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Radon Level and Effects in Public and Residential Places in Nigeria

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Abstract

Reports from the World Health Organization (WHO) regarding radon as human lung carcinogen has generated a lot of research interest on the impacts of radon exposure to people all over the world. Radon concentration of different building types such as glass house, bricks and basement house structures at different locations geographically were reviewed to evaluate sustainable radon level as a strategic pathway for environmental sustainability in Nigeria. Volumes of expertises in research domain and their respective views were crystallized to forge status of Nigerians on the risk scale. Average mean radon concentration from cumulative survey suggested that dwelling and residential houses are within the recommended limit suggested by standard international and local organizations with little variations owing to several contributory factors. Research also shows that some buildings materials containing relative parent radionuclides of radon and its progenies can also contribute to indoor radon concentration, nevertheless, soil gas containing radon found in soils overlying basement rocks constitute the main source for indoor radon concentration within dwelling places. It is wholly to write that the delineated radon map will serve as a useful tool for determination of new building sites in Nigeria and as a guide for future radon remediation and monitory plan for the safest life in our dear Nation Nigeria.

Keywords: Radon; Dwelling places; Residence; Concentration; Exposure

Introduction

Radon is a gas produced during radioactive decay of radium. Radioactive decay is a natural, spontaneous process in which an atom of one element disintegrates or breaks down to form another element by losing atomic particles (protons, neutrons, or electrons). When solid radium decays to form radon gas, it loses two protons and two neutrons. These two protons and two neutrons are called an alpha particle, which is a type of radiation. The elements that produce radiation are said to be radioactive. Radon itself is radioactive because it also decays; losing an alpha particle and forming the element polonium. Elements that are naturally radioactive include uranium, thorium, carbon, and potassium, as well as radon and radium. Uranium is the first element in a long series of decay that produces radium and radon [1].

Radon (^{222}Rn) is a gas with a half- life of (3.82 d). Produced by the decay of naturally occurring radionuclide which in turn is a by product in the Uranium (^{238}U) decay series [2]. Thorium gas (^{220}Rn), which is a Radon isotope, is a decay product in the Thorium (^{232}Th) series. The half-life of Thorium (56 seconds) is much shorter than that of Radon. Because of such a short half-life of Thorium, its emanation from building materials, as well as, its infiltration from the ground and further migration is restricted to a few centimetres only [3].

The decay of each radioactive element occurs at a very specific rate. How fast an element decays is measured in terms of the element's "half life," or the amount of time for one half of a given amount of the element to decay. Uranium has a half-life of 4.4 billion years, so a 4.4-billion-year old rock has only half of the uranium with which it started [4]. The half-life of radon is only 3.8 days. If a jar was filled with radon, in 3.8 days only half of the radon would be left. But the newly made daughter products of radon would also be in the jar, including polonium, bismuth, and lead. It exists ubiquitously, small in degree to be noticed but can only be measured using a detector. ^{238}Uranium is available in soil and rocks in limited quantity. Part of the radium migrates to the soil surface and finds their ways to the air, while other part remains at the sub-surface and penetrates the ground water [5]. Among the radioisotopes that add to general background radiation, radon posed major risk to human health. About 55% of the annual radiation dose incurred by the general public can be traced to it. Alpha particles from radon are heavy particles and can only move a short distance. It cannot permeate through human skin but it can be inhaled and settled in the lung tissue. The energy deposition in lungs is highly localized and this will likely elevate the risk of lung cancer [6,7]. Radon in buildings is considered to be the most important indoor air pollutant, with harmful effects on the health of the general populace. Inhalation of radon and its short-living decay products increases the risk of lung cancer [8]. Depending on the geological and geophysical aspects, as well as the features of building materials, Radon can migrate into the indoor air, which can lead to an increase in radon concentrations [9]. The gas disperses quickly in the open air, but can accumulate in buildings, especially in areas where the underlying ground contains more uranium than the average amount and is permeable dose from natural sources. Therefore, the measurement of environmental radon is significant [10].

