



BELLS UNIVERSITY OF TECHNOLOGY
OTA, OGUN STATE, NIGERIA

TOPIC:
**RADIATION AND HUMAN WELL-BEING - A
DOUBLE EDGED SWORD IN OUR WORLD:
BALANCING THE BENEFITS AND RISKS**

An Inaugural Lecture

By

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Deputy Dean, College of Natural and Applied Sciences

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Radiation and Human Well-being: A Doubled-Edged Sword in our World – Balancing the Benefits and Risks

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Bells University of Technology, Ota, Nigeria
On Wednesday, 8th October, 2025

By

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CITATION OF PROFESSOR AUGUSTINE KOLAPO ADEMOLA

Professor Augustine Kolapo Ademola is an eminent scholar and a distinguished icon of contemporary academia. He was born to the family of late Pa Francis Ademola and Mrs. Florence Ademola. His Father was an educationist and his mother, a seamstress.

Prof. Ademola's formative years were steeped in the values of discipline, resilience, and a passion for knowledge ingrained by his father. His early education traversed several schools due to his father's profession. He started at St. Mary's RCM Primary School, Iseyin, Oyo State from 1977 to 1979, then Akeetan Methodist School (now Griffin Memorial Primary School) from 1979 to 1980 and concluded primary education at Ibadan Municipal Government Primary School, Apata, Ibadan in 1982. He spent his early secondary school years at Government College, Ibadan between 1983 and 1985 and later at Iseyin District Grammar School, Iseyin, Oyo State, Nigeria between 1985 and 1987

The highly ambitious Ademola proceeded to St Andrew's College of Education between 1989 and 1992 where he studied Mathematics and Chemistry. With this insatiable passion for knowledge, after a National Certificate in Education, he proceeded to Ladoke Akintola University of Technology, Ogbomosho, Oyo State, for a B.Tech in Pure and Applied Physics between 1995 and 2000. With his face set as a flint, after his NYSC at St. Thomas Birch Freeman Seminary in Okigwe, Imo state, he went on to obtain a Master's degree in Physics in 2006 at the University of Ibadan, Oyo State and thereafter completed his Ph.D. in Physics at the same University in 2013 as part of requirements for academics, teaching and research.

His professional journey began as an academic in 2003 at The Polytechnic of Ibadan, Saki campus (now Michael Koleoso Polytechnic) Oyo state, as a Teaching Assistant in the Department of Science Laboratory Technology. In 2006, he joined Bells University of Technology, Ota, as an Assistant Lecturer, notably becoming the first full-time staff of the Physics with Electronics Programme in the Department of Physical Sciences. Through

dedication and scholarship, he rose steadily, attaining the rank of Professor in October 2021.

Professor Ademola has been both an inspiring teacher, consultant and an accomplished administrator. Within Bells University of Technology, he has held pivotal leadership roles, which include: Pioneer Director of Quality Assurance; Director of Sport; Acting Head of Department; Head of Department; and now Deputy Dean, College of Natural and Applied Sciences. He has been a member of so many committees including Committee of Deans and Directors (CODD); Budget Committee; Bells Resumption Committee; and College Representative at COLICT and COLENG College Boards. He is presently a Member of Senate; Post-Graduate Board; Staff Disciplinary Committee; Bullying and Assault Committee; and Examination Malpractice Committee. He is currently the Editor-in-Chief of Bells University Journal of Applied Sciences and Environment and also the Congregation Representative at the University Governing Council.

His academic contributions extend beyond Nigeria. He has participated in numerous international programmes and conferences, enriching global discourse in Physics and Radiation research. His research interests reflect in his wide range of publications in various national and international journals. He is also an Editorial Board Member and Reviewer of several international journals, as well as author of academic texts.

Prof. Ademola has provided expert service as an External Examiner to undergraduate and postgraduate programmes at Covenant University, Crawford University, Lagos State University, and Northwestern University, Mahikeng campus, South Africa. His professional affiliations include the Nigerian Institute of Physics, the Nigerian Society for Radiation Protection, the UK Society for Radiation Protection, and the International Radiation Protection Authority, among others.

Professor Ademola's research interests focus on the measurements and estimation of hazards from exposure to radiation (ionizing and non-

ionizing) which spans through radiation protection in patient audit during diagnostic examination involving medical equipment such as X-ray, CAT, Ultrasound and MRI, environmental radioactivity, low radiation and health effects in mining areas, building materials, industrial areas, dumpsites, food and radon measurements in dwellings, classrooms and offices in Nigeria. Infact, he is among the first researchers to study radon and associated lung cancer in Nigerian dwellings.

He has also made notable contributions in characterizing heavy metals in waste and food systems. As a consultant in radiation and environmental pollution, he continues to shape national and international best practices in health and environmental safety.

He is a radiation and environmental pollution consultant and researcher. He has supervised four (4) Ph.D. research and currently supervising another four (4) Ph.D. students. He has also supervised four (4) Masters and seven (7) Postgraduate Diploma students, published over 40 journal articles in national and international journals with significant impact factors in Scopus and Web of Science. His research contributions have been cited more than 700 times on Google scholar.

He is married to Mrs. Elizabeth Abosede Ademola, a Chief Executive Officer in the Ministry of Local Government, Oyo State and they are blessed with children.

Protocol
The Vice-Chancellor
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Former Inaugural Lecturers
Distinguished Colleagues
My Lords Spiritual and Temporal
Gentlemen of the Press
Ladies and Gentlemen

1.0 The Foundation

Vice-Chancellor Sir, it is with profound honour, immense pleasure, and heartfelt gratitude to the Almighty God that I stand before you today to deliver the eight Inaugural Lecture of this great University. Truly, the words of scriptures remind us: “Let everything that has breath praise the Lord” (Psalm 150 verse 6). Today, I praise Him for life, for opportunity, and for this rare privilege.

