# MEASUREMENT OF ENVIRONMENTAL EXPOSURE TO RADON IN SOME OFFICES OF THE FACULTY OF SCIENCE, AHMADU BELLO UNIVERSITY ZARIA USING RAD7

BY

**MUHAMMAD JADABABAKANO**

DEPARTMENT OF PHYSICS,
FACULTY OF SCIENCE,
AHMADU BELLO UNIVERSITY, ZARIA
NIGERIA.

NOVEMBER, 2016

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BY

**Muhammad JadaBABAKANO,B.Sc (UNIMAID) 2010**
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DEPARTMENT OF PHYSICS,
FACULTY OF SCIENCE
AHMADU BELLO UNIVERSITY, ZARIA
NIGERIA

NOVEMBER, 2016

## DECLARATION

I declare that the work presented in this thesis entitled **"MEASUREMENT OF ENVIRONMENTAL EXPOSURE TO RADON IN SOME OFFICES OF THE FACULTY OF SCIENCE, AHMADU BELLO UNIVERSITY ZARIA USING RAD7"** has been carried out by me in the Department of Physics, and supervised by Dr. A.S Arabi and Dr. Y.I Zakari. To the best of my knowledge, no part of this thesis was previously presented for another degree or diploma at this or any other Institution. Where other peoples work has been quoted, it is duly acknowledged and referenced.

| | | |
|---|---|---|
| (Name) | (Signature) | (Date**)** |

## CERTIFICATION

This thesis entitled **"MEASUREMENT OF ENVIRONMENTAL EXPOSURE TO RADON IN SOME OFFICES OF THE FACULTY OF SCIENCE, AHMADU BELLO UNIVERSITY ZARIA USING RAD7"** by Muhammad Jada Babakano meets the regulations governing the award of the degree of Masters of Science (Radiation Biophysics) of the Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

| | | |
|---|---|---|
| **Dr. A.S Arabi** | _____ | _____ |
| Chairman, Supervisory Committee | | |
| (Name) | (Signature) | (Date) |
| **Dr. Y.I Zakari** | _____ | _____ |
| Member, Supervisory Committee | | |
| (Name) | (Signature) | (Date) |
| **Dr. Y.I Zakari** | _____ | _____ |
| Head of Department | | |
| (Name) | (Signature) | (Date) |
| **Prof. K. BALA** | _____ | _____ |
| Dean, School of Postgraduate Studies | | |
| (Name) | (Signature) | (Date) |

## DEDICATION

I dedicate this research work to my beloved parents Alhaji Babakano Aliyu and Hajiya Binta Babakano Aliyu. May you live a long and prosperous life.

## ACKNOWLEDGEMENT

First and foremost I would like to thank ALLAH the Almighty for the protection, guidance and making this work a reality.

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## ABSTRACT

This study determined the radon concentration measurements and the corresponding annual effective dose rates in some offices of the Faculty of Science, Ahmadu Bello University, Zaria-Nigeria. The method adopted is a 2-day, sniff rapid recovery radon measurement protocol for short term measurement using Statistical analysis tools that track concentration averages and uncertainties. Radon levels were sniffed in each of the offices within the studied area using an electronic radon detector, RAD7. The activity concentration of radon in some of the offices were found to be low which ranges from 102Bqm$^{-3}$ to 136Bqm$^{-3}$ while in some other offices radon levels are found to be high. Higher values found ranges from201Bqm$^{-3}$ to 276 Bqm$^{-3}$. The average value found within the studied area is 165 Bqm$^{-3}$. Most of the results obtained are within the world standard limits of 200 Bqm$^{-3}$ given by ICRP (1994). The effective dose was evaluated based on the concentration of the radon gas and the time spent indoors. The annual effective dose rate (indoor) found within the study area ranges from 0.44 to 1.18 mSvy$^{-1}$with an average of 0.74mSvy$^{-1}$. The results found are below the ICRP recommended effective dose action levels of 3-10 mSvy$^{-1}$. Our results showed that most of the offices were found with indoor radon concentrations below the action level provided by the International Commission on Radiological Protection of 200 Bqm$^{-3}$ while some few offices have results higher than the action level of 200 Bqm$^{-3}$ which indicates a radiological health hazard when they are not mitigated. However, the relatively high concentrations in some offices can be reduced by increasing the natural ventilation in the offices by or supply the offices with suction fans to pull out the radon inside them. The results obtained indicate that the indoor radon concentration was significantly affected by ventilation channels.

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# CHAPTER ONE

## 1.0 INTRODUCTION

### 1.1 Background Radiation

Radionuclides have been in existence since the beginning of time. They are present in the air we breathe, the water we drink and the food we eat. They are in the soil in which we grow our crops, in the building materials we use to construct our houses, in our hospitals and in our industries. These radionuclides give rise to a cloud of background radiation that eternally engulfs us, never to escape from sources of radionuclides and subsequently background radiation can be categorized as either artificial/anthropogenic or natural. Anthropogenic radiation results from some form of human activity such as the use of nuclear medicine, nuclear power generation, military operation, agricultural, mining and industrial activities as well as use of consumer products such as smoke detectors. Radiation from these sources is generally small as its function is regulated. Its application is restricted in such a way that a balance is struck between the benefits it offers and the risks it imposes on people and the environment. Nonetheless, uncontrolled exposure can occur for example in the event of nuclear accidents as happened following the Chernobyl nuclear disaster of 1986 in the former USSR and the 2011 Fukushima disaster in Japan.

Natural sources of radiation consist primarily of cosmic rays and terrestrial radiation. Cosmic rays are a type of radiation that comes from outer space consisting primarily of charged particles (85 % protons, 12 % alpha particles and 3 % heavier nuclei). The earth‘s atmosphere absorbs some of this radiation and in the process produces secondary radiation of reduced intensity consisting of subatomic particles such as muons and electrons. At higher altitudes where the air is thinner, less cosmic radiation is absorbed compared to lower altitudes where the air is thicker. For this reason, people who live on

higher elevations or fly on commercial airplanes are exposed to cosmic radiation of higher intensity than those who, for instance, live at sea level. Air is thickest at sea level and here cosmic radiation consists mainly of muons at 68 %, electrons make up 30 % while protons are reduced to less than 1 %.

Terrestrial radiation on the other hand comes from radio nuclides that occur naturally in rock and soil. $^{238}U$, $^{232}Th$, their decay products and the singly occurring $^{40}K$ contributes the greatest fraction of this radiation (UNSCEAR, 2000). Terrestrial radio nuclides are of particular concern with respect to radiation protection due to their ability to migrate to other compartments of the ecosystem such as indoor air, groundwater and crops, and eventually to the human body thus adding to the total radiation dose. Data on this aspect of radiation exposure is limited in Nigeria, relative to that on exposure due to radionuclide concentration in soil.

Table 1.1 shows the contribution of different sources of radiation to the total global annual radiation dose (UNSCEAR, 2008). From the UNSCEAR 2008 data, natural sources are responsible for over 80 % of the radiation dose contributing an average annual exposure of 2.4 $mSvy^{-1}$. The largest proportion of this exposure (about 42 %) comes from inhalation of indoor air (UNSCEAR, 2008). In most parts of the world, rock and soil serve as the main building materials and as they naturally contain trace amounts of $^{238}U$ and $^{232}Th$, they can be important sources of radioisotopes $^{222}Rn$ (radon) and $^{220}Rn$ (thoron) in their respective decay chains, which are considered responsible for the inhaled dose. Being gases, the isotopes can escape from the building material where they are formed and into indoor air. Their movement and exhalation from the building materials, and eventual build-up in indoor air is dependent on the nature of the building material and the level of ventilation of the building (Al-Sharif, 2001; El-Taher et al., 2013).

**Table 1.1: World average annual radiation exposure to ionising radiation (UNSCEAR, 2008).**

| Radiation source | Exposure (mSv/y) |
|---|---|
| Inhalation of air | 1.26 |
| Ingestion of food & water | 0.29 |
| Terrestrial radiation from ground | 0.48 |
| Cosmic radiation from space | 0.39 |
| **Subtotal (natural)** | **2.4** |
| Medical | 0.6 |
| Consumer items | - |
| Atmospheric nuclear testing | 0.005 |
| Occupational exposure | 0.005 |
| Chernobyl accident | 0.002 |
| Nuclear fuel cycle | 0.0002 |
| Other | - |
| **Subtotal (artificial)** | **0.61** |
| **Total** | **3.01** |

Radon has long been recognized as a cause of lung cancer, and in 1988, the International Agency for Research on Cancer, IARC and the World Health Organization classified radon as a human lung carcinogen (WHO, 2009). This classification was based on a review of evidence from experimental data on animals and from epidemiological studies of underground miners exposed to relatively high radon and radon progeny concentrations. Furthermore, indoor radon has been identified as an important public-health problem, estimated by the United States Environmental Protection Agency, U.S EPA to cause about 21,000 American lung-cancer deaths per year (EPA, 2012). Moreover, numerous public health agencies rank residential radon

exposure as the second leading cause of lung cancer after cigarette smoking (EPA, 2012; WHO, 2009).

On the other hand, it is well known that human exposure to radioactivity comes mainly from natural sources, radon and its progeny breathed in the air being responsible for more than 50% of the annual dose received from natural radiation (UNSCEAR, 2000).

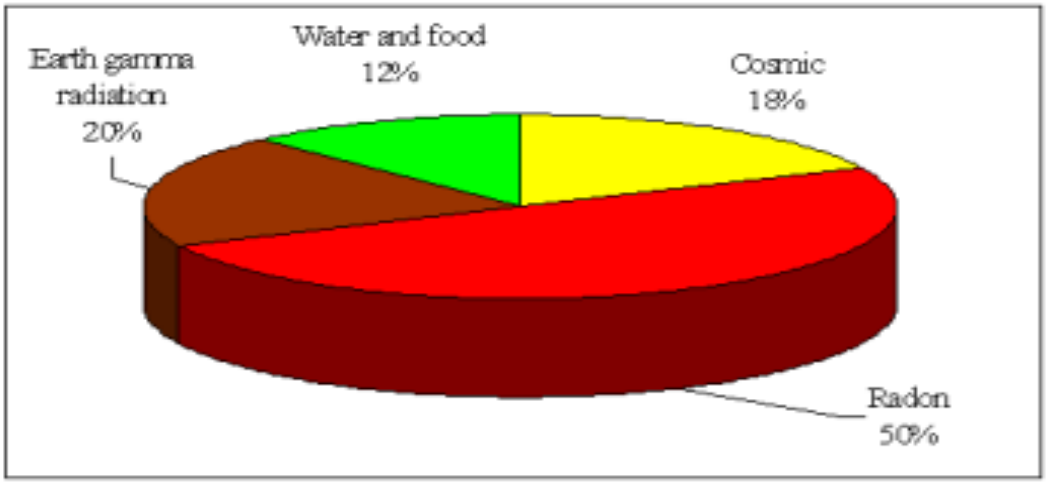



Figure1.1: This figure shows the sources and average distribution of natural background radiation for the world population (UNSCEAR, 2000).

Radon, $^{222}Rn$ is a noble radioactive gas generated by disintegration of radium, $^{226}Ra$ which is present in soil, water and building materials (Appleton, 2007). The indoor radon level is strongly influenced not only by the radium in the underlying soil (or walls), but also by the life style and building type used, that is to say by the natural or mechanical exchange of indoor air with outdoor air (Nazaroff and Nero, 1988).