As a result of inhalation, radon progenies may be deposited on the cells lining the airways where the alpha particle emitted by radon and its progenies can damage the DNA and other potential risk organs and tissues. Worldwide average annual effective dose from ionizing radiation from natural sources was reported and was estimated to be 2.4 mSv, of which about 1.0 mSv is due to radon exposure [6,7]. The problem of radon emission has attracted considerable attention worldwide. Nationwide radon surveys and case-control studies on the association of radon with cancer risk have been conducted in many countries. Human exposure to radon and its daughters comprise about 55% of the total ally cause lung cancer [11]. Concentrations of Radon in air are usually measured in picocuries per litre (pCi/L) in the U.S., however, places like western Europe, they use the regular Becquerel per cubic meter (Bq/m^3). By a simple way of explanation, 1 picocurie is equal to 0.037 Bq; subsequently, 1 pCi/L is equivalent to 37 Bq/m^3.

Attentions were drawn on Radon owing to its detrimental health effects on humans. Since it occurs in nature, humans have always been exposed to radon and its daughters. Now it accounts for nearly half or more of the total average population exposure to ionizing radiation from natural and artificial sources [6,7,12]. Radon gas is present everywhere, it enters buildings from different sources such as building materials (e.g. clay bricks, gravels), water supplies and outdoor air. Study shows that winter and rainy seasons have been marked relatively with elevated indoor radon compared to summer [13].

Research revealed how radon progeny's concentration is commonly represented in form of working levels (WL). One WL is said to be expressed as any combination of short-lived radon daughters in 1 litter of air that results in the ultimate release of 1.3×105 million electron volts of alpha energy [14]. The concentration of short-lived daughters will increase provided a particular volume of radon is supplied until an equilibrium point is reached, at such the rate of decay of each daughter will equal that of the radon in question. Under these conditions a particular unit (pCi/L) of radon will give rise to 0.01 WL definitely. Studies shows that these conditions do not hold in general: Considering our homes, the equilibrium fraction is approximately 40% which means there will be 0.004 WL of progeny 7 for each pCi/L of radon in air as reported by National Academy Press in US (NAP, 1999). In a similar expression, a term called Cumulative radon daughter exposures are simplified and measured in working level months (WLM), a unit which was designed for occupational applications. One can therefore conclude that exposure is proportional to concentration (WL) and time, with exposure to 1 WL for 170 hour being defined as 1 WLM. In attempt to relate interpretation from residential exposures expressed in pCi/L, research revealed that the fraction of time spent indoors is 70%. It follows that an indoor radon concentration of 1 pCi/L would on average result in an exposure of 0.144 WLM/y = (1 pCi/L) [(0.7) (0.004) WL/ (pCi/L)] (51.6 WLM/ WL-y) [14].

Building materials in use in our homes produce some radon; similarly building materials of certain types can act as significant sources of indoor radon. Such building materials have a combination of elevated levels of ^{226}Ra and a high porosity that allows the radon gas to escape. Examples are lightweight concrete made with alum shale, phosphogypsum and Italian tuff [15]. Radon also gets into our houses through water supply, flour drain, well and connecting pipes, sub pump, cracks in foundations, slab joint, porous cinderblocks, diffusion from the ground, gas appliances, even if they are properly vented, pressure-driven flow of air in the home (most important mechanism), water supply, especially from private wells [14,16]. The pressure-driven mechanism occurs when radon escaping the soil, encounters a negative pressure in the home relative to the soil. This pressure differential is caused by exhaust fans, kitchen, bathroom, and clothes dryers, rising warm air created by fireplaces, furnaces, ovens, stoves etc [16]. The United Nations Scientific Committee on the Effects of Atomic Radiation reported that most people are exposed to high radon gas in small buildings than in big buildings [17]. Looking at the relationship between inhabitants' safety to safe-culture of contractors at work in construction industries and the final project output of any building was established by an international body named United Nations Scientific Committee on the Effects of Atomic Radiation [6,7]. A conclusion was reached that the healthy state of the building is not directly proportional to health safety and convenience of the dwellers.