Bells University of Technology holds a special place in the educational landscape of Nigeria as the first private university of technology. From its beginning, it has championed excellence in teaching, research, and innovation, becoming a trailblazer in private higher education. The Department of Physical Sciences, as one of the foundation departments in the College of Natural and Applied Sciences, has contributed significantly to this vision by training students in Physics with Electronics, Mathematics, and Statistics. Today's occasion is therefore not only a personal milestone for me but also a historic moment for my Department, as we present the very first Inaugural Lecture from the Department of Physical Sciences.

I remain deeply grateful to the Vice-Chancellor, Professor Jeremiah Oludele Ojediran, *RE (COREN), FNSE, FNIAE*, for granting me the permission to stand before this distinguished gathering. Sir, your encouragement and leadership have provided a fertile ground for scholars like myself to thrive. It is a privilege I do not take lightly.

Looking back, my journey in Physics began humbly. In my secondary school days,

I felt a sense of pride and destiny when I was placed in the science class. At that time, my community did not enjoy the luxury of a stable Physics teacher. Yet, despite this gap, we persevered. We relied heavily on the famous Nelkon and Parker textbook, generously passed down to us by our seniors preparing for the Higher School Certificate. With determination, we studied and sought to unravel the mysteries of Physics, even when clear guidance was scarce.

The turning point came in 1995, when I gained admission into Ladoke Akintola University of Technology, Ogbomoso. There, Physics moved from being abstract concepts in a book to a living subject with exciting applications. My fascination grew particularly towards the health-related aspect of Physics. This interest was nurtured and sustained by outstanding teachers and mentors such as Professor Tunde Oni, Professor Margaret Akinloye, and the late Professor Ajadi, who each, in their own way, ignited my passion for applied Physics.

That passion deepened when I proceeded to the University of Ibadan for my Master's and Doctoral degrees in Physics. At Ibadan, I encountered inspiring scholars, including Professor I. A. Babalola, Professor J. A. Ademola, Professor N. N. Jibiri, and my supervisor, Professor Rachel Obed. Each of them shaped my academic journey in profound ways. Professor Obed, in particular, went beyond the call of duty. Through her networks, she secured vital research materials with the support of the Italian Government. She ensured that I lacked nothing crucial for the completion of my doctoral research. Beyond this, she played a pivotal role in facilitating my appointment at Bells University of Technology, a step that allowed me to balance financial needs with academic pursuit. Madam, I owe you an immeasurable debt of gratitude. May God continue to bless you richly.

Today's lecture is built on this journey of growth, learning, and mentorship. Its title highlights two broad yet interconnected themes: the application of Physics for the benefit of humanity, and the hazards that can arise from the use of radiation.

Radiation is one of the most transformative discoveries in science. Its applications have revolutionized medicine, industry, agriculture, and energy production. It enables us to see inside the human body, to diagnose illnesses early, to treat diseases such as cancer, and even to power homes and industries through nuclear technology. At the same time, radiation is a double-edged sword. When uncontrolled or misused, it can inflict serious harm on human health, damage ecosystems, and threaten generations to come.

This duality, its benefits and dangers, forms the central theme of today's

discourse. My aim is to show how Physics, as a discipline, equips us not only with tools to harness radiation for good but also with the responsibility to minimize its risks. Whether in nuclear reactors, medical imaging, particle accelerators, or industrial applications, society must always approach radiation with respect, caution, and wisdom (Jian and Tom, 2020).

In this lecture, therefore, I will invite you to reflect with me on the balance between promise and peril, benefit and hazard. By exploring this delicate balance, we can better understand how to maximize the contributions of radiation to human welfare while safeguarding the health of individuals and the integrity of our environment.

2.1 Nucleus of an atom and stability

2.1.1 Structure of an Atom

The atom is considered to be the basic building block of all matter. It is the smallest amount of matter that retains the properties of an element.

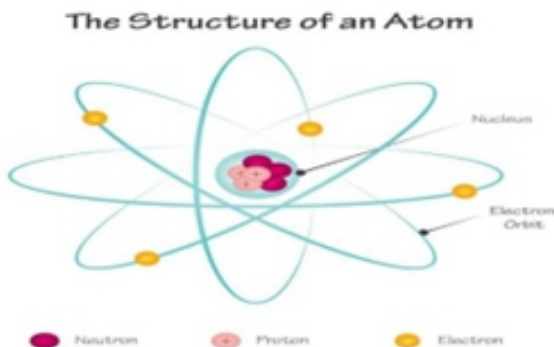
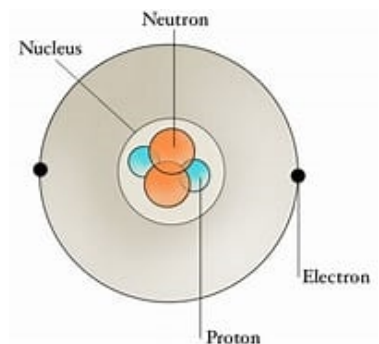


Figure 1: The structure of an atom

2.1.2 Nucleus of an atom

The nucleus of an atom is composed of protons and neutrons. A proton is about 1840 times more massive than the electron, and the neutron is slightly heavier than the proton. Proton and Neutron is collectively known as nucleons



2.1.3 Isotope

An isotope is an element that has the same number of protons but different numbers of neutrons.

An isotope that contains more than the usual number of neutrons is referred to as a heavy isotope. Heavy isotopes tend to be unstable, and unstable isotopes are radioactive. A radioactive isotope is an isotope whose nucleus readily decays, giving off subatomic particles and electromagnetic energy (IAEA, 2022)

2.1.4 Nuclear Stability

Nuclear stability refers to the tendency of a nucleus to decay in order to achieve stability. In the nucleus, stability is achieved by neutrons attracting each other and the protons, thereby offsetting the electrical repulsion between protons. This strong nuclear force is greater than the electrostatic repulsion between protons.