Exposures to radon and its short-lived decay products at concentrations typically found indoors, deliver a dose to the sensitive cells of the lung corresponding to a dose of 1.3 mSv $y^{-1}$out of the total effective dose of 2.4 mSv $y^{-1}$ (UNSCEAR, 2000). However, due to the enhanced children sensitivity, The ICRP estimates that for groups of younger pupils, the risk coefficient for lung cancer from inhaled radon daughters is about a

factor of two (age < 20 years) to four (age < 10 years) higher than that for adults (Malanca et al., 1998).

$^{222}$Rn is a naturally occurring radioactive gas that is part of the Uranium decay series. Its presence in the environment is associated mainly with trace amounts of uranium and its immediate parent, radium-226 ($^{226}$Ra), in rocks, soil and groundwater. About one-half of the effective doses from natural sources are estimated to be delivered by inhalation of the short lived radon progeny. Owing to this fact, radon is the most popular subject of studies on environmental radioactivity. The presence of high level of radon in indoor environment constitutes a major health hazard for man. Radon and its daughters are a significant health threat linked to thousands of preventable death each year (Boschi *et al.*,1998). Radon may cause about 15,000 lung cancer deaths per year in the US (BEIR VI 1999, NAS- USA). The World Health Organization (WHO) says radon causes up to 15% of lung cancers worldwide. The United States Environmental Protection Agency (U.S. EPA) estimates that as many as eight million homes throughout the country have elevated levels of radon gas (Kumar *et al.,* 2011). In Europe, radon in the home accounts for about 9% of deaths from lung cancer and 2% of all deaths from cancer (Darby *et al.,* 2005).

$^{222}$Rn occurs in the environment mainly in the gaseous phase. Consequently people are mainly exposed to radon through breathing air. Background levels of radon in outside air are generally low but in indoor locations, radon levels in air may be higher. In homes, schools and other occupational buildings, radon levels may be high due to the reasons of improper ventilation channels in the buildings. The fact that radon is present in indoor air has been known since 1950's and research on its effects on human health started since 1970's. The danger of radon exposure in dwellings received more widespread public awareness after 1984, as a result of the case of Stanley Watras, an

employee at the limerick nuclear power plant in Pennsylvania U.S.A. Mr Watras set off the radiation alarms on his way into work for two weeks straight while authorities searched for the source of contamination. They were shocked to find that the source of radon was very high in the basement and it was not related to the nuclear plant. The risk associated with living in watras house was estimated to be equivalent to smocking 135 packs of cigarette every day (The radon council 2001). The European Union recommends that mitigation should be taken starting from concentrations of 400 $Bqm^{-3}$ for old houses and 200 $Bqm^{-3}$ for new ones (Boyd David .R 2008). The national council on radiation protection and measurement (NCRP) recommends action for any building with a concentration higher than 8Pci/L (300 $Bqm^{-3}$).

Natural radiation accounts for the majority of human exposure to radiation with radon decay product being the largest contributor in spite of the increased use of man-made radiation in industries, medical centres and scientific research establishments (Tso and Li, 1987). The earth's crust contains trace amount of $^{238}U$ and $^{232}Th$ which decay to $^{222}Rn$ (radon) and $^{220}Rn$ (thoron) gas respectively (Tso and Li,1987). Most of the radon to which people are exposed emanates from soil and rock. The other sources of significance are building materials, potable water, and natural gas (UNSCEAR, 1993).

The link between residential radon and lung cancer among the general public is not unequivocal (Letourneau *et al.*, 1994*;* Rousteenoja *et al.*, 1996). However, in order to forestall risks of cancer among the general public, many national authorities and some international organizations (Ahmed, 1993; Colgan and Gutierrez, 1996) have already adopted reference levels for radon in air and water.

The radiation dose from radon inhalation constitutes a major part of the total natural background dose received by man. The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) reported that nearly half of dose received by

humans from natural sources is due to radon inhalation and its progenies in the indoor environments. The lower air pressure indoors gives rise to a pressure-driven flow of radon-rich soil air into the indoor environment through cracks in the bottom slab and cellar walls. Certain rocks and soil, such as some granites and shales, contain more uranium than others. However, ground with moderate contents of uranium and/or radium can also give high indoor radon concentrations (Hubbard*et al.*, 1991).Building materials made from soil (e.g. clay bricks) or rocks always contain uranium and radium. The content is usually low, but some materials may have high concentrations of radium-226, for example alum shale concrete and building materials made of volcanic tuff, gypsum waste etc. The radon concentration can reach several thousand Becquerel per litre (Bq/l) in water from drilled wells in regions with granite rock, for example in Finland and Sweden (SALONEN.L. 1994).This contributes to indoor radon and to exposure via ingestion. The inflow depends largely on the building construction and the permeability of the ground materials. According to some information published by the United Nations Scientific Committee on effects of atomic radiation (UNSCEAR 2008 report) inhalation of radon and its daughters, are the most important factors in happening natural human exposure from natural radioactive sources.

Radon's half-life of 3.8 days is long enough for it to enter into the indoor environment and to cause an increase in its indoor concentrations, but it is relatively too long to be inhaled into the respiratory tract and to irradiate cells (Yamada *et al.*,2006). Radon's unique properties as a naturally occurring radioactive gas have led to its use as a geophysical tracer for locating buried faults and geological structures, in exploring for uranium, and for predicting earthquakes. Radon has been used as a tracer in the study of atmospheric transport process. There have been several other applications of radon in meteorology, water research and medicine.

$^{222}$Rn's lifetime is considered long relative to the other isotopes. This is of significance, since radon is formed in the ground or building materials and has significantly more time to diffuse through the material into the indoor environment in buildings or the outdoor atmosphere. The radon formed relatively close to the earth's surface can diffuse through the soil or be driven by pressure gradients.

Underground miners have historically been exposed to very high concentrations of radon, especially in uranium mines. Nowadays the levels in most mines have been reduced substantially. The general population in several regions is exposed to high concentrations of radon due to the geology, building construction and domestic habits. Indoor concentrations of 10 000 Bq/m$^3$ and higher have been found in dwellings, for example in Finland (CASTRÉN, O. 1987), Sweden (SWEDJEMARK, G.A. & MJÖNES, L. 1983)and Germany (KELLER, G. 1990).Other buildings may also have high concentrations. EPA recommends testing all schools for radon. As part of an effective indoor air quality(IAQ) management program, schools can take simple steps to test for radon and reduce risks to occupants. If high radon levels are found, immediate measures should be taken to reduce it. The only way to know if elevated radon levels are present in an environment is to test. Radon has become a topic of growing significance as research shows that high concentrations of radon can have a negative impact on human health. Due to this reason IAEA in collaboration with WHO organized a workshop in April 2014 which was attended by European member states to review national radon programmes (Plate 1.1).



Plate 1.1: Pictorial view of a conference on Radon held in Vienna 2014 at the IAEA's headquarters.

Radon levels in buildings will generally provide a useful indication of areas in which elevated occupational or environmental exposures to radon might be expected since it is likely that the radon prone areas for above ground workplaces will coincide with the radon prone areas for domestic exposures.

The magnitude of radon concentration indoors depends primarily on a building construction and the amount of radon in underlying soil. The concentration of radon and its decay products show large temporal and local fluctuations in the indoor atmosphere due to meteorological variables. (Ramachandran, 1990 and Singh, 2001) reports thatradon gas enters from the soil beneath the house/school buildings through cracks and openings in the foundation. Air pressure inside a building is sometimes lower than pressure in the soil under the foundation. Because of this difference in pressure, a

building acts like a vacuum, drawing radon inside from the soil. Typical cracks and openings include joints where the floor meets the wall, expansion joints in the floor, openings in the floor for pipes and wires, and hollow masonry walls that penetrate the floor. Elevated radon-activity concentration in soil air, often combined with fractures and cracks in the bedrock, or extensive layers of gravel underneath buildings, lead to high radon-levels in cellars of dwellings located in areas hitherto not associated with radon-problems. The "stack-effect" due to temperature difference between the indoor- and outdoor air was identified as a frequent mechanism for further increasing radon-levels inside dwellings (UNSCEAR, 1988).

In many countries, radon is the second most important cause of lung cancer after smoking. The proportion of lung cancers attributable to radon is estimated to range from 3 to 14%. Significant health effects have been seen in uranium miners who are exposed to high levels of radon. However, studies in Europe, North America and China have confirmed that lower concentrations of radon such as those found in homes, also confer health risks and contribute substantially to the occurrence of lung cancers worldwide. The risk of lung cancer increases by 16% per 100 $Bq/m^3$ increase in radon concentration. The dose-response relation is linear – i.e. the risk of lung cancer increases proportionally with increasing radon exposure. Below is the chat for the result of deaths per year in the United States due to different causes with radon being the highest contributor.

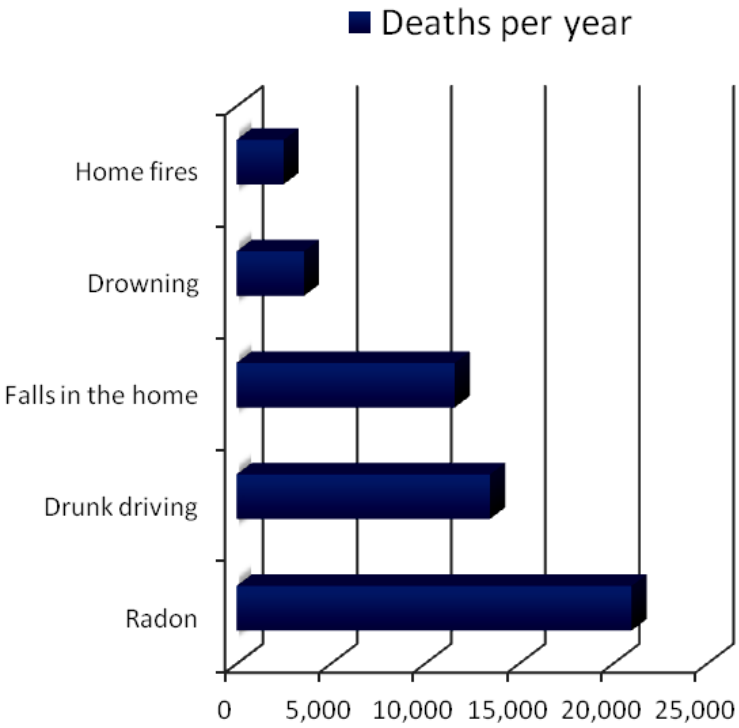



Figure1.2: Comparison of deaths from various causes in the United State (U.S EPA, 2003).

### 1.2.1 Area of Study

The area studied were selected offices in six departments and the dean's office of the faculty of science, Ahmadu Bello University Zaria, Kaduna state.

### 1.2.2 Geology of the study area

The study area is in Samaru, Zaria which falls within the semi-arid region of Nigeria (Harold 1970). It is underlain by Gneisses, Migmatite and Meta-sediments of Precambrian age which have been intruded by series of granitic rocks of late Precambrian to lower Palaeozoic age, (McCurry, 1976).

However, some portion of the study area fall within region underlain by older Granite that belongs to a single batholith called Zaria Granite batholith, while the remaining portion is underlain by Gneissic rocks. Details on contact of Zaria batholith with schist and gneissic rocks are given in the works of Webb (1972).