Review of Works

The distribution of radon concentration in public places and residential home has raised a major concern to many scientists which has resulted to the successful conduct of several researches to ascertain the safety of humans from the dangers of hazards associated with it in both public and residential areas. Studies have shown that direct exposure to radon gas and radiation in residential homes and public places are relatively low while others were proven to be high and needed attention on how it can be minimized and monitored. Health consequences of chronic low-level exposure are much more difficult to determined, however, Health Canada estimates that radon is linked to 1900 lung cancer deaths per year in Canada.

Olusegun, et al, [18] in a work: Radon Level in Nigeria University Campus determined the environmental level of radon in selected offices in the Obafemi Awolowo University, Ile-Ife. The study was conducted using Pro 3-series radon detector to determine the radon levels in randomly selected offices. The result revealed that the radon level obtained in the sampled offices ranged from 0.0 to 5.3 pCi/L (196 Bq/m^3). The median concentration of radon obtained from sampled offices was 0.9 pCi/L. Almost all (95 %) of the offices had radon levels within the 'permissible' reference level recommended by World Health Organization. Radon levels also showed a statistically significant decline with height of office building with the mean concentration of radon in offices located on the basement, ground floor and first floor being 1.54 ± 1.32, 0.99 ± 0.56, 0.63 ± 0.41 pCi/L respectively. The radon levels obtained in most assessed offices in Obafemi Awolowo University were found to be within the permissible reference levels.

Mark, et al. [19] in a work: Assessment of Indoor Radon Concentration Levels in Offices of University of Nigeria, Enugu Campus, Nigeria. Samples selected at random from offices in each of the five faculties in the campus, making a total of twenty surveyed offices. Electret Ion Chamber Technology ((EIC) E-PERMTM) was employed for the measurement of radon concentration in the offices. The result showed that, the average indoor radon concentration in the offices ranged between 2.5 Bq m^{-3} to 21.3 Bq m^{-3} with an arithmetic mean of 11.8 Bq m^{-3}. Indoor Radon levels in the offices were within acceptable safe limits.

In an article: Determination and Evaluation of Radiological Risk due to Indoor Radon Concentration Levels in Offices at a University Faculty in Ibadan South western Nigeria, Ojo, et al. [11] revealed the exposure to Radon (^{222}Rn) especially indoors, identified as an important factor that could result in a health hazard, particularly up ward threat of lung cancer. Measurements were made at 54 locations in five departments of the faculty. Indoor radon concentrations in these departments were found to vary from 39.70 to 126.77 Bqm^{-3} with an average mean of 65 ± 20 Bqm^{-3}. The results obtained showed variation with ventilation and type of building materials. The average indoor radon concentration obtained was below the indoor radon concentration action level (148 Bqm^{-3}) recommended by Environmental Protection Agency [20].

Oni, et al. [21] in a research: Estimation of Lifetime Fatality Risk from Indoor Radon in Some Offices in a Nigerian University. They measured indoor ^{222}Rn concentration levels at some offices in Ladoke Akintola University of Technology (LAUTECH) Ogbomoso, Nigeria. The performed investigation employed an active electronic radon gas detector, safety Pro3 (model HS71512) between February and July 2011. The result showed that the average radon concentration is 26.3±4.17 Bq/m^3. This value was converted to an annual effective dose of 0.13 mSv/y and lifetime fatality risk of 9.94×10G6. The research showed that some values were higher than values reported safe some countries but smaller than the world average value and below the acceptable action level.

In an article, Measurement of Radon Concentration in Selected Houses in Ibadan, Nigeria. Indoor radon was measured in mud and brick houses within the selected locations. Fifty houses were considered within three Local Government Areas. A radon monitor type (RAD7) by Durridge Company was used for assessment. A distance of 100 to 200 m between houses in all the locations was maintained. The mean radon concentration measured in Egbeda was recorded to be 10.54 ±1.30 Bqm^{-3}; Lagelu was 16.90 ± 6.31 Bqm^{-3} and OnaAra was 17.95 ± 1.72 Bqm^{-3}. The mean value of the annual absorbed dose and annual effective dose for the locations were recorded as 0.19 $mSvy^{-1}$ and 0.48 $mSvy^{-1}$ respectively. The radon concentration for only one location (Ono-Ara local government) was found to have exceeded the recommended standard limit. The overall average indoor radon concentrations in the three local governments were found to be lower than the world average value of 40 Bqm^{-3} [13].