To achieve stability, the nucleus must either decrease in size by emitting cluster of nucleons (alpha particle)

OR

It must rearrange the nucleons to balance the nuclear force and the Coulomb force (beta particle)

Nuclei are most stable if they contain an equal number of protons and neutrons i.e $N = Z$. But above $Z = 20$ for heavier nuclei, they are more stable if the number of neutrons exceeds the number of protons at 1:1.5 for protons to neutrons (Khairi, 2014)

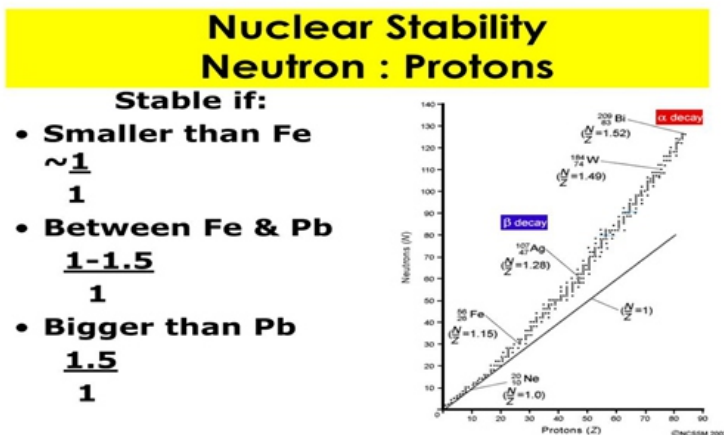


Figure 3: Graph of nuclear Stability

2.2 What is radioactivity? (Natural and artificial radioactivity)

Radioactivity is the property of certain nuclides to spontaneously emit particles or electromagnetic waves, or is the process in which an unstable atomic nucleus loses energy by emitting radiation in the form of particles or gamma radiation (Nanda, 2021).

This decay, or loss of energy, results in an atom of one type, called the parent nuclide transforming to an atom of a different type, called the daughter nuclide.

Radioactivity, whether natural or artificial releases radiation in form of energy. This radiation is the energy that travels in the form of waves and particles (Karmaker, 2021).

Radiation is a natural part of our environment. It has always been present in our environment and will forever be (Jha et al., 2024). Every day, we are exposed to radiation from the ground beneath our feet (soil), the air we breathe, food we eat, water we drink and even the sun above us.

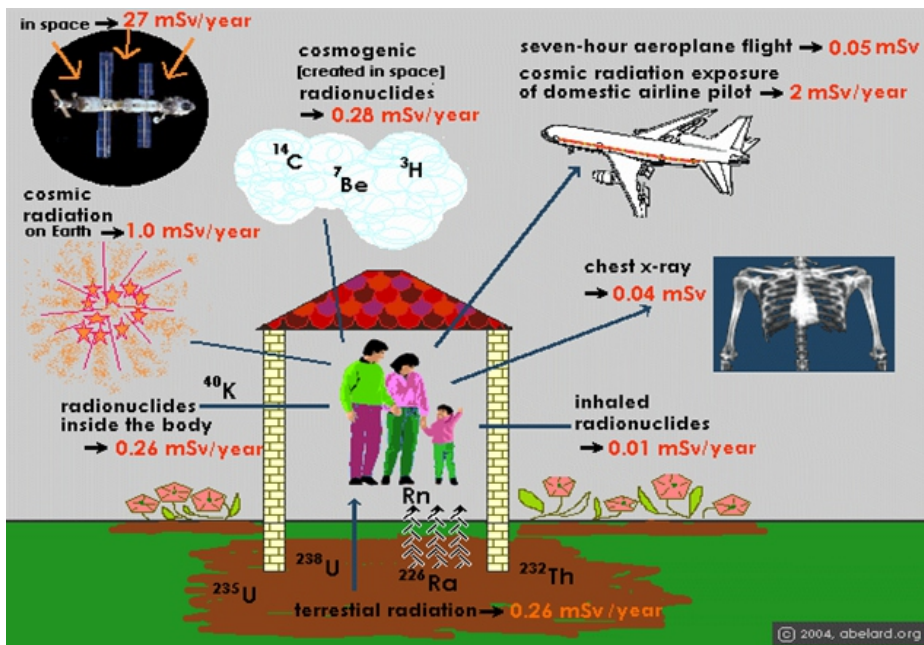


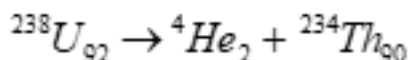
Figure 4: Radiation in the whole environment (UNSCEAR, 2000)

The phenomenon of radioactivity was discovered by accident in 1896 by Henry Becquerel when a Uranium compound was placed in a drawer containing photographic plates, wrapped in a black paper. When the plates were examined later, it was found that they were exposed. This exposure gave rise to the concept of radioactive decay

2.2.1 Types of radioactive decay

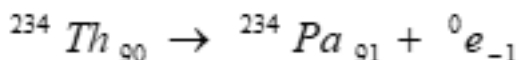
(i) Alpha decay- α -particle is a helium nucleus, having two protons and two neutrons, and when atom decays by emission of α -particle, its nucleon number decreases by four and its proton number by two. This particle has a high energy and positive electrical charge, which makes it easily detectable.

A common example of alpha decay is the decay of [uranium](#)-238 into [thorium](#)-234, releasing an alpha particle in the process.



(ii) Beta decay

Beta decay involves the transformation of a neutron into a proton or vice versa within the nucleus. When a neutron turns into a proton, it emits a negative beta particle (an [electron](#)) and an antineutrino. On the other hand, when a proton turns into a neutron, a positive beta particle (a positron) and a neutrino are emitted.



2.2.2 Laws of Radioactivity

- (i) Radioactivity is the result of the decay of the nucleus.
- (ii) The nucleus's decay rate is independent of temperature and pressure.
- (iii) Radioactivity is dependent on the law of conservation of charge.
- (iv) The physical and chemical properties of the daughter nucleus are different from the mother nucleus.
- (v) The emission of energy from radioactivity is always accompanied by alpha, beta, and gamma particles.
- (vi) The rate of decay of radioactive substances is dependent on the number of atoms that are present at the time.