## 1.3 Statement of the Research Problem

Until the late 1970s, radon and its progenies were regarded as radiation health hazards only encountered in the mining and milling of uranium, this dramatically changed as a result of widespread indoor measurements of radon in parts of the world. Attention to the problem of radon exposure and the associated health risks has thus been growing around the world. Today radon and its progeniesare known to be carcinogenic in a high radon concentration places, especially if poorly ventilated and if the radon input from its sources is high, such as mines, caves, cellars, ancient tombs and energy conserved air tight houses. The inhaled radon and its progenies pass from lungs into the blood and body tissues and may indicate many types of soft tissue cancers such as lung cancer, kidney cancer and prostatic cancer. Henshaw*et al*., (1990) has reported that indoor radon exposure is associated with the risk of leukaemia and certain other cancers, such as melanoma and cancers of the kidney and prostate. Some radon may be dissolved in body fats, and its daughter products transferred to the bone marrow. There is a positive association between coronary heart disease and radon exposures where an elevated risk of mortality from coronary heart disease was observed among miners with accumulative radon exposure exceeding 1000 Working Level Month (WLM). Radon daughters $^{218}$Po and $^{214}$Po could be regarded as potential carcinogenic agents for the induction of skin cancer. It is also reported that the combination of inhalation of radon gas and smoking increases the risk of lung cancer (Villeneuve and Morrison,1997). Because most of the offices in A.B.U Zaria are old buildings made from granitic and other geologic materials known to be harbouring some levels of Radio nuclides, and also of the old nature of the buildings, Cracks in the buildings may have evolved over time which is known to be radon entry points into the building. There is no documented evidence that

this study has been carried out in A.B.U hence the need for such research work becomes significant.

It is therefore, very vital to understand the information on radon build up in offices where people spend some appreciable amount of time 8hr/day (8am-4pm).

### 1.4Justification

$^{222}$Rn, a radioactive inert gas is a large component of the natural radiation that human beings are exposed to which can pose a threat to the public health when it accumulates in poorly ventilated residential and occupational settings, (offices). About half of the total radiation effective dose to the general public is due to the irradiation of the lungs by alpha particles following the inhalation of $^{222}$Rn decay products. In this research work, a study of the radon build up in some offices within the faculty of science, A.B.U Zaria and the determination of the associated dose levels are carried out. This type of work has never been done in A.B.U. The buildings are made of geologic materials that are good sources of radon parent. Buildings in A.B.U Zaria are old as such cracks may have developed over time which is known to be good entry points for radon.

### 1.5Aim and Objectives

This study aims to carry out a survey of environmental exposure to radon within some offices of the faculty of science, Ahmadu Bello University, Zaria using an electronic radon detector (RAD7), with the following objectives:

i. To measure the In situ indoor $^{222}$Rn concentration in some randomly selected offices of the faculty of science, A.B.U Zaria on and off working hours.
ii. To assess the radiological hazard/effect associated with the measured $^{222}$Rn concentrations.
iii. To establish a baseline data for $^{222}$Rn concentrations within office buildings.

## 1.6 Scope and limitation of the Research

This study was limited to the determination of $^{222}Rn$ concentrations (build up) in offices within faculty of science A.B.U Zaria on and off working hours using RAD7 electronic radon detector only. The limitation of this research work is that only RAD7 analytical equipment is used for the radon measurement.

# CHAPTER TWO

## 2.0 Literature Review

### 2.1 Introduction

Several studies on indoor and outdoor radon have been performed in various places around the world. Background radiation might be occurred from radioactive elements such as $^{40}K$, $^{232}Th$, $^{238}U$and $^{226}Ra$, which can be found in many natural rocks (Arafa,2004).

Most of the identified radio nuclides belong to one of three decay series, each of these group starts with an unstable parent radionuclide that decays into a radioactive daughter nuclide, which in turn decays into another radionuclide (Human Health Fact Sheet, 2005). The three groups of radio nuclides are referred to as the $^{238}U$ decay series, $^{232}Th$ decay series and $^{235}U$ decay series. Indoor air can be considered the medium for transport and interaction for radio nuclides within soil, rocks, sediments, and atmosphere (Michael, *et al,* 2007). Nearly all radio nuclides found in indoor air are naturally occurring (Cothern, *et al,* 1990) and the elements of concern in air which may pose health risks, are $^{226}Ra$ and $^{222}Rn$ (Marques, *et al,* 2004). Both $^{226}Ra$ and $^{222}Rn$ originate from the decay of uranium that is present in most rocks (Lamontagne, *et al,* 2008). However, radon comes from the alpha decay of radium, which can be hazardous to human health. Radium is a common radionuclide in the environment and it is the parent of radon (Michael, *et al,* 2007). $^{222}Rn$is chemically inert, colourless, odourless radioactive gas formed through the decay of $^{226}Ra$ (Bonotto, *et al,* 2002, and Amrani1999), and both are members of $^{238}U$ decay series, which is generated from the decay of the uranium presence in rocks, soil, and water (Badhana, *et al,* 2010). On the other hand, radon has been considered dangerous and cancer causing by WHO (Kozlowska, *et al,* 1999). Researchers from countries such as India (Badhana, *et al,*

2010), Saudi Arabia (Alabdula'aly, 1999), Iraq (Al-Hamidawi, et. al 2012),Germany (Kiisters, *et al,* 2009), Lebanon (Kobeissi*et al,* 2014) and Algeria (Amrani, 1999) have reported negative effects of radiation from radon.

Uranium and thorium isotopes are primary natural radio nuclides that undergo decay into other radioactive radio nuclides. The first member of each series has a very long half-life and the final product of each series is a stable isotope of lead (Martin, 2006, Harb, *etal,* 2008, and Michael *et al,* 2007). Uranium series starts with $^{238}$U and ends with $^{206}$Pb and the daughters of concern particularly in this work is $^{222}$Rn.

**2.2 Radon**

In 1900, Friedrich Dorn discovered the emanation in the uranium series that eventually became the well-known gas Radon. Radon with symbol Rn and atomic number 86 is a chemically inert, odourless, colourless, and the heaviest noble gases (Nagda, 1994), formed through the radioactive decay of $^{226}$Ra (Harris *et al,* 2006). Radon has 36 radioactive isotopes and isomers which range in mass number from 198 to 228 (NRC, 1999). There are three naturally occurring isotopes of radon, each associated with a different radioactive decay series that begins with the radio nuclides $^{238}$U, $^{232}$Th, $^{235}$U, respectively (Nagda, 1994). The radon isotope of greatest interest is $^{222}$Rn having a 3.84 days half-life (Marques, *et al,* 2004, Shizuma, *et al,* 1998, Kralik, *et al,* 2003, Legarda, *etal,* 2010, and Amrani, *et al,* 1999), and is part of the Uranium ($^{238}$U) decay series (Farid, 1996, Lee, *et al,* 2006, and Marques, *et al,* 2004). The second radon isotope is $^{220}$Rn produced naturally from ($^{232}$Th) thorium decay series and called *thoron,* which has a half-life of 55.6 seconds (Nagda, 1994). However, the dose from $^{220}$Rn is small compared to $^{222}$Rn, because of the time for $^{220}$Rn diffusing from underlying rocks and soil (Al-Doorie, *et al,* 1993). The third radon isotope is $^{219}$Rn, which is produced from $^{235}$U(actinium decay series) and called *actinon,* which has a half-life of 3.96 seconds,

and does not contribute to human radiation exposure due to, both low abundance of $^{235}U$ and the short half-life of $^{219}Rn$ (Nagda, 1994). Therefore, consideration can be focused on just $^{222}Rn$ because of the long half-life compared with other isotopes (Oliveira *et al,* 2001).

$^{222}Rn$ decays by emitting 5.49 MeV alpha progenies, which are $^{218}Po$, and $^{214}Po$, and they contribute over 90% to the total radiation dose received from exposure to radon (Marques, *et al,* 2004). However, there are two essential characteristics of $^{222}Rn$ that makes it radiologically active even though radon is a Noble gas. Once it is produced from $^{226}Ra$, a $^{222}Rn$ atom is relatively free to move, provided it first reaches the material's pore space. After reaching the pore space, $^{222}Rn$ transport may occur by molecular diffusion and/or through flow of the fluid in the pore space (Nazaroff*et al.,* 1988). The second important characteristic of $^{222}Rn$ is that it decays toα- and β- emitting radio nuclides that are chemically active and relatively short-lived. The four radio nuclides following decay of $^{222}Rn$ are also radioactive, and they are metals and have half-lives of less than 30 minutes (NRC, 1999), so that, if deposited they are likely to decay to $^{210}Pb$ before removal. Because the decay products of $^{222}Rn$ are electrically charged when first formed, they tend to attach themselves to dusts that are normally present in the atmosphere (Nazaroff*et al*., 1988).

### 2.2.1 Indoor radon sources

The primary sources of indoor radon are the soil adjacent to the building which contain amount of radium that is fixed in the soil grains. Buildings in general tend to have a slightly lower indoor air pressure compared to that in the ground. This is normally sufficient to draw soil gas from the ground into the building (Abd El-Zaher and Fahmi, 2008).

Radon gas can enter a building through many mechanisms but the most significant are diffusion and pressure driven flow from the ground beneath and immediately adjacent to the building, provided suitable entry routes are available. Entry routes for radon gas are usually cracks and holes in floors and walls, and gaps around service pipes and cables in the buildings (Bodansky*et al*., 1989). In most dwellings with elevated indoor radon concentrations, pressure-driven flow is recognized as the dominant mechanism of ingress (Ahmed and Haji, 2012).

Radon from domestic water and gas supplies and from building materials can contribute to the indoor radon concentration in a building, but in most cases the contribution is considered minor when compared with that from the soil gasses in the ground on which the building is constructed (George, 2009).

Building materials generally contribute fairly little to the total indoor radon concentration, except when the radium content in it is above the normal values. All building materials are derived from soil and rocks that contain trace amount of radioactive nuclides occurring in the earth's crust.

Many of the buildings materials such as bricks or concrete are sufficiently porous and emanate radon that enters into the indoor air. Materials which are not derived from the earth's crust, such as wood, tend to have a very low radium concentration (Al-Mosa, 2007).

Radon might enter into buildings via the water supply. With municipal water or surface reservoirs, most of the radon volatilizes to air or decays before the water reaches buildings, leaving only a small amount from decay of uranium and radium. Dissolved radon is easily released into the air when the water is used for showering, cleaning, and other daily purposes in homes (Mehral*et al*., 2010).

The most important factors controlling radon migration and accumulation in buildings include: 1) the transmission characteristics of the bedrock, including porosity and permeability; 2) the nature of the carrier fluids, including carbon dioxide gas, surface water, and groundwater; 3) weather; 4) Soil characteristics, including permeability; 5) house construction characteristics, and 6) life style of house occupants (Appleton, 2007).

### 2.2.2 Health risk from radon

Human beings are exposed to radiation from many sources, which may come from NORM (Naturally Occurring Radioactive Materials)that is present in food, water, and the atmosphere. The biggest percentage of natural radiation comes from a radioactive gas called radon, and the term radon usually refers to $^{222}$Rn. However, the global average for natural radiation that human beings are exposed to is 2.4 mSv/y and radon contributes about 1.2 mSv/y (Gorur, *et al.*, 2011). Exposure to radiation from all sources can make changes to the sensitive biological structures, both directly by the transfer of energy to the atoms within the tissue or indirectly by the formation of free radicals. Since the most sensitive structure in the cell is the deoxyribonucleic acid (DNA) molecule (Ottawa, *et al.*, 2009), therefore, radiation can damage the DNA, either through direct interaction between radiation and DNA cells or by the creation of chemically reactive free radicals (Wakeford, 2004). However, radon can be a public health concern (NRC, 1999, and Amrani, *et al.*, 1999), in both inhalation and ingestion (Vinson, *et al*, 2009). There are two pathways through which radon can affect people, either directly, from inhalation of radon's daughters resulting from the decay of $^{222}$Rn or indirectly, through drinking water (ingestion), (Cothem, *et al,* 1990, Kozlowska, *et al,* 2010, Vinson, *et al,*2009, Choubey*et al,* 2001, Amrani, *et al,* 1999, Abdallah*et al,* 2007, Farid, 1996, Oliveira *et al,* 2001, and Ouabi, 2009). $^{222}$Rn itself, is not a problem when

it is inhaled, because it will be exhaled, unless it decays into progenies in the body (Al-Doorie, *et al*, 1993). Moreover, the two diseases of concern are stomach cancer from ingestion of radon and lung cancer from inhalation of radon's daughters (Cothern, *et al*, 1990).