Evaluation of indoor radon concentration in some residential buildings made of different building materials within Okrika local Government Area, in Rives State, Nigeria, was investigated using a Corentium Digital Radon Detector. The report showed maximum mean value of the indoor radon concentration to be 19.36 ± 2.26 Bq/m^3 for mud houses; with minimum mean value of 09.35±0.78 Bq/m^3 for houses made of cemented solid blocks, lucked floor with ceramic tiles, had an overall mean of 11.70 ± 3.28 Bq/m^3. The values were below the limit (200 - 600 Bq/m^3) recommended by ICRP for residential buildings respectively. Values of the computed annual absorbed dose measured ranged from 0.24 ± 0.01 to 0.49 ± 0.03$mSvy^{-1}$, with an average mean of 0.30 ± 0.08 $mSvy^{-1}$. This is lower than (3-10) $mSvy^{-1}$ limit recommended by ICRP [17].

A research “Outdoor Radon Concentration in the Township of Ado-Ekiti Nigeria [11]” was conducted using a Solid State Nuclear Track Detectors (CR-39). The annual effective dose of radon and its progenies to the residents was calculated from the results of the measurement. The concentrations of radon varied between 2.22 and 92.50 Bqm-3 with an overall mean of 29.57 Bqm^{-3}. The annual absorbed dose was found to range from 0.09 to 3.81 mSv y^{-1} with an average measurement of 1.18 mSv y^{-1}. The estimated annual effective dose to lung ranged from 0.22 to 9.14 mSv y^{-1} with an average of 2.88 mSv y^{-1}.

Comparative Survey of Radon-222 Level in Some Residential Houses in Barkin-Ladi Local Government Area, Plateau State, Nigeria was yet another significant assessment to better knowledge of radon level. The radon activity concentrations were measured in some selected resident houses in Barkin-Ladi and its environs. Most residential houses were built on rocks with cement block, burnt bricks and mud. The concentration of ^{222}Rn was determined with the help of Safety siren pro radon gas detector. The result showed that the concentrations of ^{222}Rn for houses built on rock ranges from 173Bq/m^3 to 222Bq/m^3 and for houses built on levelled ground, the ^{222}Rn concentration ranges from 177Bq/m^3 to 218Bq/m^3. The values obtained when compare with the world average were found to be lower than that of the allowed limits in some communities and above the acceptable safe limits in some communities [22].

Olaoye, et al. [23] in “Residential Indoor Radon Assessment in the Vicinity of some Dumpsites in Lagos, Nigeria” took it to a dump site also. In their expository quest, Eight (8) dumpsites (4 dormant and 4 active dumpsites) were considered. Detectors were exposed in houses randomly selected up to 50 between 0-100m away from the dumpsites selected. Within the interval of 3 months, the detectors were exposed for radon gas and etched in an acid. Radon concentrations were recorded, ranged from 24.00±4.86 to 656.00±131.20 Bqm^{-3} in the active dumpsites. Mean concentrations were recorded as 120.3±24.0, 257±51.4, 179.8±33.6, and 131.5±19.4, respectively in Oke-Odo, MRF, Olusosun, and Solus-3. The dormant sites on the other hand had concentration ranged from 16±3.2 to 931±186.3 Bqm^{-3} having means of 194.17±38.80, 206.75±41.33, 223.25±44.6985Bqm^{-3}, and 334±66.85Bqm^{-3}, respectively in Oke-Afa, Solus-1, Solus-2, and Solus-4. The annual effective dose assessment and cancer risk measured in the active and dormant dumpsites were (3.60 mSv, 8.97 per million person-yearly) and (4.53 mSv, 12.47 per million person-yearly). They find out that these values were relatively higher than the safe level. In conclusion, they suggested that the residents of building in the vicinity of the dumpsites may likely be at higher risk of contracting lung cancer owing to continuous radon exhalation from the dumpsite.

