in Nigeria. Infect Agent Cancer 6: S8.
2. World Health Organisation (2016) Management of radioactivity in drinking-water, Geneva.
3. Ezenma IC, Abubakar GM, Nzotta CC, Chieghu HU, Nwodo KV (2022) Natural radionuclide concentration and associted health hazard indices in tailing and non- tailing enriched soil sample from okobo coal mine Kogi State. Nigeria. Nigerian Journal of Imaging and Radiation Therapy 11: 43-50.
4. International Agency for Research on Cancer (IARC) (2001) Man-made mineral fibres and radon. IARC Publications 43.
5. Health Canada (2016) Radon - reduction guide for Canadians; Information on how to reduce exposure to radon.
6. United States Environmental Protection Agency (2013) America's children and the environment. (3rd edn).
7. (2000) Sources and effects of ionizing radiation. United Nations scientific committee on the effect of atomic radiation.
8. International Commission on Radiological Protection (2007) The 2007 recommendations of the international commission on radiological protection. ICRP Publication 103, 37: 2-4.
9. Afolabi O, Falode D, Onayade A, Tobih JE (2015) Radon risk awareness among university employees of Obafemi Awolowo University, ILE-IFE. Education.
10. Field RW, Steck DJ, Smith BJ, Brus CP, Fisher EL, et al. (2000) Residential radon gas exposure and lung cancer: The iowa radon lung cancer study. Am J Epidemiol 151: 1091-1102.
11. Esan DT, Obed IR, Afolabi OT, Sridhar MK, Olubodun BB, et al. (2020) Radon risk perception and barriers for residential radon testing in Southwestern Nigeria. Public Health Pract 1: 100036.
12. Peterson EW, Howland J (1996) Predicting radon testing among university employees. J Air Waste Manag Assoc 46: 2-11.
13. Niphadkar PV, Rangnekar K, Tulaskar P, Deo S, Mahadik S, et al. (2009) Poor awareness and knowledge about indoor air, pollution in the urban population of Mumbai, India. Journal of Association of Physicians of India.
14. United State Environmental Protection Agency (2012) A citizen's guide to radon.
15. Alzabadi H, Musmar S, Issa S, Dwaikat N, Saffarini G (2017) Exposure assessment of Canadian center for occupational health and safety.
16. United Environmental Protection Agency (2011) Health indoor environment protocols for homes.
17. International Agency for Research on Cancer (1988) Man-made mineral fibres and radon.
18. Cheng W (2017) Radon: An overview.
19. Homeowner Protection Centre (2012) The radon challenge - building awareness and encouraging action.
20. Geofery L, Basirat M, Eze CU, Chigozie NI, Auwal A, et al. (2015) Evaluation of the knowledge and awareness of non-ionizing radiation among final year students of college of medical sciences university of Maiduguri. International Research Journal of Pure and Applied Physics 3: 8-14.
21. Health Canada (2017) Radon Reduction Guide for Canadians; Information on how to reduce exposure to radon.
22. Duckworth LT, Frank-Stromborg M, Oleckno WA, Duffy P, Burns K (2002) Relationship of perception of radon as a health risk and willingness to engage in radon testing and mitigation. Oncol Nurs Forum 29: 1099-1107.
23. Esan DT, Sridhar MKC, Obed R, Ajiboye Y, Afolabi O, et al. (2020) Dertermination of residential soil gas radon risk indices over the lithological units of a Southwestern Nigeria university. Sci Rep 10: 7368.
24. Nwodo VK, Chiaghanam NO, Ogolodom MP, Ohagwu CC, Nwodo CU, et al. (2020) Assessment of knowledge and awareness of radiation hazard and protection among patients relatives in Southeast, Nigeria. Journal of Clinical and Diagnostic Research 14: TC10-TC13.
25. Lantz PM, Mendez D, Philbert MA (2013) Radon, smoking, and lung cancer: The need to refocus radon control policy. Am J Public Health 103: 443-447.
26. Lubin JH, Boice JD, Edling C, Hornung RW, Howe GR, et al. (1995) Lung cancer in radon-exposed miners and estimation of risk from indoor exposure. J Natl Cancer Inst 87: 817-827.
27. Darby S, Hill D, Auvinen A, Barros-Dios JM, Baysson H, et al. (2005) Radon in homes and risk of lung cancer: Collaborative analysis of individual data from 13 European case-control studies. BMJ 330: 223.
28. Lubin JH, Steindorf K (1995) Cigarette use and the estimation of lung cancer attributable to radon in the United States. Radiat Res 141: 79-85.
29. Mendez D, Alshanqeety O, Warner KE, Lantz PM, Courant PN (2011) The impact of declining smoking-radon related lung cancer in the United States. Am J Public Health 101: 310-314.
30. United States Environmental Protection Agency (2005) Energy upgrades. Office of air and radiation.
31. Hajo Z, Ferid S (2009) WHO handbook on indoor radon: A public health perspective. World Health Organization.
32. Environmental Protection Agency (2011) Health indoor environment protocols for homeenergy upgrades.
33. Hill WG, Butterfield P, Larsson LS (2006) Rural parents' perception of risks associated with their children's exposure to radon. Public Health Nurs 23: 392-399.

34. World Health Organization (2006) Handbook on indoor radon: A public health perspective, Geneva.

35. Turner MC, Krewski D, Chen Y, Pope CA, Gapstur S, et al. (2011) Radon and lung cancer in the American cancer society cohort. Cancer Epidemiol Biomarkers Prev 20: 438-448.

36. International Atomic Energy Agency (2014) Radiation Protection and safety of radiation sources: International basic safety standards.

37. WHO (2018) Guidelines for drinking-water quality. (4th edn), WHO, Geneva.

38. WHO (2011) Guidelines for drinking-water quality. (4th edn), Geneva.

39. Ezenma IC, Nzotta CC, Chieghu HU, Ugwu AC, Nwodo KV, et al. (2022) Natural radionuclide concentration and associated health hazard indices in coal samples from okobo coal mine, Nigeria. Int J Appl Res 8: 470-476.