According to Bonotto, *et al*, (2002), exposure to radon and its decay progenies are associated with increased lung cancer, while ingestion of radon in water is associated with the increased risk of several internal organs cancer mainly the stomach. In addition, radon itself can be inhaled but most of it is exhaled therefore, it does not accumulate in the lungs, but some of the radon can reach to the interior regions of the lung which can transfer to blood and dispersed throughout the body, therefore, radon and its decay products formed inside the body can deliver radiation dose to tissues and organs (NRC, 1999). Moreover, USEPA has estimated that inhalation of radon and its products, is the second leading cause of lung cancer after smoking.

### 2.3 Review of Previous Works

Many studies on outdoor and indoor radon measurement have been performed in various places around the world. Some of which were summarised and discussed below;

Abidabojassim *et al*,.(2013) carried out a measured Radon concentrations in drinking water at 42 locations in Al- Najaf city, using RAD-7 radon monitoring system of Durridge company USA. The annual effective dose for all samples of drinking water was estimated by equations depending on UNSCEAR organization. It was found that the radon concentrations in samples of the studied area were varied from (2.43±0.87Bq/$m^3$) to (225.50±12.65Bq/$m^3$), while the mean annual effective dose of Ingestion and Inhalation varied from (0.017 μS/y) to (1.64 μS/y) and (0.08 μS/y) to (0.70μS/y) respectively. Therefore, they concluded that the drinking water in Al-Najaf

city is safe as far as radon concentration is concerned upon comparing with international reference level of 500 Bq/$m^3$ and 1 mSv/y for annual effective dose.

Ajay Kumar *et al,*.(2014) carried out a research on Radon and its daughter products which are regarded as a major source of radiation exposure and recognized as one of the health hazards for mankind. They assessed the levels of radon concentration in some drinking water samples and radon exhalation rate in soil samples belonging to some locations of Kapurthala district, Punjab. Radon concentrations were measured using RAD7 electronic detector and radon exhalation rate were measured using CAN technique. The alpha sensitive solid state nuclear track detectors (LR-115 Type II) were used in the CAN technique. The radon values vary from 0.03Bq/L of KaulTalwandi village to 0.20Bq/L of Kapurthala. The Radium concentration in soil samples were found to vary from 2.40 Bq/kg to 4.65 Bq/kg and the values of exhalation studies ranges from 2.96 $mBqkg^{-1}hr^{-1}$ to 5.74 $mBqkg^{-1}hr^{-1}$. The values are found to be within the safe limits as recommended by the International Commission on Radiation Protection (ICRP) and World Health Organization (WHO). The results revealed that these areas are safe from the health hazard point of view as far as radon is concerned. A good correlation has been observed between radon and its exhalation rate.

Ajay Kumar *et al,*.(2012) carried out a study on Indoor radon measurements in some dwellings of Rajasthan and Delhi areas using LR-115 type II Cellulose Nitrate films in the bare mode. The Radon values vary from 22.30 $Bqm^{-3}$ to 219.3 $Bqm^{-3}$ in the Delhi region and 55.76 $Bqm^{-3}$ to 107.80 $Bqm^{-3}$ in the Rajasthan areas, which is well within the recommended action level. The Radon concentration in water samples of some locations of Rajasthan and Delhi have also been measured using RAD7. The radon values vary from 0.581 Bq/L to 1.54 Bq/L in the Delhi region and from 0.03Bq/L to 3.45 Bq/L in the Rajasthan region. The Radium concentrations in soil samples have been found to

vary from1.74 Bq/kg to 5.03 Bq/kg in the Delhi region and from 1.97 Bq/kg to 2.91 Bq/kg in the Rajasthan region. The values are found to be within the safe limits. Some of the physico-chemical properties such as pH, conductivity, hardness and total dissolved solids (TDS) have been reported in water samples. The results revealed that these areas are safe from the health hazard point of view as the radioactivity is concerned. A weak correlation has been observed between radon and radium.

Alenezy *et al*,.(2014) carry out measurement of Radon concentrations in Aljouf, Saudi Arabia where he based his work on the fact that $^{222}$Rn being the most important source of natural radiation and is responsible for approximately half of the dose received from all sources. Most of this dose is from inhalation of the $^{222}$Rn progeny, especially in closed areas. Portable alpha particle detector, RAD7 was used for $^{222}$Rn measurements inside the main campus of Aljouf University at Saudi Arabia in order to estimate the effective dose to the occupants from $^{222}$Rn and its progeny. The values of annual effective doses for radon inhalation by the inhabitants were found to vary in the range 0.08 - 0.80 mSv/y, with a mean of 0.4 mSv/y. These results are lower than the value of 1 mSv/y recommended by ICRP, 1990. The variation of dose relationship from indoor radon in lung tissue is calculated and tabulated. In addition to environmental value of the present survey, the results are considered to be essential in analysing any data for future activities in this field.

Badhana *et al*,.(2010) conducted his work based on study which represent the set of measurement for radon concentration levels in ground water using electronic radon meter (RAD7) and for assessment of indoor radon using the RL-115 Type 2 plastic track detectors. The measurement has been taken for the environs and ground water of national institute of technology, Jalandhar. The radon concentration in drinking water has been found to vary from 2560 to 7750 Bq/m$^3$. The pH value for ground water under

study has also been measured and it varies from 6.96 to 7.0 with an average value of 6.99. No correlation has been observed between pH value and radon concentration values for groundwater. The calculated indoor radon concentration values vary from74 to 190Bqm$^{-3}$ with an average values for the absorbed dose are in range 1.26-3.24mSv/y, which is well below the action level.

Garba *et al.,* (2013) investigated $^{222}$Rn concentration in some groundwater (well and borehole) samples from various locations of Zaria and environs including Sabongari, Danmagaji, Samaru and Bomo have been investigated for their radon concentrations by liquid scintillation counter. The concentration of $^{222}$Rn in open well water was found to vary in the range (0.77-28.87) Bq/L and (2.32-48.80) Bq/L for borehole with a geometric mean of 12.43 and 11.16 Bq/L for borehole and well sources respectively.Their results showed that $^{222}$Rn concentration in borehole sources is higher than that of well water sources and were both greater than maximum concentration limit (MCL) of 11.1Bq/L set by USEPA,1999.

Shafique *et al.,* (2012) conducted a research on Monitoring of $^{222}$Rn/$^{220}$Rn concentrations at the work places of Muzaffarabad, Azad Kashmir. Thoron ($^{220}$Rn), due to its-short half-life of 55.5s is unable to travel far from its point of generation. A number of studies report indoor radon ($^{222}$Rn) concentration in different locations of Azad Jammu and Kashmir (2012), while no study reports indoor $^{220}$Rn concentration. The CR-39 based passive alpha track detectors were used for the measurement of $^{222}$Rn and $^{220}$Rn concentrations at different selected workplaces of Muzaffarabad. $^{222}$Rn and $^{220}$Rn concentration were measured simultaneously. Alpha track detectors (ATD) were enclosed in a thin polyethylene film to exclude $^{220}$Rn (closed detector) while the other Alpha track detectors (ATD) has a coarse metal grid and cloth covering the large entry port allowing for rapid radon gas ingress. The results showed that the measured $^{222}$Rn

concentration varied from 18.7 $Bqm^{-3}$ to 160.2 $Bqm^{-3}$ with an average value of 67.0 ± 3.0 $Bqm^{-3}$. Whereas the $^{220}Rn$ concentration varied from 14.7 $Bqm^{-3}$ to 100.4 $Bqm^{-3}$ with an average value of 50.0 ± 2.0 $Bqm^{-3}$. Preliminary results show that indoor $^{220}Rn$ concentration is significantly higher and should be taken into consideration while calculating the dose due to radiation of natural origin.

Yamada *et al.,* (2006) carried out his research work on Indoor radon measurements in cave dwellings of the Chinese loess plateau in Gansu province, where previously the Laboratory of Industrial Hygiene (LIH), China, and the U.S. National Cancer Institute (NCI) had conducted an international collaborative epidemiological study. The LIH–NCI study showed an increased lung cancer risk due to high residential radon levels, and estimated the excess odds ratio at 100 $Bqm^{-3}$ to be 0.19 (Wang *et al*., 2002). The present study used two types of newly developed passive monitors: One is a discriminative monitor for radon and thoron; the other is a selective monitor for thoron decay products. The arithmetic mean concentrations of indoor radon and thoron were 91 and 351 $Bqm^{-3}$, respectively. As reported by some previous study in Shanxi and Shaanxi provinces (Tokonami*et al*., 2004), the presence of high thoron concentration was confirmed and thoron was predominant over radon in the cave dwellings. However, the mean equilibrium equivalent thoron concentration (EETC) was found to be much lower than expected when assuming the equilibrium factor of 0.1 provided by the UNSCEAR (2000) report. The effective dose by radon and thoron decay products was estimated to be 3.08 mSv/yr. It was significantly lower than the dose of 8.22 mSv/yr estimated from the measurements that did not take into consideration any discrimination between radon and thoron. Excess relative risk of lung cancer per Sievert may be much higher than the risk estimated from the LIH–NCI study, considering that discriminative measurements were not used in their study.

# CHAPTER THREE

## 3.0 MATERIALS AND METHOD

### 3.1 Materials

The materials used for this research work:

- RAD7 electronic radon detector
- RAD7 Printer Supplies
- Battery Charger and rechargeable batteries.
- Drying Tubes and Desiccant
- RAD7 Filters
- Vinyl Tubing Set (3ft x 3)
- Key span USB-19HS serial adapt

## 3.2Methodology

### 3.2.1Instrument description

The DURRIDGE RAD7(Fig. 3.1)employed in this work uses a solid state alpha silicon detector. A solid state detector is a semiconductor material (usually silicon) that converts alpha radiation directly to an electrical signal. One important advantage of solid state devices is ruggedness. Another advantage is the ability to electronically determine the energy of each alpha particle. This makes it possible to tell exactly which isotope (polonium-218, polonium-214, etc.) produced the radiation, so that old radon can be immediately distinguished from new radon, radon from thoron, and signal from noise. These techniques, known as alpha spectrometry, are a tremendous advantage in sniffing, or grab sampling applications. Very few instruments other than the RAD7 are able to do this. With the use of this particular radon detector (RAD7), it has the ability to distinguish between true, real-time continuous monitors, and other instruments and devices. With a continuous monitor, someone can be able to observe the variation of radon level during the period of the measurement. This can sometimes show big swings in radon concentration and may allow us to infer the presence of processes influencing the level. For us to get a good data, it is therefore important that there could be sufficientcounts to provide statistically precise readings.

The RAD7 being an electronic detector measures radon gas concentration. Radon daughters do not have any effect on the measurement. The RAD7 pulls samples of air through a fine inlet filter, which excludes the progeny, into a chamber for analysis. The radon in the RAD7 chamber decays, producing detectable alpha emitting progeny, particularly the polonium isotopes. Though the RAD7 detects progeny radiation internally, the only measurement it makes is of radon gas concentration. In short, the

RAD7 does not measure radon daughter concentrations (working levels), but radon gas concentrations.