A comparative study of the indoor radon concentration of different building types; such as glass house, bricks and basement house structures was done to evaluate sustainable radon level using radon detector (RAD7) machine in a work titled “Monitoring of radon concentration for different building types in Covenant University, Nigeria”. The mean radon concentration for glass house, brick house and basement house were 14.96, 10.74 and 144.61 Bqm^{-3} respectively. Glass house radon concentration figured out ranged from 11.03 to 17.46 Bqm^{-3}. The radon concentration measured ranged from 6.62 to 20.85 Bqm^{-3} for bricks house structure. Basement structure radon concentration ranged from 15.75 to 614.52 Bqm^{-3}. It was observed from the study that the mean radon concentration measured from the basement structure was above the recommended limit by a factor of 4. The estimated annual effective doses were 0.377, 0.271 and 3.644 $mSvy^{-1}$ for glass, brick and basement houses, respectively [13].

In another work, “Determination of Excess Relative Risk of Radon from Residential Buildings in Some Selected Cities in South-western, Nigeria” by Olukunle, et al. [24]. A total of 210 residential buildings fully furnished, having almost a prototype form of covering materials for walls, ceilings and floors in some cities in South-western Nigeria were investigated with the help of RAD7 radon detector. Similarities between buildings covering materials were (i): paint, carpet; (ii): paint fibre board, plastic tiles;

(iii): ceramic tiles for walls, (iv): ceilings and (v): floors respectively. The research outcome indicated that: the mean indoor radon concentration measured ranged between 54.03Bqm^{-3} to 65.01 Bqm^{-3} for all the combined investigated from one to another were found to be higher than the world recommended average value of 40 Bqm^{-3} however lower than the recommended action level of 200 Bqm^{-3} set by International Committee on Radiological Protection (ICRP). This result crystallises the risk of developing lung cancer from exposure of radon in residential buildings investigated. The building materials used, the topography, the geology and the rainfall distribution within the city may be responsible for the variation recorded. As obvious, the consequences of high concentration are grievous especially within the residential buildings where accumulation of same is unavoidable. The excess relative risks as measured in the research increases cumulatively with age up to 54 years and declines discontinuously for ages 55 and above for both the duration and concentration models used. At age 75 and upward, there was no noticeable difference in the rise in death rate between the duration and concentration models adopted.

Relative Impacts

Radon been a colourless and odourless inert gas, emanates from soil –its major source, and decays into radioactive metal ions by α-decay in air [25]. The internal exposure of humans to nuclear radiation due to inhalation of radon constitutes about 50% of the worldwide average annual effective dose of 2.4 mSv y^{-1}. As a gas, it may escape into the air from the material in which it is formed or host, and since Uranium and Radium occur widely in soil, rocks and water, Radon gas is ubiquitous outdoors as well as indoors; the air that we inhale contains Radon. When inhaled, it penetrates into the lungs emitting damaging α particle. Radon as a noble gas is rapidly exhaled when breathed in: however, radon progeny mixed with other molecules in air and with dust particles, aerosols or smoke from within and without, and readily deposit in the airways of the lung in human. While deposited there, the progeny emit ionizing radiation in the form of alpha particle, which damage the cell lining the airways (ACS, 2010 and EPA, 2009). The continue deposit and interaction of such high energy particles with the lungs leads to its damage and incidence of lungs cancer [24]. Similar report has it that when inhaled, radon decay products (polonium-218 and polonium-214, solid form), unattached or attached to the surface of aerosols, dusts, and smoke particles, become deeply lodged or trapped in the lungs, where they can radiate and penetrate the cells of mucous membranes, bronchi, and other pulmonary tissues [18].

The adverse effects of exposure to radon are caused primarily by damage due to alpha-particle as mentioned. Radon particles have sufficient energy to ascend, penetrate human tissue and damage cells (ACS 2010). Study revealed that there are two ways radon daughters successfully enter the human body; either through inhalation or ingestion. It is also believed from research that the ingesting is not a danger in the presence of food in the stomach regardless of the food substances, even thickness not exceeding 1.5 mm can stop most of alpha particles generated from the disintegration of same radon and its daughter nuclides [19]. The possible effect were said to depend on exposure level and duration. The most sever effect from high radon exposure is an upward trend of lung cancers reported in our hospitals today (EPA 2009).

