AWARENESS OF POTENTIAL AMBIENT RADON GAS INHALATION HAZARDS AMONG UNDERGRADUATE STUDENTS AND STAFF OF A MEDICAL SCHOOL IN SOUTH-EAST, NIGERIA

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ABSTRACT

Background: Radon is a noble radioactive gas considered as one a significant ambient indoor air pollutant and eminently associated with lung carcinoma. There is paucity of research on knowledge and awareness of ambient inhalation of radon gas and associated potential radiological hazards among health workers.

Aim: This study aimed at assessing the awareness of potential ambient radon gas inhalation hazards among undergraduate students and staff of students and staff of College of Health Sciences, Nnamdi Azikiwe University.

Materials and Methods: This cross-sectional study involved students and staff of College of Health Sciences, Nnamdi Azikiwe University, using a questionnaire. A 20-item semi-structured questionnaire was administered to 550 participants (undergraduate students, academic staff and non-academic staff). Information on demographic characteristics of the respondents, knowledge of radon gas and radiological effects hazards were collected. The obtained data were summarized using descriptive statistics.

Results: 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 to the general population.

Conclusion: Poor knowledge and awareness of ambient Radon gas and associated potential health hazards due to inhalation were eminent among students and staff of the College of Health Sciences, Nnamdi Azikiwe University.

Key Words: Knowledge, Awareness, Radon, Radiation, Radiological Hazards.

Introduction

Radon is a naturally occurring noble radioactive gas formed by disintegration of radium, which is domiciliary in earth crust, groundwater and building materials such as granites, cement, among others[1]. Radon is a colorless, odorless, tasteless noble 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 lead 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 respiratory organ such as the lungs. It can radiate inside our homes, offices, classrooms through cracks in floors, walls, or building foundation 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 particle. 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 hazard 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 to the 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[6]. 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 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 2.4mSv from natural radiation sources to man, about 1.2mSv 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 in Obafemi Awolowo University (OAU), Ile-Ife, it was revealed that there were poor awareness and knowledge of Radon gas among staff of the studied institution.[9] Low knowledge about radon among respondents and poor/negative perception of radon risk[10] was also noted in another related study carried out among lecturers in the same institution.

Nnamdi Azikiwe University, Nnewi Campus hosts significant number of staff and students who spend about eight hours (8:00am to 4:00pm) 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. Documented reports are available concerning the level of awareness and knowledge of radon gas in some other institutions, but there is dearth of information concerning this subject at Nnamdi Azikiwe University, Nnewi Campus. Assessment of this possible knowledge gap will aid the Government through the Ministry of Health in mapping out blueprint for public health care policy making. Therefore this study is aimed at assessing the knowledge and awareness of radon gas and potential radiation hazard among students and staff of College of Health Sciences, Nnamdi Azikiwe University, Nnewi Campus, and Anambra State, Nigeria.

Materials and Methods

Study Design: A cross sectional survey design was adopted for this study and involved selected members of the community of Nnamdi Azikiwe University, Nnewi Campus.

Study setting/area: The College of Health Sciences, Nnamdi Azikiwe University, Nnewi Campus was used for this study, located geographically on latitude 5.970191 and longitude 6.944716 coordinates.

Study Population: Undergraduates, academic and non-academic student of the university were involved in the study.

Sample Size Calculation and Sampling: A total of 550 participants (undergraduates, academic staff and non-academic staff) from the aforementioned area who were previously informed and consecutively sampled were recruited for this study upon consenting to voluntarily participate.

Eligibity Criteria: 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.

Study Instrument Design: A 20 items semi-structured questionnaire developed in English language was used for this study.

Validity and Reliability Testing: A test re-test study was conducted among twenty-four (24) subjects prior to full commencement of the study and the Cronbach's alpha reliability test was carried out. The questionnaire had an acceptable internal consistency (Cronbach's alpha = 0.81).

Ethical Consideration: Ethical approval was obtained from the Ministry of Health, Anambra State with approval number MH/Awk/M/321/423.