Radon concentrations are determined by measuring the radioactivity of the radon or by measuring the radioactivity of the radon decay products. Instruments that measure radon decay products in the air are called "working level" monitors. Working level monitors sample air through a fine filter and then analyse the filter for radioactivity. The radon progeny are metal and they stick to the filter and are counted by a working level instrument. $^{222}Rn$, an inert gas, passes through the filter, so it is not counted in such an instrument. Therefore, a working level instrument measures the radon progeny concentration (polonium-218, etc.), in the air, but not the radon gas concentration.

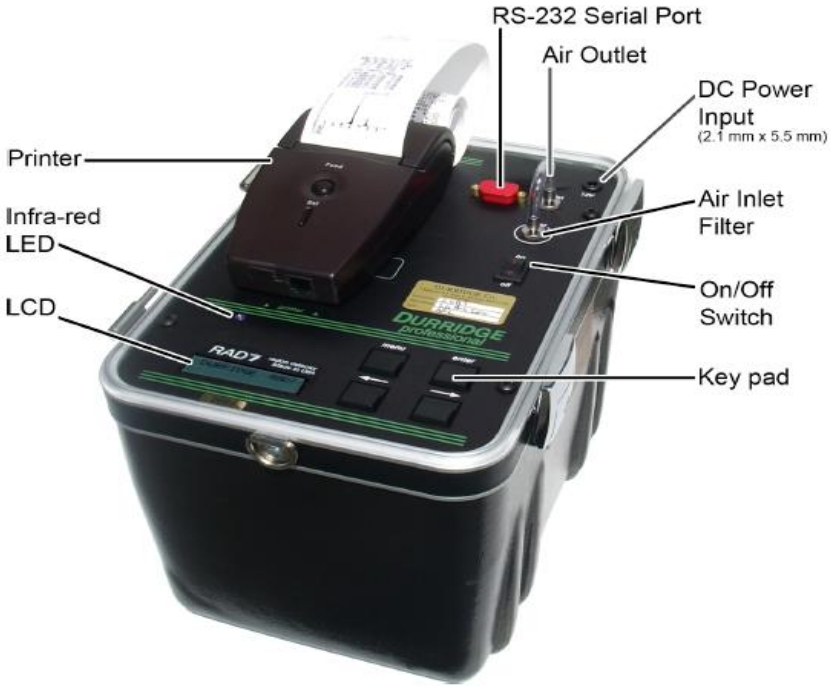



Plate 3.1: The RAD7 Electronic Radon Detector (DURRIDGE Company Inc. www.durridge.com).

### 3.2.2 Method

The method used for the measurement of indoor radon concentration in someselected offices of the faculty of science, Ahmadu Bello University Zaria is the continuous active radon sampling/sniffing using electronic radon detector RAD7.The detector is stationed at three different locations (corner, side and centre) in each of the offices. For each office, measurement is made over a period of 48hours; the lowest and highest readings are then recorded. Two regimes of data were recorded i.e. during working and after working hours. Where possible, the RAD7is connected to DC power to conserve and recharge the batteries. After setting up the detector carefully, the detector start a continuous test of radon in the office location.The detector is then allowed to work continuously until ready to take the results, and the readings are recorded automatically by the system.

The protocol adopted for the study is a 2-day, short term rapid sniff radon recovery measurement using RAD7 Statistical analysis tools that track average concentrations and uncertainties. Values recorded for radon levels within the study area during the measurement period of 48hours over twelve offices in the faculty are presented in table 4.1 and table 4.2 respectively.

The radon concentration was measured in 5minutes cycles for an average time of 48 hours (during and after working hours) in each office as the measurements period. The measurements were taken and recorded in the morning and in the evening (8am-4pm for working hours and 4pm-8am for after working hours). The average radon concentration was calculated automatically by the system (RAD7). Since the RAD7 detector has a printer attached to it, it prints out the results for every measurement period.

### 3.2.3 RAD7 Calibration test




Plate 3.2 shows a typical experimental setup of the RAD7 taking continuous measurement of the Zircon sand.

The plate (3.2) above gives the detailed experimental setup for RAD7 calibration tests. Two (2) grams of the zircon sand is placed in the sample container and the loop is setup as shown in plate 3.2. The setup is set on a protocol called sniff mode where both radon and thoron from the samples are sniffed into the detector chamber and their daughter nuclides ($^{216}$Po and $^{218}$Po) are detected. Each cycle of measurement took twenty four hours before the radon isotopes are evaluated and a total of five cycles (5 days) were carried out. This measurement was carried out with increment of weight of the zircon sand of 2grams until it reaches 10grams for the period of five days. This procedure was adopted to confirm the calibration of the machine which was achieved by having a straight line graph, in other words the calibration has not drifted therefore, the machine is found to be in its accurate form.

**Table 3.1: Activity Concentration of Zircon Sand**

| Days | Hours of measurement | weight of zircon sand (grams) | concentraion (Bq/$m^3$) |
|---|---|---|---|
| **1** | 24 | 2 | 1310 |
| **2** | 48 | 4 | 4840 |
| **3** | 72 | 6 | 11600 |
| **4** | 96 | 8 | 13800 |
| **5** | 120 | 10 | 18100 |

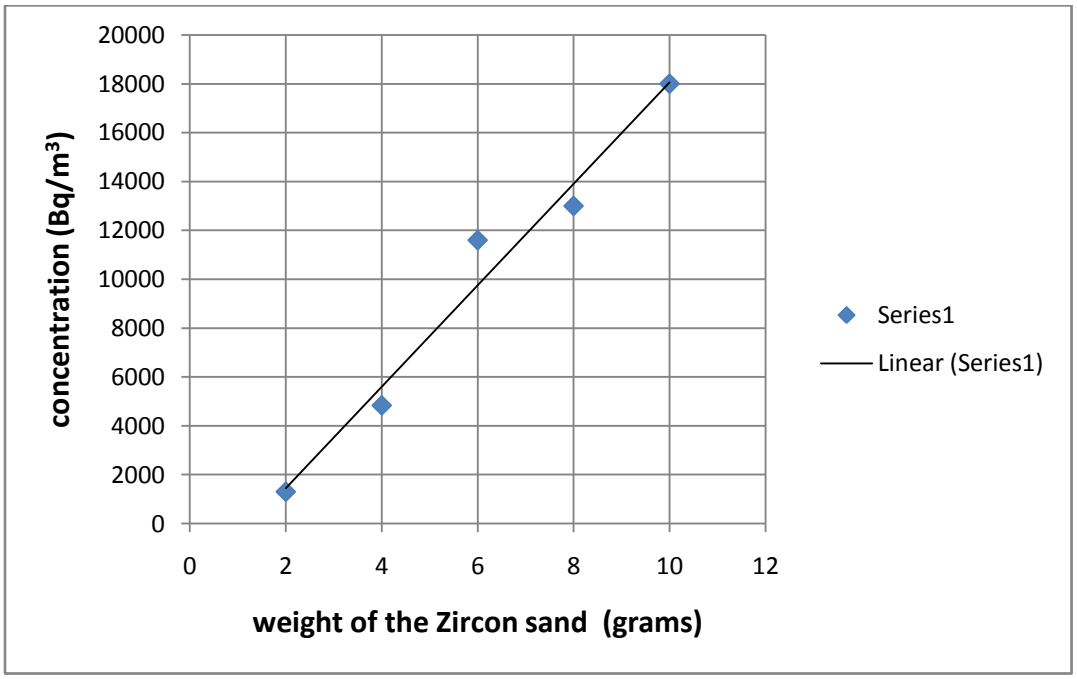



**Figure 3.1:** showing a straight line graph of the radon concentration in Bq/$m^3$ from zircon Sand to the weight of the sand in grams.

### 3.3.1 Radon measurement

In this study, RAD7® electric radon detector was employed for the evaluation of radon levels in the indoor air around some departmental offices of the faculty of science, Ahmadu Bello University, Zaria during and after working hours with the objective of ascertaining the levels of these gases emanating from the buildings, through cracks, subsurface materials within those areas. A calibrated portable continuous radon monitor type RAD7 (Durridge Company, USA) was used for this study; this radon measuring system can be operated either on battery or online electrical circuitry. The system also registers air temperature, parametric pressure and relative humidity. The laboratory drying tubes and desiccants are used in absorbing the air moisture before reaching the detector chamber. The measurements were carried out in a total of 29locations(offices) from 6 departments of the faculty of science, Ahmadu Bello University, Zaria. The six departmental offices and the dean's office were chosen on the basis of ease of access, hours spent on them, and age of the buildings, while handling the instrument every day during the measurement period.

For all runs, the RAD7 was put on a bare floor in the centre of the office as shown in figure 3.3.These offices were closed after working hours and usually opened during working hours, so due to the flow of ventilation during working hours, radon gas can escape there by reducing its indoor levels but after working hours when offices are left closed, radon gasusually accumulate to higher levels inside the offices.




Plate 3.3 shows a typical experimental setup of the RAD7 taking continuous radon measurement in one of the offices within the study area.

### 3.3.2Radon concentration units

The concentration of radon in the air is measured in units of picocuries per litre (pCi/L) or Becquerel's per cubic meter ($Bqm^{-3}$). One Bq corresponds to one decay per second. One pCi/L is equivalent to 37 $Bqm^{-3}$. The concentration of radon daughters is measured in units of working level (WL) which is a measure of the potential alpha particles energy per litre of air (Niren, 1994). Occupational exposure to radon daughters is expressed in working level months (WLM) and a working level month is equivalent to the exposure at an average concentration of 1 WL for 170 working hours (Wilkening, 1990). Measurement data are reported in either of the above units.

The United States Environment Protection Agency (USEPA) recommends reducing the concentration of radon in the air within a school building to below EPA's radon action level of 4 pCi/L that is equivalent to 0.016 WL and 148 $Bqm^{-3}$ (EPA, 1993;Al-Mosa, 2007).

### 3.3.3Working level month (WLM)

For Radon exposure; Working Levels (WLs) are any combination of the short-lived radon progeny in one litre of air that results in the ultimate emission/release of 1.3 x $10^5$ MeV of potential alpha particle energy. The cumulative exposure of an individual exposed to this concentration over a "working month" of 170 hours (2,000 working hours per year/12 months per year = approximately 170 hours per month) is defined as a "Working Level Month" (WLM). In this study, WLM was evaluated by assuming 2,000 hours are spent in the working environment (offices) per year as detailed below: (ICRP, 1994)

**(A) At home: assuming 7,000 hours spent indoors per year**

1 $Bqm^{-3}$ = 0.0156 mJ h $m^{-3}$

1 $Bqm^{-3}$ = 0.0044 WLM

1 WLM = 4 mSv

1 $mJhm^{-3}$ = 1.1 mSv

**(B) At work: assuming 2,000 hours work per year**

1 $Bqm^{-3}$ = 0.00445 mJ h $m^{-3}$

1 mJ h $m^{-3}$ = 1.4 mSv

1 WLM = 5 mSv

**Source:** ICRP Publication 65, Protection against Radon at Home and at Work

### 3.3.4 Estimation of the annual effective dose

It is a common practice in radon surveys to convert the radon concentration to radiation dose, and in case of school/offices surveyed; the annual effective dose for the staff/lecturers can be calculated. It has been reported that $^{222}Rn$ and its short-lived decay products accounted for about 1.3 $mSvy^{-1}$ out of the total effective dose of (2.4 $mSvy^{-1}$) from the natural sources (UNSCEAR, 2000). The effective dose in $mSvy^{-1}$ at any

location depends upon the occupancy factor. The occupancy factor for the staff of the Faculty of Science, A.B.U Zaria was calculated using the following equation:

40 h /wk. × 52 wks. /yr. = 2080 h /yr. (3.1)

So the offices occupancy factor (H) = 2080h/ 8784h = 23%.