2.2.3 Radioactive decay law

The radioactive decay law states that the probability per unit time that a nucleus will decay is constant and independent of time (Huestis, 2002).

The average number of disintegrations (i.e. decaying atoms) per second of a sample is its activity. If it is measured at different times (e.g. by finding the count-rate using a GM tube and rate meter), a decay curve of activity against time can be plotted. The ideal curve for one element (Figure 7) shows that the activity decreases by the same fraction in successive equal time intervals. If N is the number of nuclei present in the sample at a certain time, the change in number of those nuclei with time, rate of decay, is the activity A , and can be given by:

$$-A = \frac{dN}{dt} \quad 1$$

The minus sign is used to make A a positive quantity since dN/dt is, of course, intrinsically negative. In addition, the activity is the product of the decay constant and the number of atoms present in the sample. The relationship between the activity A , number of atoms N , and decay constant λ is given by:

$$A = \lambda N \quad 2$$

Since λ is a constant, the activity and the number of atoms are always proportional. Two common units to measure the activity of a substance are the Curie (Ci) and Becquerel (Bq).

A curie is a unit of measure of the rate of radioactive decay and it is equal to 3.7×10^{10} disintegrations per second. This is approximately equivalent to the number of disintegrations that one gram of radium ^{226}Ra will undergo in one second.

A Becquerel, as the metric system, is a more fundamental unit of measure of radioactivity than Curie. The conversion between Curie and Becquerel is as shown.

$$115.1 \text{ Bq} = 1 \text{ dis/sec} \quad 3a$$

$$1 \text{ Curie} = 3.7 \times 10^{10} \text{ Bq} \quad 3b$$

From the previous two basic relationships, Eq 1 and 2, it is possible to use calculus to derive an expression that can be used to calculate how the number of atoms present will change over time.

$$-Nd = N\lambda dt \quad 4$$

This equation describes the situation for any short time interval dt .

To find out what happens for all periods of time, adding up what happens in each short time interval is the solution. In other words, integrate Equation 4 over the period of time $t = 0$ to any time t .

The number of radioactive nuclei will then decrease from N_0 to N_t , so that the equation becomes $-dN = N_0 \exp(-\lambda t)$ 5

Equation 5 is known as the Radioactive Decay Law (Huestis, 2002).

It tells us that the number of radioactive nuclei N_0 at time $t = 0$ will decrease in an exponential fashion to N_t with time with the rate of decrease being controlled by the decay probability per unit time, decay constant λ . The decay constant is characteristic of individual radio nuclide.

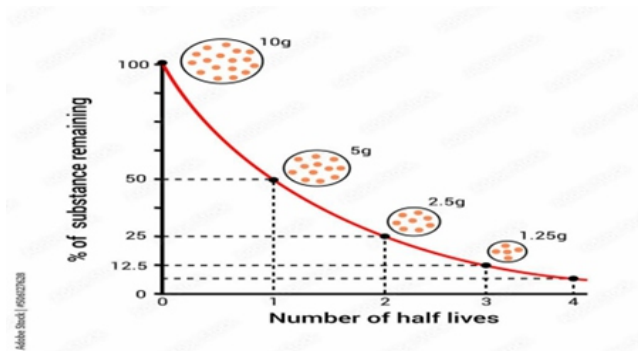


Figure 5: Graph of Radioactive decay

2.2.4 Half-life

The rate of decay is unaffected by temperature but every radioactive element has its own definite decay rate, expressed by its half-life. This is the average time for half the atoms in a given sample to decay. It is difficult to know when a substance has lost its radioactivity, but the time for its activity to fall to half its value can be found more easily.

Setting $N = \frac{N_0}{2}$ and $t = T_{1/2}$ Equation 5 becomes

$$\frac{N_0}{2} = N_0 e^{-\lambda T_{1/2}} \quad 6$$

Cancelling the N_0 factor, we obtain

$$1/2 = e^{-\lambda T_{1/2}} \text{ Or } 2 = e^{\lambda T_{1/2}} \quad 7$$

Taking natural log of both sides gives

$$T_{1/2} = \frac{\ln 2}{\lambda} = \frac{0.693}{\lambda} \quad 8$$

2.2.5 Radioactive equilibrium

The parent nucleus produces a daughter nucleus and other particles. These parent nuclei are unstable and decay to daughter nuclei which may be unstable too. This continues until stability is achieved. If the daughter product in a decay is stable, then after a time t , the number N_d of the daughter present in the decay process, is given by

$$N_d = N_o - N_o e^{-\lambda t} = N_o (1 - e^{-\lambda t}) \quad 9$$

But if the daughter itself is unstable and radioactive, then the rate of change in the number of daughter nuclei per unit time is equal to the (rate of formation) – (rate of transformation) i.e.

$$\frac{dN_d}{dt} = \lambda N - \lambda' N_d \quad 10$$

Where λ' represents the decay constant of the daughter
Thus

$$\frac{dN_d}{dt} + \lambda' N_d = \lambda N \quad 11$$

Using $N = N_o e^{-\lambda t}$ equation 11 becomes

$$\frac{dN_d}{dt} + \lambda' N_d = \lambda N_o e^{-\lambda t} \quad 12$$

This is the first order linear differential equation which can be shown to have the solution

$$N_d = N_o \left[\frac{\lambda}{\lambda' - \lambda} \right] (e^{-\lambda t} - e^{-\lambda' t}) \quad 13$$

If the parent nucleus has a much longer half-life compared to the daughter nucleus, then $\lambda \gg \lambda'$ and therefore $\lambda' - \lambda \gg -\lambda'$ where equation 1 becomes

$$N_d = N_o \lambda / \lambda' (1 - e^{-\lambda' t}) \quad 14$$

After a long time, $e^{-\lambda' t} \Rightarrow 0$ Then

$$N_d = N_o \lambda / \lambda' \quad \text{or} \quad \lambda' N_d = N_o \lambda \quad 15$$