In 2006, the American Cancer Society estimated 8 million homes in the United States had radon levels risen drastically (ACS 2010). The U.S. Environmental Protection Agency (EPA) also estimated that approximately 6 million homes have concentrations of radon above 4 picocuries per liter (pCi/L) (EPA 2009).

It was also reported that over 50 % of the average individual radiation dose comes from exposure to radon decay products. Two of the radon decay products, Polonium-^{218} and Polonium-^{214}, account for vast majority of the radiation exposure to lungs. Exclusive measurements of radon concentrations in dwelling places and homes show that although concentrations may vary widely, radon is universally present, raising concerns that the observed rise in lung cancer cases among the general public could be as a result of radon exposure, especially those who spend a lot hours indoors [23].

It was also experimentally revealed that radon at any level has potential to cause genetic disorder [24]. Some Radon progenies (^{218}P0 and ^{214}Po) react with the biological tissue and cause damages to the cells and even DNA and chromosomes degenerating to diverse health problems. The degree of concentration of indoor radon depends exceptionally on many factors such as the geological and geophysical orientation of the area, building materials for construction, meteorological variation, and outdoor radon concentration among others. This has weighty meanings to the little variance recorded as depreciable values of concentration in some dwelling and residential places reported above [26,27].

The missing critical factor to be considered which is building homes without radon resistant features has exposed more people to radon than ever before [28]. Uranium and Radium in the soil are considered to be some of the paramount source of indoor radon concentration, although some building materials especially quartz and cement affords a significant contribution to the level of natural radioactivity in closed places [29]. Radon concentrations in dwellings also depend on meteorological and geological conditions, construction materials and ventilation in place, experts revealed how critical these are for a Radon safe society [30]. UNSCEAR reported that, the slightly elevated radon levels, found in most homes is considered inconsequential or at least not more hazardous than other normally acceptable risks set by international organizations. This however isn't a shield from taking responsibility by concerned bodies. A significant fraction of homes have what some authorities considered to be unacceptable levels of indoor radon [20].

Early discovery and knowledge of the dangers awaked some nations of the world like The United States of America and other developed countries, identified the health risk this gas poses to humans and are developing mitigating measures to keep exposure levels low; on the contrary the story is different in many developing countries like Nigeria. Radon is only known to few people, and there is limited documented research yet on its health hazards in Nigeria. Only in recent was several efforts have been in place to measure, monitor and control the uncertain level particularly in our dwelling places. A thorough search of the literature suggests that Nigeria has insufficient records of its radon emanation levels either at the level of home or at work places [18].

Summary

Strategic control measures peculiar to different nations of the world are in place, nevertheless, Radon Action Levels (RAL) for dwelling places in many countries are set in the range of 200–600 Bq/m^3 as recommended by ICRP [31-33]. Also, the World Health Organization proposed a reference level of 100 Bq/m^3 to minimize health hazards due to indoor radon exposure. This in no small measure has helped in checkmating excesses and likelihood of underestimation of the dangers associated with the exposure. Similarly, becoming more knowledgeable of potential risk, possible hazards and safety alertness of building structures has gone a long way to minimize or eliminate risk factors as reported by several researchers Gallucci Raymond, Javadi & Komjani, Kyere, et al. [13].

In a more stable, efficient and effective measure, there should be implementation of radon sustainability operational structures in all the buildings and proper awareness with supportive policies and regulations. This will fight a block of mitigate radon off shot and sustainability of safe radon concentration level in all the new and possibly existing buildings, proper aeration of the building structures, most especially the basement house should be enforced in the country.

Conclusion

Results of the average lung cancer risk obtained at different study locations which happened to be one of the cardinal areas of concern shows that there is no known threshold concentration below which radon exposure presents no risk and so, critical steps towards sustenance should be top on the priority. Overview of this review suggests that to a reasonable extend, dwellings and residences in Nigeria appear safe from the possible hazards associated with radon exposure as at the time of this review. However, continue monitoring is strongly recommended for variations of several factors and introduction of environmental pollutants are likely possibilities worthy of note.

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