The expected annual effective doses received by the staff of the surveyed area were calculated using equation 3.2 below, the UNSCEAR model (2000, 2009) (Nasir and Shah, 2012).

$$E = C_{Rn} \times H \times F \times D \times T \quad (3.2)$$

Where $C_{Rn}$: is the radon concentration ($Bqm^{-3}$)

H: is the occupancy factor (0.23)

F: is the equilibrium factor (0.4)

T: is hours in a year (8840)

D: is the dose conversion factor ($9 \times 10^{-6}$ m $Svh^{-1}$ per $Bqm^{-3}$).

# CHAPTER FOUR

## 4.0 RESULTS AND DISCUSSIONS:

The results obtained were presented and discussed in this chapter.Activity of the radioactive gas (radon) alone is not a determining factor but exposure time and ventilation conditions of these locations (offices). The main sources of radon within the scope of this research work are the soil gas and the building materials which were used for the construction of the offices.

**Table 4.1:Radon Activity Concentration during Working Hours**

| | | Radon concentration ($Bqm^{-3}$) | | |
|---|---|---|---|---|
| **S/NO** | **Location** | **Range** | **Mean** | **Std. Error** |
| 1 | Physics (P107) | 0.00-136 | 25.5 | 3.2 |
| 2 | Physics (GPA09) | 0.00-136 | 30.5 | 3.1 |
| 3 | Physics (P112) | 0.00-170 | 55.6 | 4.2 |
| 4 | Physics (GPA 08) | 0.00-205 | 72.2 | 4.3 |
| 5 | Physics (GPA082) | 0.00-203 | 83.1 | 4.2 |
| 6 | Physics (radiation pit) | 0.00-259 | 86.1 | 6.3 |
| 7 | Physics (GPA080) | 0.00-101 | 31.0 | 3.1 |
| 8 | Maths (M103) | 0.00-238 | 86.5 | 5.2 |
| 9 | Maths (CP LAB2) | 0.00-263 | 92.0 | 6.8 |
| 10 | Maths (CP LAB3) | 0.00-187 | 52.8 | 6.2 |
| 11 | Maths (CP LAB4) | 0.00-178 | 50.3 | 6.0 |
| 12 | Biology (C1.15) | 0.00-136 | 38.4 | 3.6 |
| 13 | Biology (C1.19) | 0.00-125 | 35.2 | 4.1 |
| 14 | Biology (C1.10) | 0.00-142 | 39.2 | 4.5 |
| 15 | Biology (C1.13) | 0.00-147 | 39.8 | 4.3 |
| 16 | Geography (GG1) | 0.00-201 | 47.1 | 4.1 |
| 17 | Geography (GG2) | 0.00-192 | 43.1 | 4.5 |
| 18 | Geography (GG2) | 0.00-197 | 46.1 | 3.1 |
| 19 | Deans office | 0.00-170 | 33.2 | 3.1 |
| 20 | Geology (GL 1) | 0.00-136 | 44.6 | 3.5 |
| 21 | Geology (GL 2) | 0.00-156 | 46.3 | 3.9 |
| 22 | Geology 3(GL 3) | 0.00-127 | 41.4 | 3.3 |
| 23 | Faculty office(GP6) | 0.00-165 | 34.6 | 4.1 |
| 24 | Faculty office2(GP7) | 0.00-127 | 33.3 | 3.7 |
| 25 | Faculty office3 (GP4) | 0.00-123 | 15.3 | 2.5 |
| 26 | Chemistry 1 (C101) | 0.00-204 | 67.2 | 5.0 |
| 27 | Chemistry 2 (C118) | 0.00-208 | 72.8 | 5.5 |
| 28 | Chemistry 3 (C116) | 0.00-194 | 67.8 | 5.0 |
| 29 | Chemistry 4 (C119) | 0.00-198 | 69.8 | 5.2 |

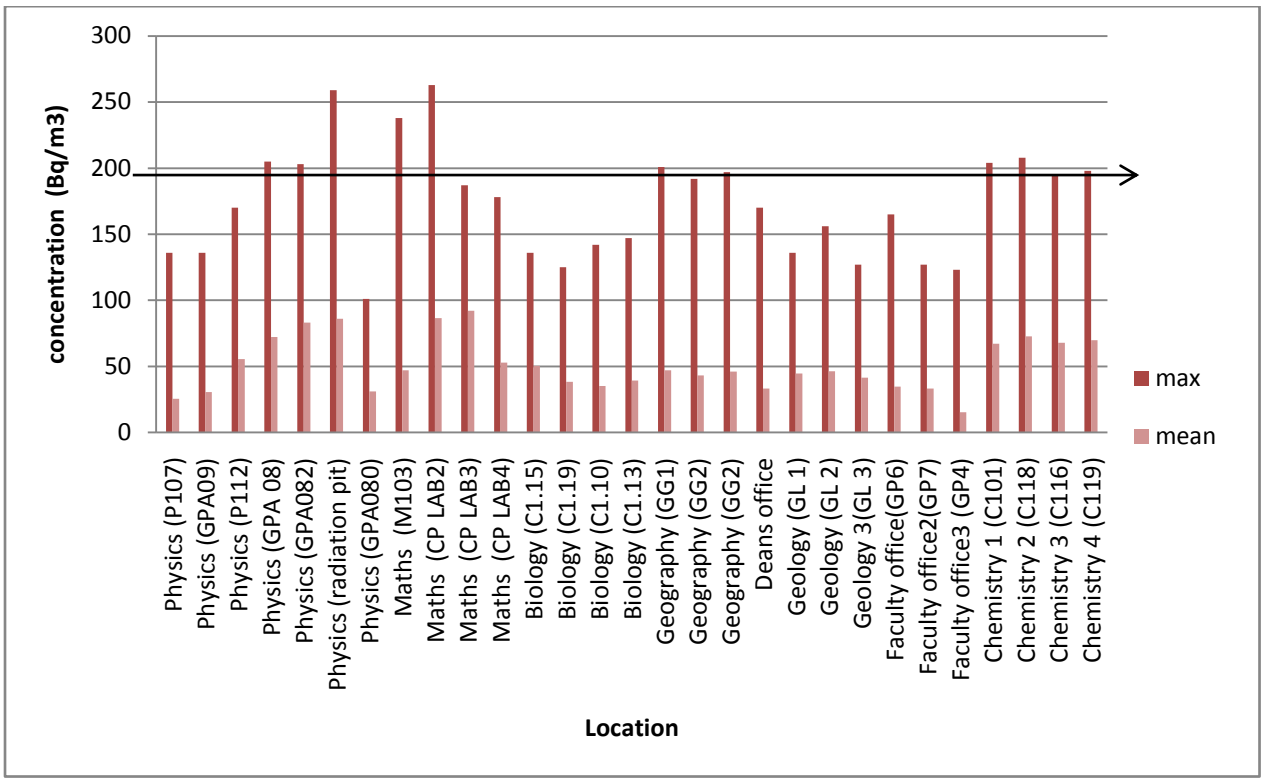



**Figure 4.1:** The chart representation of Radon measurement during working hours in some offices of the study area.

The results obtained in this work for the period of working hours as given in table 4.1 above, indicates that most of the offices are found with lower radon levels build up within them while some few offices are found with radon level concentrations higher than 200Bqm$^{-3}$ given as action level by ICRP as drawn by the arrow in the above chart given as Figure 4.1, these offices with higher radon levels found in them needs to be mitigated within two (2) years as recommended by Environmental and workplace health (Health Canada 2008).

Using some of the higher values that are greater than 200Bqm$^{-3}$ (201Bqm$^{-3}$, 204Bqm$^{-3}$, 205Bqm$^{-3}$, 208Bqm$^{-3}$, 238Bqm$^{-3}$, 259Bqm$^{-3}$and 263Bqm$^{-3}$) found in these offices of the faculty during working hours, a Working Level of 1.00, 1.02, 1.04, 1.19, 1.29 and 1.31

WLM was obtained which is far below the ICRP, EPA, NRC and USDOE value of 4WLM per year for radon.

**Table 4.2:Radon Activity Concentration after Working Hours**

**Radon concentration (Bq/m$^3$)**

| S/NO | Location | Range | Mean | Std. Error |
|---|---|---|---|---|
| 1 | Physics (P107) | 0.00-170 | 60.7 | 4.2 |
| 2 | Physics (GPA09) | 0.00-168 | 54.8 | 4.6 |
| 3 | Physics (P112) | 0.00-195 | 48.1 | 4.4 |
| 4 | Physics (GPA 08) | 0.00-220 | 82.4 | 4.9 |
| 5 | Physics (GPA082) | 0.00-223 | 87.1 | 4.7 |
| 6 | Physics (radiation pit) | 0.00-295 | 89.1 | 7.3 |
| 7 | Physics (GPA080) | 0.00-111 | 33.0 | 3.4 |
| 8 | Maths (M103) | 0.00-248 | 88.5 | 5.2 |
| 9 | Maths (CP LAB2) | 0.00-273 | 95.0 | 6.8 |
| 10 | Maths (CP LAB3) | 0.00-192 | 56.8 | 5.4 |
| 11 | Maths (CP LAB4) | 0.00-190 | 53.3 | 5.5 |
| 12 | Biology (C1.15) | 0.00-142 | 39.9 | 3.8 |
| 13 | Biology (C1.19) | 0.00-132 | 37.2 | 3.4 |
| 14 | Biology (C1.10) | 0.00-149 | 41.2 | 4.4 |
| 15 | Biology (C1.13) | 0.00-153 | 43.8 | 4.7 |
| 16 | Geography (GG1) | 0.00-211 | 49.8 | 4.5 |
| 17 | Geography (GG2) | 0.00-199 | 47.4 | 4.5 |
| 18 | Geography (GG2) | 0.00-199 | 46.8 | 4.4 |
| 19 | Deans office | 0.00-182 | 38.2 | 3.5 |
| 20 | Geology (GL 1) | 0.00-143 | 46.6 | 3.8 |
| 21 | Geology (GL 2) | 0.00-161 | 46.8 | 4.1 |
| 22 | Geology 3(GL 3) | 0.00-139 | 41.6 | 3.9 |
| 23 | Faculty office(GP6) | 0.00-169 | 35.6 | 4.2 |
| 24 | Faculty office2(GP7) | 0.00-139 | 33.6 | 3.7 |
| 25 | Faculty office3 (GP4) | 0.00-132 | 17.3 | 2.6 |
| 26 | Chemistry 1 (C101) | 0.00-214 | 69.2 | 5.0 |
| 27 | Chemistry 2 (C118) | 0.00-220 | 76.8 | 5.7 |
| 28 | Chemistry 3 (C116) | 0.00-198 | 69.9 | 5.3 |
| 29 | Chemistry 4 (C119) | 0.00-199 | 71.8 | 5.5 |