Study Procedure: The questionnaires were administered to the participants using one-on-one method of administering questionnaire. All completed questionnaires were retrieved by researchers and the research assistants. Information on demographic variables of the respondents, knowledge of radon gas inhalation, its sources and radiological hazards were collated.

Data Analysis: The obtained data were summarized using descriptive statistics of frequency and percentages.

Results

A total of 550 respondents participated in the study, amongst which 250 (45.5%) respondents were males, while 300 (54%) were females. Most of the participants (300 or 54.5%) were within the 15-25 years age range, while the age range of 56-65years 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%). Majority of the student participants were from Anatomy department with 370 (15.4%) while the least were students from Environmental Sciences department 20 (5.4%). Majority of the staff participants were from Anatomy department with 30 (16.7%), while Medicine department 8 (4.4%) recorded the least. 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.

On respondent's 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. Majority 328 (59.6%) of the participants did not know that radon gas is colorless, odorless and tasteless noble gas as against 98 (17.8%) who were aware.

A significant majority 550 (69.5%) did not know that Radon gas could radiate into houses, offices and class rooms through cracks in the floors, on the walls and even accumulate indoor, 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, tiles, among others, while 80 (14.5%) of the respondents were aware. 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 about 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 499 (90.7%) of the participants were not aware that Radon gas can be routinely checked using Radon survey meter or Radon test kit as against 51 (9.3%) who were aware of it, as shown in table 2.

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 lungs 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 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.

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**
ANATOMY	57	15.4	30	16.7
BIOCHEMISTRY	0	0.0	25	13.9
ENVIRONMENTAL SCIENCES	20	5.4	17	9.4
MEDICINE	35	9.5	8	4.4
MEDICAL LAB SCIENCES	55	14.9	20	11.1
MEDICAL REHABILITATION	55	14.9	15	8.3
NURSING	53	14.3	20	11.1
PHYSIOLOGY	40	10.8	25	13.9
RADIOGRAPHY	55	14.9	20	11.1
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

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.

	Frequency	P Percent
Do You Know That Radon Gas can Cause Serious Health Hazard That Can Damage DNA and Potentially Cause Lung Cancer in the General Population?		
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

Discussion

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 Obafemi Awolowo 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.

Majority of the respondents were not aware that radon as is an important source of ionizing radiation of natural origin, and they did not also know that Radon gas is colorless, odorless and tasteless noble gas. Radon gas is a radioactive colorless, odorless 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 the houses are high, people spend long times indoors and even severe in heavy smokers.[14-16]

A significant majority of the studied population were not aware that Radon gas could radiate into houses, offices and class rooms through cracks in the floors, on the walls and even from accumulated indoor. Radon gas enters into houses, offices, and class rooms through cracks in the floors, on the wall 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 number of respondents were not aware that Radon gas was present in soil, water and building materials like bricks, cement, tiles, among others. Most of the respondents were unaware that building basements and first floors often possess high Radon gas levels because of its 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 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, improve the overall ventilation of the building, and sealing all cracks and holes in the floors and wall among others to minimize the spread of radon gas throughout the building. When this radioactive substances are inhaled/ingested, they tend to transfer their energy to the cells, thereby causing cellular changes which results 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 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 need by the government and healthcare professionals as well as regulatory bodies to intensify effort in creating public health awareness of radiation hazards.[24]

This study found a poor level knowledge among the participants on the potential health hazards associated with exposure to Radon gas. Radon gas was labelled 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 life time 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 an 8.86 times increased tendency of developing lung cancer for a smoker if exposed to radon gas than non-smoker in a life time.[29] Thus the recommended test for all homes by the U.S surgeon general and the United Sates Environmental Protection Agency[14,30,31] 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 in 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 home owner is advised to take certain remedial actions.[28,32, 33]. It is also very important to note that DNA damage may occur at any levels of exposure as no threshold values has been established, therefore, indoor residential radon concentration should be reduced to the barest minimum as possible. [20,31,34-39] There is therefore 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.