This means that the activity of the daughter becomes equal to the activity of the parent which remains essentially constant during the period of observation (Karmaker, 2021). This is referred to as Secular equilibrium. This is a type of radioactive equilibrium in which the half-life of the parent radioisotope is so much longer than that of the daughter, that the radioactivity of the daughter becomes equal to that of the parent with time. Thus for ^{232}Th and ^{238}U , and their gaseous daughters, secular equilibrium can be attained within four weeks by trapping in the measurement container through hermetic sealing (Olomo et al. 1994)

2.2.6 Radioactive decay series

Radioactive decay series are naturally occurring radioactive decay chains of unstable heavy atomic nuclei that decay through a sequence of alpha and beta decays until a stable nucleus is achieved. Naturally occurring radionuclides can be divided into three primary decay series, beginning with uranium-238, thorium-232, and uranium-235. Figure 1 shows the decay chain of uranium-238, which culminates in lead-206 after forming intermediates such as uranium-234, thorium-230, radium-226, and radon-222 (Zehringer, 2019)

Uranium, radium, and thorium occur in three natural decay series, headed by uranium-238, thorium-232, and uranium-235, respectively. In nature, the radionuclides in these three series are approximately in a state of secular equilibrium, in which the activities of all radionuclides within each series are nearly equal. Two conditions are necessary for secular equilibrium.

- (i) The parent radionuclide must have a half-life much longer than that of any other radionuclide in the series.
- (ii) A sufficiently long period of time must have elapsed, for example ten half-lives of the decay product having the longest half-life, to allow for in growth of the decay products (Galanda et al. 2025)

Under secular equilibrium, the activity of the parent radionuclide undergoes no appreciable changes during many half-lives of its decay products. The radionuclides of the uranium-238, thorium-232, and uranium-235 decay series are shown in Figure 6;

Radioactive decay occurs when an unstable (radioactive) isotope transforms to a more stable isotope, generally by emitting a subatomic particle such as an alpha or beta particle as shown in the Figure. Gamma radiation is not a mode of

radioactive decay but a mechanism by which excess energy is emitted from certain radionuclides, i.e. high energetic electromagnetic radiation are emitted from the nucleus of the atom.

Of the two conditions noted above for secular equilibrium, the first is generally met for the uranium-238, thorium-232 and uranium-235 decay series in naturally occurring ores. While the second condition may not be met for all ores or other deposits of uranium and thorium (given the extremely long half-lives for the radionuclides involved and the geological changes that occur over similar time scales)

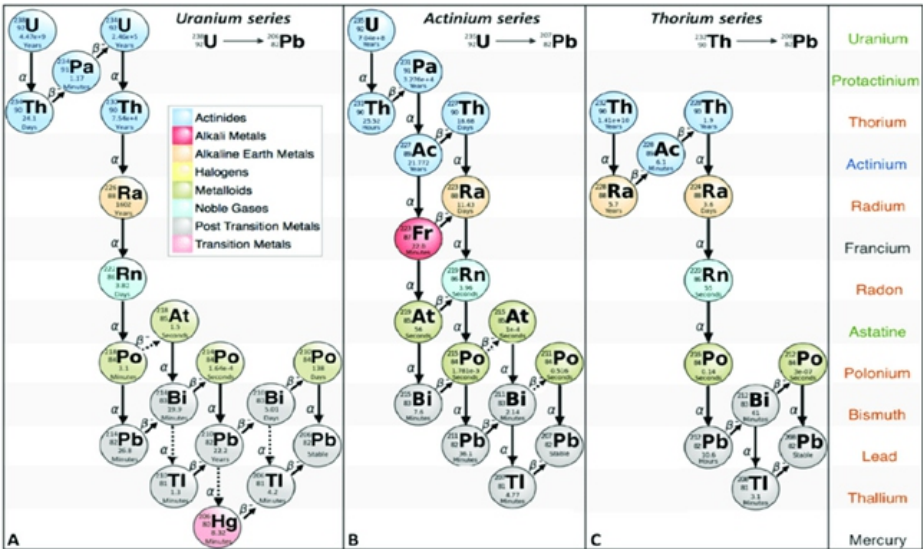
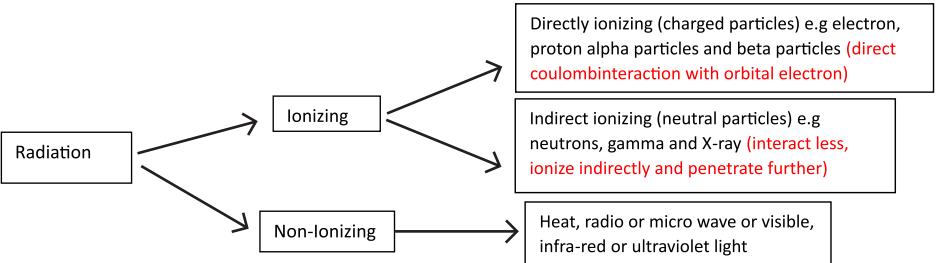


Figure 8: Natural decay series (Galanda et al. 2025)

2.3 Types of Radiation:

There are two basic types of radiation which are:



2.3.1 Ionizing Radiation

Ionizing radiation is the type of radiation that has enough energy to ionize atoms or molecules by detaching electrons from them and therefore making the atom a positively charge (ion) (Karmaker, 2021). Radiation that can produce ions is called ionizing radiation. Ionizing radiation is more energetic and can damage living tissues and DNA, potentially leading to mutations, cancer, and other health problems (Talapko et al., 2024)



Figure 8: Ionizing Radiation

The types of ionizing radiation include among others:

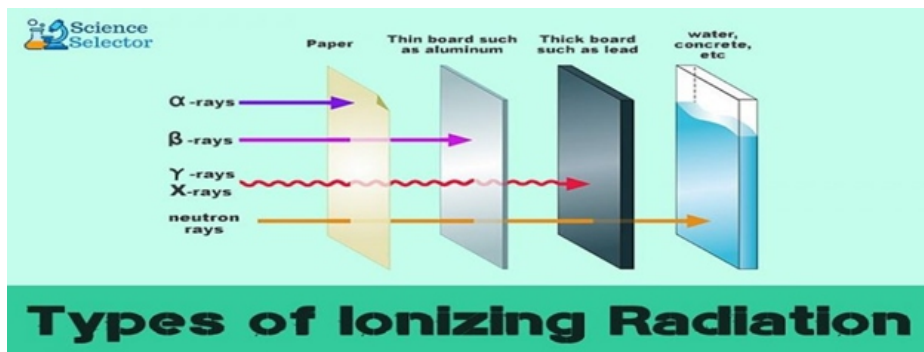


Figure 9: Types of ionizing radiation

2.3.1.1 Alpha Particles: Alpha particles consist of two protons and two neutrons. Although they have low penetration power (unable to penetrate skin), they are highly damaging if ingested or inhaled.

2.3.1.2 Beta Particles: Beta particles are high-energy, high-speed electrons or positrons emitted from certain types of radioactive decay. They can penetrate skin to some extent and may cause harm if exposure is prolonged.

2.3.1.3 Gamma Rays: Gamma rays are the most energetic form of electro-

magnetic radiation and are emitted from the nucleus of radioactive atoms during radioactive decay processes. They are used in cancer treatment and industrial imaging

2.3.1.4 X-rays: X-rays are a form of electromagnetic radiation with very short wavelengths and high energy; widely used in medical imaging (e.g., radiography, CT scans). They can penetrate body tissues and provide clear images of internal structures.

2.3.1.5 Neutrons: Neutron radiation occurs primarily in nuclear reactors and during certain industrial processes. Neutrons are uncharged particles and can deeply penetrate materials, making them a concern in nuclear safety.

2.3.2 Non-Ionizing Radiation

Non-ionizing radiation does not carry enough energy to ionize atoms or molecules. Instead, it can cause atoms to vibrate or move, leading to an increase in temperature (Intakhab and [Maqbool](#), 2023). It is less harmful than ionizing radiation however, prolonged or intense exposure to non-ionizing radiation can have some adverse health effects, such as burns or tissue damage. Common examples of non-ionizing radiation include:

2.3.2.1 Microwaves: microwaves are widely used in household appliances (e.g. microwave ovens) and for telecommunications (e.g., mobile phones, Wi-Fi). They cause molecules, particularly water molecules, to vibrate, producing heat. Prolonged exposure to high levels of microwaves can cause burns and tissue damage.

2.3.2.2 Radio Waves: radio waves are used for communication (e.g., radio, television, mobile phones). They have the longest wavelengths and the lowest frequencies in the electromagnetic spectrum. While it is generally safe, extremely high levels of radio frequency radiation can cause thermal effects (heating tissues).

2.3.2.3 Infrared Radiation: Infrared radiation is commonly associated with heat. It is emitted by heated objects and is used in various applications, such as thermal imaging and remote controls. Exposure to intense infrared radiation can cause thermal injury to the skin and eyes.

2.3.2.4 Visible Light: The only part of the electromagnetic spectrum detectable by the human eye. While visible light is essential for vision and daily life,

exposure to extremely bright light or UV radiation from the sun can damage the eyes and skin.

2.3.2.5 Ultraviolet (UV) Radiation: UV radiation, especially from the sun, is a non-ionizing form of radiation with a higher energy level than visible light. Prolonged exposure to UV radiation can damage the skin (e.g., sunburn) and increase the risk of skin cancer.

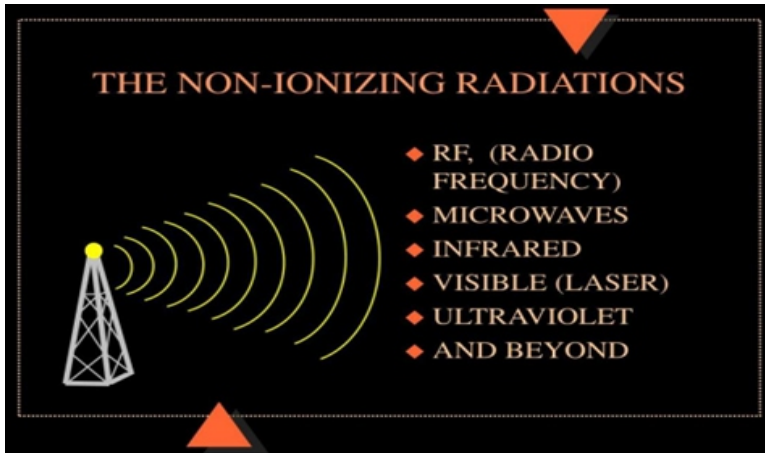


Figure 10: Non-Ionizing radiation

2.4 Sources of Radiation

Radiation comes from natural sources (earth and space) and artificial (man-made) sources e.g. medical equipment, cell phones, researches etc. Considerable amount of the radiation humans are exposed to come from natural sources.

2.4.1 Natural Sources of Radiation

Natural radiation, also known as background radiation, is radiation that has been part of the Earth's environment since the beginning of time (Al-Khawlanly et al, 2018). The primary sources of natural radiation include:

2.4.1.1 Cosmic Rays: These are high-energy particles from space (sun and star) that constantly enter the Earth. The atmosphere provides some shielding from cosmic radiation, but at higher altitudes (e.g., in airplanes or mountain regions), exposure to cosmic rays increases. Cosmic rays contribute to the natural background radiation we are exposed to daily.

2.4.1.2 Terrestrial radiation: The Earth's crust contains small amounts of

radioactive materials such as uranium, thorium, and potassium-40. These elements emit radiation as they decay. Depending on the geographical location, terrestrial radiation levels can vary, particularly in areas with high concentrations of these materials.