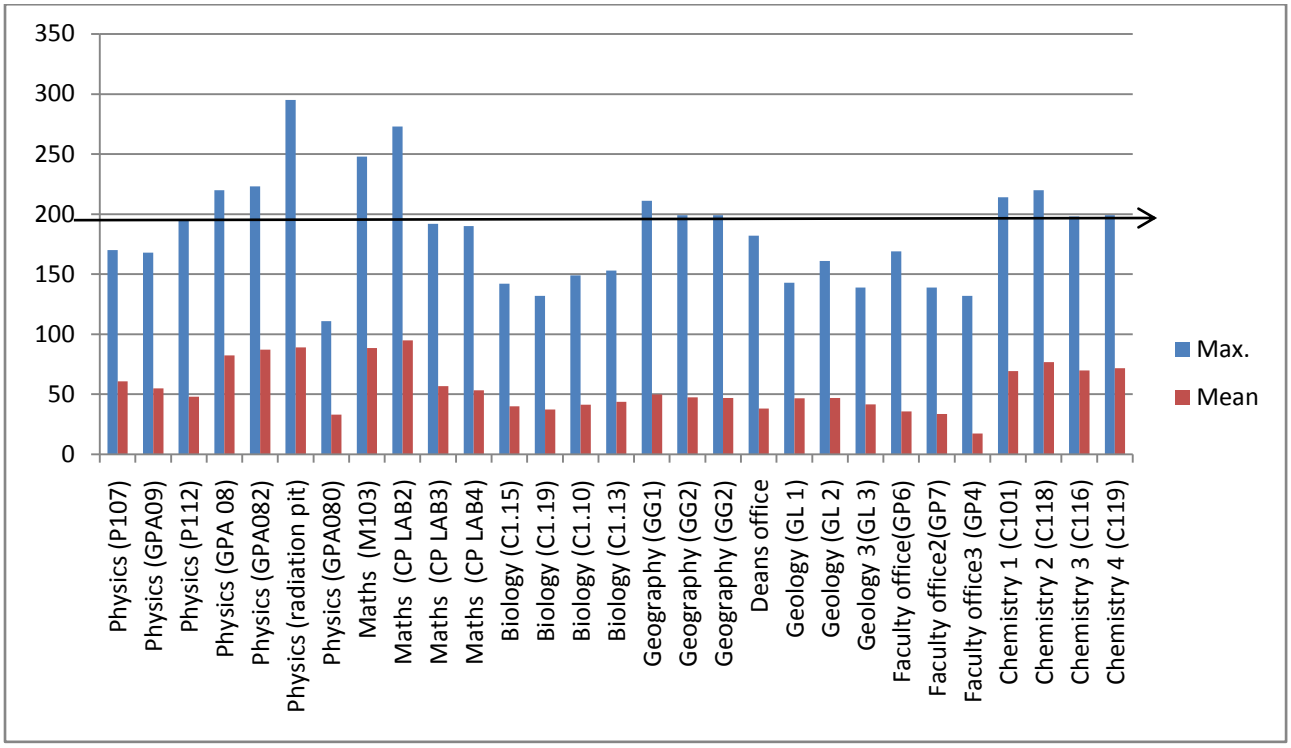



**Figure 4.2:** The Chart representation of Radon measurement after working hours in some offices of the study area.

Similarly, the results obtained after working hours as given in table 4.2 above indicates that some of the offices are found with lower radon levels build-up within them while some other offices are found with radon level concentrations higher than 200Bq/$m^3$ given as action level by ICRP as drawn by the arrow in the above chart given as Figure 4.2, these offices which are found with higher radon levels in them needs to be mitigated within two (2) years as recommended by Environmental and workplace health (Health Canada 2008).

Using the higher values (211Bq/$m^3$, 214Bq/$m^3$, 220Bq/$m^3$, 223Bq/$m^3$, 248Bq/$m^3$, 273 Bq/$m^3$ and 295Bq/$m^3$) found in these offices of the faculty after working hours, a Working Level of 1.05, 1.07, 1.10, 1.15, 1.24, 1.36 and 1.47WLM was obtained which is far below the ICRP, EPA, NRC and USDOE value of 4WLM per year for radon.

This particular study was carried out during winter season where radon build-up is mostly found to be high due to the fact that radon gas stick to the harmattan dust and

most offices are kept closed; therefore the relevance of the study during this period of the year becomes more appropriate.Radon concentration was observed to have slightly increased after working hours when windows of the offices and laboratories were closed/locked and ventilation within were lowest, even though since its cold/winter season most of these offices are always closed unless some people are coming in to the offices or going out from them. This indicates that ventilation channels affect the radon build-up within the scope of this particular work.

**Table 4.3: Comparison for the highest and lowest Radon activity concentration during and after working hours**

| | | **Radon concentration (Bq/m$^3$)** | | | |
|---|---|---|---|---|---|
| | | During working hours | | After working hours | |
| S/NO | LOCATION | MAX. | MEAN | MAX. | MEAN |
| 1 | Physics 1(P107) | 136 ± 3.2 | 25.5 | 170 ± 4.2 | 60.7 |
| 2 | Physics 2(GPA09) | 136 ± 3.1 | 30.5 | 168 ± 4.6 | 54.8 |
| 3 | Physics 3(P112) | 170 ± 4.2 | 55.6 | 195± 4.4 | 48.1 |
| 4 | Physics (GPA 08) | 205 ± 4.3 | 72.2 | 220 ± 4.9 | 82.5 |
| 5 | Physics (GPA082) | 203 ± 4.2 | 83.1 | 223 ± 4.7 | 87.1 |
| 6 | Physics (radiation pit) | 259 ± 6.3 | 86.1 | 295 ± 7.3 | 89.1 |
| 7 | Physics (GPA080) | 101 ± 3.1 | 31.0 | 111 ± 3.4 | 33.0 |
| 8 | Maths 1 (M103) | 238 ± 5.2 | 86.5 | 248 ± 5.2 | 88.5 |
| 9 | Maths 2 (CP LAB2) | 263 ± 6.8 | 92.0 | 273 ± 6.8 | 95.0 |
| 10 | Maths 3 (CP LAB3) | 187 ± 6.2 | 52.8 | 192 ± 5.4 | 56.8 |
| 11 | Maths 4 (CP LAB4) | 178± 6.0 | 50.3 | 190± 5.5 | 53.3 |
| 12 | Biology 1 (C1.15) | 136 ± 3.6 | 38.4 | 142± 3.8 | 39.9 |
| 13 | Biology 2 (C1.19) | 125 ± 3.1 | 35.2 | 132 ± 3.4 | 37.2 |
| 14 | Biology 3 (C1.10) | 142 ± 4.1 | 39.2 | 149 ± 4.4 | 41.2 |
| 15 | Biology 4 (C1.13) | 147 ± 4.5 | 39.8 | 153 ± 4.7 | 43.8 |
| 16 | Geography 1 (GG1) | 201± 4.3 | 47.1 | 211 ± 4.5 | 49.8 |
| 17 | Geography 2 (GG2) | 192 ± 4.1 | 43.1 | 199 ± 4.5 | 47.4 |
| 18 | Geography 3 (GG3) | 197 ± 4.5 | 46.1 | 199 ± 4.8 | 46.8 |
| 19 | Deans office | 170 ± 3.1 | 33.2 | 182 ± 3.5 | 38.4 |
| 20 | Geology 1(GL 1) | 136 ± 3.5 | 44.6 | 143 ± 3.8 | 46.6 |
| 21 | Geology 2(GL 2) | 156 ± 3.9 | 46.3 | 161 ± 4.1 | 46.8 |
| 22 | Geology 3(GL 3) | 127 ± 3.3 | 41.4 | 139 ± 3.9 | 41.6 |
| 23 | Faculty office(GP6) | 165 ± 4.1 | 34.6 | 169 ± 4.2 | 35.6 |
| 24 | Faculty office2(GP7) | 127 ± 3.7 | 33.3 | 139 ± 3.7 | 33.6 |
| 25 | Faculty office3 (GP4) | 123 ± 2.5 | 15.3 | 132 ± 2.6 | 17.2 |

| | | | | | |
|---|---|---|---|---|---|
| 26 | Chemistry 1 (C101) | 204 ± 5.0 | 67.2 | 214 ± 5.0 | 69.2 |
| 27 | Chemistry 2 (C118) | 208 ± 5.5 | 72.8 | 220± 5.7 | 76.8 |
| 28 | Chemistry 3 (C116) | 194 ± 5.0 | 67.8 | 198 ± 5.3 | 69.9 |
| 29 | Chemistry 4 (C119) | 198 ± 5.2 | 69.8 | 199 ± 5.5 | 71.8 |

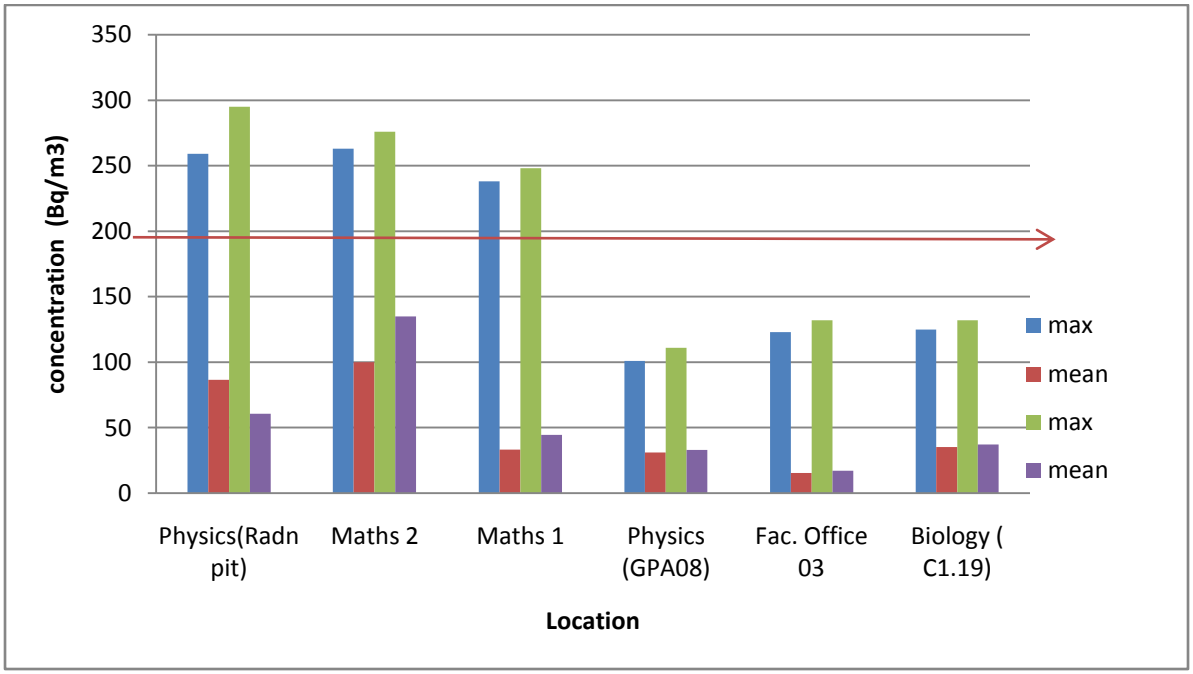



Figure 4.3 gives the summary of the locations found with the highest and lowest radon levels.

Taking into consideration the radon activity concentration during and after working hours of the studied area, it was observed that most of the offices have radon levels lower than 200Bqm$^{-3}$ which the recommended action level isgiven by ICRP whereas some few offices recorded radon levels greater than 200 Bqm$^{-3}$. The offices with highest radon levels and those with lowest levels are depicted in fig (4.3) above.