Conclusion

Participants revealed poor knowledge and awareness of Radon gas and its associated potential health hazards when inhaled. Public health education through seminars, webinars, workshops, billboards, print and electronic media, will go a long way in enlightenment and creating awareness to the general public about the potential hazards of high ambient radon gas as well as regular home and building radon testing are possible ways of ameliorating the potential health hazards associated with radon gas.

REFERENCE

1. National Cancer Institute (NCI). Review of Prostate Cancer Research in Nigeria.2011 *Open Access journal.* Available at Link. Spinger.com.
2. World Health Organisation. Management of Radioactivity in Drinking-water, *Geneva.2016*
3. Ezenma IC, Abubakar GM, Nzotta CC, Chieghu HU, Nwodo KV. Natural Radionuclide Concentration and Associated 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.2022:*11(1): 43-50
4. International Agency for Research on Cancer. Man-made mineral fibres and radon. IARC Monographs on Evaluation of Carcinogenic Risks to Humans.2001: 11(43): 1–300.
5. Health Canada. Radon Reduction Guide for Canadians: Information on how to reduce exposure to radon.2016
6. United States Environmental Protection Agency. America's Children and the environment. Office of Air and Radiation.2013
7. United Nations Scientific Committee on the Effect of Atomic Radiation (UNSCEAR). Sources and effects of ionizing radiation, Report of the United Nations Scientific Committee on the Effects of Atomic Radiation to the General Assembly, *New York, USA, United Nations Publication.2000;6(7):*95-120
8. International Commission on Radiological Protection. The 2007 recommendations of the international Commission on Radiological Protection. *ICRP Publication 103. Annal of ICRP*.2007;7(17); 2-4.
9. Afolabi OT, Falode DT, Banjoko B, Onayade AA, Tobih JE. Radon Risk Awareness among University Employees of Obafemi Awolowo University, Ile-Ife. *Education. 2015;5(8);23-35*
10. Field RW, Steck Dj, Smith BJ, Brus CP, Fischer EL, Neuberger JS, Platz CE, Robinson RA,Wooiso RF, Lynch CF. Residential Radon Gas Exposure and Lung Cancer: The Iowa Radon Lung Cancer Study. *American Journal of Epidemiology*.2000; 15(11): 45-72
11. San DT, Obed IR, Afolabi O. T, Sridhar M.K, Olubodun BB, Ramos C. Radon Risk Perception and Barriers for Residential Radon Testing in Southwestern Nigeria. *Public Health in Practice*.2020; 9(1): 10-36
12. Peterson EW, Howland J, Predicting Radon Testing Among University Employee Journal of Air Waste Management Association.1996: 46; 2-11.
13. Niphadkar P.V, Rangnekar, Tulaskar P, Deo S, Mahadik S, Kakade A.M. (2009). Poor Awareness and Knowledge about Indoor air, Pollution in the Urban Population of Mumbai, India. 57(8); 447-450.
14. United State Environmental Protection Agency. (2012). A citizen's guide to radon. *EPA 402/K-12/002*. http://www.epa.gov/radon/pdfs/citizensguide.pdf
15. Al Zabadi H, Musmar S, Issa, S., Dwaikat N, & Saffarini G. Exposure assessment of Canadian Center for Occupational Health and Safety. 2017;5(10);42-50
16. United States Environmental Protection Agency. Health indoor environment protocols for homes.2011;18(19); 22-38
17. International Agency for Research on Cancer (IARC). Man-made mineral fibres and radon. 1998; 3(5);17-30)
18. Cheng W. Radon: An Overview.2017; Retrieved from https://www.canada.ca/en/healthcanada.html
19. Homeowner Protection Centre. The Radon Challenge, http://www.homeownerprotection.ca//home_owner_protection/, /hpc_th… accessed on 16/08/2022.