2.4.1.3 Radon. Radon is a naturally occurring radioactive gas formed from the decay of uranium in the Earth's crust. It is found in dwellings, especially in basements and poorly ventilated spaces. It is a significant source of natural radiation exposure and is the second leading cause of lung cancer after smoking.

2.4.1.4 Internal Radiation: Some radioactive elements, like potassium-40 and carbon-14, are naturally present in our bodies. These contribute to internal radiation exposure as they undergo radioactive decay. Although these levels are low, they are a part of the natural radiation we are exposed to.

2.4.2 Artificial Sources of Radiation

Artificial sources of radiation are those generated by human activities (Obed et al. 2005). Urbanization and technological advancement over the past centuries has significantly increased exposure to man-made radiation (Ademola et al. 2014). Major artificial sources of radiation include:

2.4.2.1 Medical Imaging: Medical procedures like X-rays, CT scans, and nuclear medicine rely on radiation to provide diagnostic images of the body. These procedures are invaluable for diagnosing diseases and guiding treatment. Medical imaging is the largest source of artificial radiation exposure to the general population.

2.4.2.2 Radiotherapy: In cancer treatment, radiation therapy uses high-energy ionizing radiation to destroy cancerous cells. While beneficial, it also presents the risk of collateral damage to healthy tissues.

2.4.2.3 Nuclear Power Plants: Nuclear reactors use controlled nuclear reactions to generate electricity. While modern reactors are designed with extensive safety protocols, accidents like Chernobyl and Fukushima have demonstrated the potential for harmful radiation releases into the environment.

2.4.2.4 Industrial Applications: Radiation is used in a variety of industrial applications, including non-destructive testing (e.g., checking for flaws in materials and structures), sterilization of medical equipment, and in research.

2.4.2.5 Consumer Products: Some consumer products, such as smoke detectors, metal detector, medical equipment, electronics and even some fertilizers, contain small amounts of radioactive materials. While these products contribute to radiation exposure, the levels are generally very low and regulated for safety.

Many industries, medical facilities, defense plants, and research laboratories make use of radiation in different ways and therefore demand professionals who understand radiation hazards and their prevention and control. The health physicist, who controls the beneficial use of radiation while protecting workers and the public from potential hazards, is mostly needed in many areas. The health physics profession is diverse and one of the most interesting and rewarding fields in the scientific world.

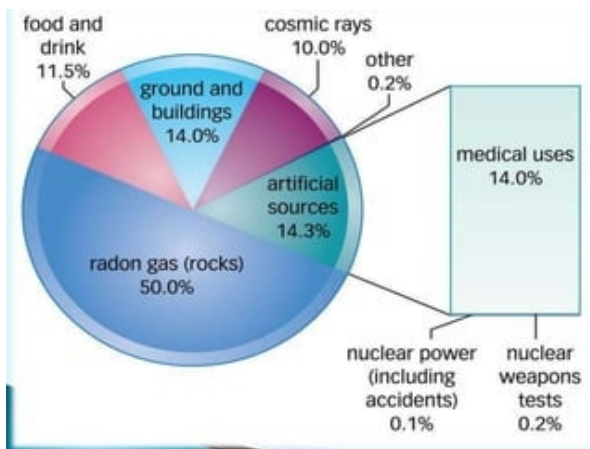


Figure 11: Sources of background radiation (UNSCEAR, 2000)

2.5 Exposure to Ionizing Radiation

Exposure to ionizing radiation can be in two ways.

- (i) Source of radiation external to the human body and
 - (ii) Internal irradiation due to ingestion of radioactive contamination (UNSCEAR, 2008)
- At high exposures, it can cause "tissue" effects, also called "deterministic" effects due to the certainty that it will occur.
 - For low level exposures there can be statistically elevated risks of radiation-induced cancer, called "stochastic effects" due to the uncertainty of them occurring.

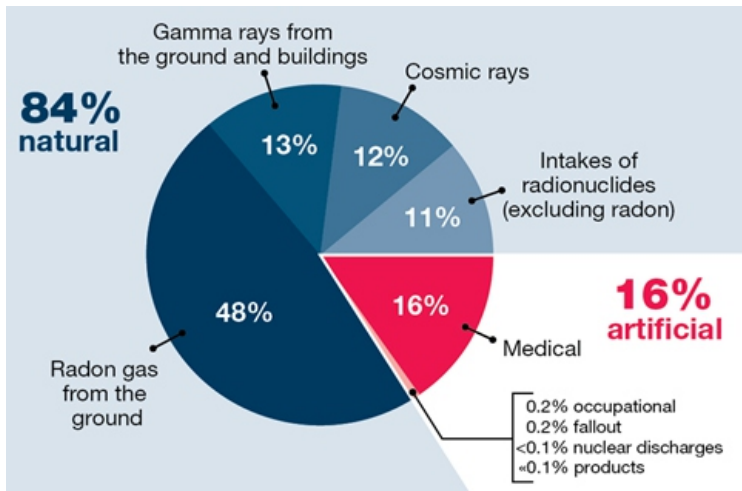


Figure 12: Total exposure to ionizing radiation

2.5.1 Types of Exposure

The International Commission on Radiation Protection (ICRP) recognizes 3 types of exposure which are as described below (ICRP, 2007)

2.5.1.1 Planned exposure —: radiological protection is planned in advance, before exposures occur, and where the magnitude and extent of the exposures can be reasonably predicted e.g. occupational exposure situations, where it is necessary for personnel to work in a known radiation environment.

2.5.1.2 Emergency exposure —: unexpected situations that may require urgent protective actions" e.g. emergency nuclear event.

2.5.1.3 Existing exposure —: this is an exposure that already exists when a decision on control has to be taken" e.g. naturally occurring radioactive materials which exist in the environment.

3.0 The Friend: Radiation's Role in Medicine and Technology

From diagnosing medical conditions to helping ensure the safety of our food, radiation is an essential part of various fields, playing a significant role in both medicine and technology.