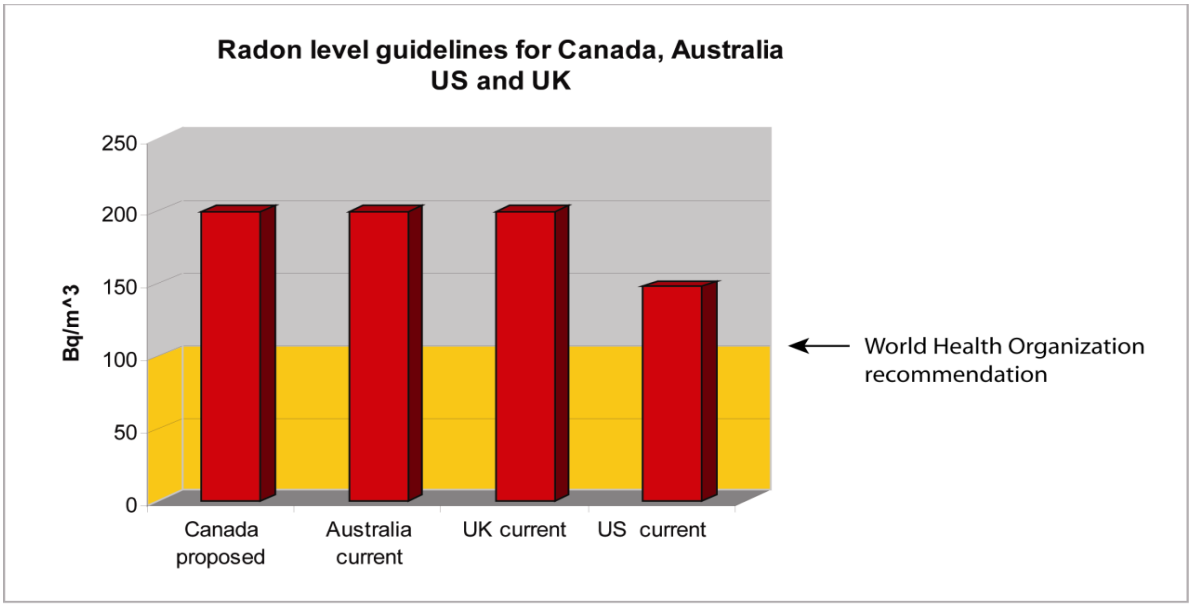



Figure 4.4: Guidelines for radon levels for US, UK, Canada, Australia and the WHO recommended level.

Upon comparing the result obtained in this study with that of the international guidelines adopted by US (150 Bqm$^{-3}$), UK (200 Bqm$^{-3}$), Canada (200 Bqm$^{-3}$), Australia(200 Bqm$^{-3}$) and the World Health Organisation, WHO (100 Bqm$^{-3}$) given in fig (4.4) above, a clear information on whether the studied area is radiologically safe or not for the inhabitants is obtained. With the result obtained in this study, it was found that the environmental hazard due to radon gas is minimalin order word the area studied is radiologically safe for living.

**Table 4.4 Calculated Annual effective dose ($mSvy^{-1}$) of the study Area.**

| S/NO | LOCATION | $^{222}Rn$ Conc.($Bqm^{-3}$) | AED($mSv^{-y}$) |
|---|---|---|---|
| 1 | Physics (P107) | 170 | 0.68 |
| 2 | Physics (GPA09) | 168 | 0.67 |
| 3 | Physics (P112) | 195 | 0.78 |
| 4 | Physics (GPA 08) | 220 | 0.88 |
| 5 | Physics (GPA082) | 223 | 0.89 |
| 6 | Physics (radiation pit) | 295 | 1.18 |
| 7 | Physics (GPA080) | 111 | 0.44 |
| 8 | Maths 1 (M103) | 248 | 0.99 |
| 9 | Maths 2 (CP LAB2) | 273 | 1.09 |
| 10 | Maths 3 (CP LAB3) | 192 | 0.77 |
| 11 | Maths 4 (CP LAB4) | 190 | 0.76 |
| 12 | Biology 1 (C1.15) | 142 | 0.57 |
| 13 | Biology 2 (C1.19) | 132 | 0.53 |
| 14 | Biology 3 (C1.10) | 149 | 0.60 |
| 15 | Biology 4 (C1.13) | 153 | 0.61 |
| 16 | Geography 1 (GG1) | 211 | 0.84 |
| 17 | Geography 2 (GG2) | 199 | 0.80 |
| 18 | Geography 3 (GG3) | 199 | 0.80 |
| 19 | Deans office | 182 | 0.73 |
| 20 | Geology 1(GL 1) | 143 | 0.57 |
| 21 | Geology 2(GL 2) | 161 | 0.65 |
| 22 | Geology 3(GL 3) | 139 | 0.56 |
| 23 | Faculty office(GP6) | 169 | 0.67 |
| 24 | Faculty office2(GP7) | 139 | 0.55 |
| 25 | Faculty office3 (GP4) | 132 | 0.53 |
| 26 | Chemistry 1 (C101) | 214 | 0.86 |
| 27 | Chemistry 2 (C118) | 220 | 0.88 |
| 28 | Chemistry 3 (C116) | 198 | 0.80 |
| 29 | Chemistry 4 (C119) | 199 | 0.80 |

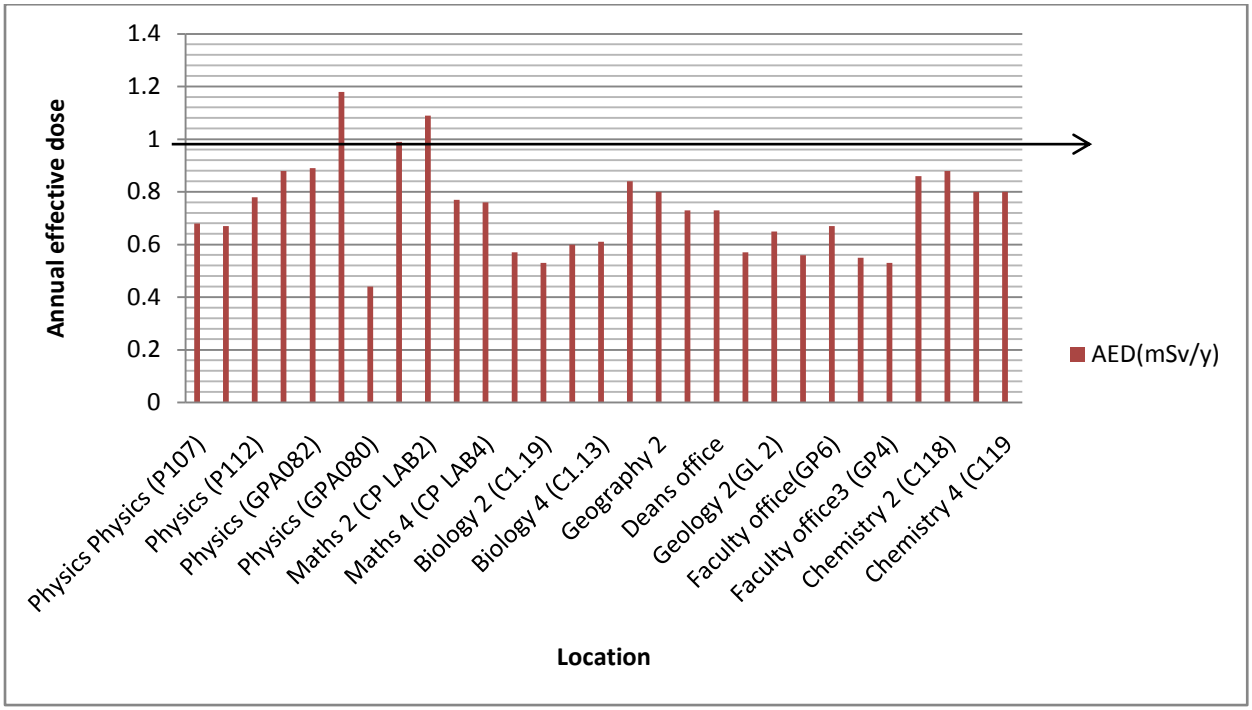



**Figure 4.5** gives the bar chart that shows the annual effective dose (mSv $y^{-1}$) from $^{222}Rn$ found within the offices of the study area.

Figure (4.5) above shows the annual effective dose attributable to radon within the studied area. The dose due to radon gas ranged from 0.44 to 1.18mSv $y^{-1}$with an average of 0.74mSv $y^{-1}$, resulting in a total inhaled dose of 21.48mSv $y^{-1}$ for all the offices measured. The ICRP(1993) recommends effective dose action levels of 3-10 mSv $y^{-1}$. While the estimated average annual effective dose attributable to radon in this present work was below the ICRP(1993) recommendation of 3-10 mSv $y^{-1}$. With respect to annual effective dose found in this research work within the studied area, it is assumed that the inhabitants of the offices studied are safe from some levels of radiological hazards due to radon.

# CHAPTER FIVE

## 5.0 CONCLUSIONS AND RECOMMENDATIONS

### 5.1Conclusions

Measurement of indoor radon build-up within randomly selected offices of the faculty of science, A.B.U Zaria has been successfully carried out. The selection of RAD7 electronic radon detector for this study was due to its precision in taking radon measurements and its ruggedness in the field of work. Moreover the method of validation of alpha spectrometry has demonstrated that, this analytical technique is able to produce a quality and reliable result for measuring indoor air radon.

The result obtained in this study for the activity concentration of radon in sampled offices ranges from 102 $Bq/m^3$ to 276 $Bq/m^3$ for both the measurement periods of during working hours and after working hours. The annual effective dose obtained ranges from 0.99 to 2.01 mSv $y^{-1}$ with an average value of 1.45 mSv $y^{-1}$, the data obtained from most of the offices in the study area is within the permissible limit set by international organizations. Therefore these results shows a significance of indoor radon measurement for the entire University due to the fact that in some offices within the study area, radon levels are found to be high and as a result, remedial measures should be put in place to avoid more exposure which may lead to a threat of lung cancer. In the outcomes of this research work, offices found with higher concentration of radon gas are mostly not carpeted with rugs neither tiled like other offices in the study area, therefore, it has been observed that radon emanation from terrazzo floor is higher than tiled and carpeted floors, also the radon emanation in the offices surrounded by red bricks walls were found to be higher as well. Terrazzo floor is made from concrete materials which originate from granite rocks; as a result they release more radon gas than the other building materials.

Based on the result obtained, it’s indicated that the people living within the study area and the materials which are used in the construction of the buildings may not cause some serious radiological hazard to the inhabitants of the offices.

## 5.2 Recommendations

International guidance on radon has evolved significantly in recent years all over the world, and this necessitates the Federal Republic of Nigeria to establish a guideline for radon in indoor air. Concern for exposure to radiation from indoor air $^{222}Rn$ sources has necessitated studies to reduce/mitigate the dangers. International organizations have established recommended limits for indoor air $^{222}Rn$ concentration but Nigeria has not introduced any legal regulation concerning permissible radon concentration yet; therefore, there is need for indoor air radon concentration to be investigated thoroughly so that guidelines for regulations on the indoor radon concentrations in Nigeria may be established. It is also important for the guideline to match the leading international standards. At the same time, implementation measures must be reinforced by the government to reduce/mitigate the indoor radon concentrations across the country and minimize the number of homes and public buildings with indoor concentrations of radon that exceed the set guideline.

Radon is a recognised carcinogen(WHO, 2009). For this reason, agencies and countries the world over had come up with reference levels beyond which radon mitigation measures are recommended. The majority of these reference levels are within the range of 200–600 $Bqm^{-3}$.

It is also recommended that similar research work should be taken with another analytical technique to verify the results obtained in this work and to evaluate the safety of the inhabitants of the university environment. And also radon reduction strategies should be put in place where measurements are found to be high. Radon reduction strategies fall into two basic categories: those that prevent the entry of radon gas into the building, and those that attempt to remove the radon gas once it has entered the building. In most situations, the first approach i.e. preventing radon entry is the most

effective. When the remedial action is taken, radon levels should be reduced to a value as low as reasonably achievable (ALARA) based on the principles of radiation protection. Within the area studied, radon values and exposure could also be reduced by proper ventilation of the offices most especially during working hours by opening all the windows, sealing of cracks (if any exists) and by reducing the exposure time.

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