20. Luntsi G, Basirat M, Eze CU, Nwobi IC, ABubakar A, Ochie K, Nkubli B.F, Njiti M, Moi A.S, Mathew A.G. Evaluation of the Knowledge and Awareness of Non-Ionizing Radiation among Final Year Students of College of Medical Sciences, University of Maiduguri. *International Journal of Pure and Applied Physics*.2015; 13(3): 8-14.
21. Health Canada. Radon Reduction Guide for Canadians. Information on how to reduce exposure to radon.2017;5(7); 10-17
22. Tammy D.L, Marilyn F.S, Oleckno W.A, Pam D, Kenneth B. Relationship of perception of Radon as a health risk and willingness to engage in radon testing and mitigation. *Oncology Nursing Forum*.2002; 29(7): 10-19.
23. Esan DT, Sridhar MK, Ajiboyr RO, Afolabi O, Olubodun B, Oni OM. Determination of Residential Soil Das Radon Risk Indices over the Lithological Units of a Southwestern Nigeria University.2020; 8(11): 25-30
24. Nwodo VK, Chiaghanam NO, Ogolodom MP, Ohagwu CC, Nwodo CU, Agbadaola OA, Mmbaba AN, Ezenma IC, Abubakar U. Assessment of Knowledge and Awareness of Radiation Hazard and Protection among Patients Relatives in Southeast, Nigeria. *Journal of Clinical and Diagnostic Research.2020;* 14(8): 10-13
25. Lantz P.M, Mendez AD, Philbert M.A. Radon, Smoking, and Lung Cancer. (2013). The Need to Refocus Radon Control Policy. Framing Health Matters. *American Journal of Public Health*; 2013; 1(3): 443-447
26. Lubin JH, Boice JD Jr, Edling C. Lung cancer in radon-exposed miners and estimation of risk from indoor exposure. *Journal of National Cancer Institute*.1995; 87(11): 817-827.
27. Darby S, Hill D, Auvinen A. Radon in homes and risk of lung cancer: collaborative analysis of individual data from 13 European case---control studies. *British Medical Journal.2005;* 330(7485):223---228.
28. Lubin JH, Steindorf K. Cigarette use and the estimation of lung cancer attributable to radon in the United States. Radiation Research Journal.1995; 141(1): 79-85.
29. Mendez, D., Alshanqeety, O., Warner, K. E., Lantz, P. M., & Courant, P. N. The impact of declining smoking -radon related lung cancer in the United States. *American Journal of Public Health*.2011;101 (2): 310-314.
30. United States Environmental Protection Agency (EPA). Energy upgrades. Office of Air and Radiation. (6609J) EPA 402/K-11/003.2005;7(8);67-88
31. World Health Organization (WHO). A Handbook on indoor radon: a public health perspective. 2009;3(5);35-51
32. United States Environmental Protection Agency. Health indoor environment protocols for home energy upgrades. Office of Air and Radiation. *(6609J) EPA* 402/K- 11/003.2011
33. Hill, W., Butter, P., & Larsson, L. Rural parents perception of risks associated with their children's exposure to radon. *Public Health Nursing*.2006; 23(5): 392-399.
34. World Health Organization (WHO). Handbook on Indoor Radon: A Public Health Perspective, *Geneva*.2006
35. Turner, M. C., Krewski, D., Chen, Y., Pope, C. A., Gapstur, S., & Thun, M. J. Radon and lung cancer in the American Cancer Society cohort. *Cancer Epidemiology Biomarkers &Prevention*.2011; 20(3): 438-448.
36. International Atomic Energy Agency (IAEA). Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, *Vienna*.2014; Accessed on 07/09/2022
37. World Health Organization. Guidelines for drinking-water quality, 4th edition *Geneva.2018;32(5);35-52*
38. World Health Organization. Guidelines for drinking-water quality, 4th edition Geneva.2011;5(6);773-96
39. Ezenma I.C, Nzotta C.C, Chiegwu H.U, Ugwu A.C, Nwodo V.K, Abubakar M, Luntsi G and Oladipupo O.W. Natural radionuclide concentration and associated health hazard indices in coal samples from Okobo Coal Mine, Nigeria. International Journal of Applied Research.2022; 8(6):470-476.