3.1 Diagnostic Effects

One of the greatest contributions of radiation in medicine is its ability to help doctors visualize inside the human body without the need for invasive surgeries.

Some of the main diagnostic tools that employ the use of radiation are:

- 3.1.1 X-rays:** X-rays are made to pass through the body, create images of bones and other internal structures. This makes the job of Health Workers easier to diagnose fractures or dental issues. The radiation used is low, making X-rays safe when used in moderation.
- 3.1.2 CT scans:** A CT scan (Computed Tomography) is essentially a more advanced X-ray. It creates detailed cross-sectional images of the body by taking many X-ray images from different angles. CT scans provide far more detailed information, making it useful for spotting conditions like tumors, internal bleeding, or infections. Although the radiation dose is higher than that of a simple X-ray, the detailed images can be lifesaving.
- 3.1.3 Nuclear Medicine (PET Scans):** Positron Emission Tomography (PET) scans take things up a notch. A small amount of radioactive material is injected into the body, and this material gives off radiation as it travels through different organs. A scanner picks up this radiation and creates images, allowing Doctors to assess how organs and tissues are functioning. PET scans are incredibly useful in detecting cancers, heart conditions, and brain disorders.
- 3.1.4 Gamma rays** are also used in scanning the internal parts of the body
- 3.1.5 Radioactive Iodine - 131** is used as tracer in medicine to study the function of the thyroid gland thereby assisting in detecting thyroid-related diseases. Radioactive tracers are commonly used in the medical field and also in the study of plants and animals.

3.2 Therapeutic Uses

3.2.1 Radiation Therapy

Radiation therapy works by delivering high doses of ionizing radiation to target cancer cells. The aim is to damage the DNA in the cancerous cells, preventing them from growing and multiplying. While some healthy cells may be affected, doctors carefully plan treatments to minimize exposure to surrounding healthy tissue. Radiation therapy is often used alongside other treatments like chemotherapy or surgery. It plays a critical role in shrinking tumors or destroying cancerous cells entirely, making it one of the key tools in the fight against cancer.

There are two main types of radiation therapy:

- (1) **External Beam Radiation:** This is the most common form. A machine outside the body focuses radiation on the cancerous area.

- (2) Internal Radiation (Brachytherapy): In this method, small radioactive implants are placed inside or near the cancerous tumor. This allows for a much-targeted treatment, minimizing damage to surrounding tissues.

For example,

- (i) Gamma rays are used to kill cancerous cells and hence used in radiotherapy.
- (ii) Cobalt-60 is also used in radiotherapy to destroy carcinogenic cells.

3.2.2 Radiation in Sterilization and Food Safety:

Radiation also plays a significant but silent role in sterilizing medical equipment and ensuring food safety.

(I) Sterilizing Medical Equipment

Radiation is one of the most effective ways to sterilize medical tools in hospitals and clinics e.g. scalpels, syringes, and bandages to prevent infections. Radiation can penetrate sealed packages and sterilize items without leaving any residues behind unlike boiling or chemical disinfectants. This makes it especially useful for equipment that must remain sterile until it is used in surgeries.

(ii) Food Irradiation: Extending Shelf Life and Reducing Risk

Radiation is used to preserve food and keep it safe. The process is called food irradiation and uses ionizing radiation to kill harmful bacteria, viruses, and parasites that could cause food borne illnesses. It is an effective way to extend the shelf life of food products, especially those that need to be stored for long periods. Spices, meats, fruits, and vegetables are often irradiated to keep them fresh and safe without making them radioactive. This process reduces food waste and helps ensure the safety of the global food supply. For example, gamma rays are used to kill microbes present in food and prevent it from decay by increasing the shelf life.

3.2.3 Industrial Applications of Radiation

Beyond the medical and food sectors, radiation has found essential uses in industry in ensuring the safety of structures and powering our homes. Radiation is a powerful tool in technological applications in industry as follows:

(i) Non-Destructive Testing: Checking for Hidden Flaws

In industries like construction, manufacturing, and aerospace, it is essential to ensure the integrity of materials and structures without

causing damage. Just like doctors use X-rays to check bones; engineers use X-rays to look inside materials like metal or concrete. This method allows them to detect cracks, weak spots, or corrosion that could cause problems in the future. In airplane manufacturing, radiation is used to inspect engine parts to ensure they are strong enough to withstand extreme conditions. This testing prevents accidents and ensures the safety and reliability of structures, machinery, and vehicles.

(ii) **Energy Production: Nuclear Power**

Radiation also powers some of the world's energy needs. Nuclear reactors harness the energy released during nuclear fission—the process where atoms are split apart, releasing a tremendous amount of heat which is used to generate steam, that drives turbines and produces electricity.

This kind of nuclear energy produces a huge amount of power from a small amount of fuel, with much lower carbon emissions than fossil fuels like coal or oil. In this era of climate change and environmental concerns, nuclear energy is seen as a cleaner alternative to traditional fossil fuels.

However, safety is always a concern in managing radioactive waste and preventing accidents like those seen at Chernobyl and Fukushima.

Therefore, thinking of radiation, we often focus on its potential risks without judging from the truth that radiation is a powerful supporter in both medicine and industry; from diagnosing and treating diseases to ensuring the safety of medical equipment, food, and infrastructure, radiation plays a critical role in our modern world.

The key to maintaining radiation as a “friend” is careful management and respect for its power. When handled properly, radiation can continue to serve humanity in countless positive ways for generations to come.

4.0. The antagonist: Health Risks Associated with Radiation Exposure

Although radiation has numerous benefits in medicine and industry, it has also some probable hazards which should be noticed. When exposure is not properly controlled, radiation can become a serious threat to human health and also to the environment. Some of these dangers/risks are as follows:

4.1.1 Biological Effects of Ionizing Radiation

Ionizing radiation is powerful enough to damage the cells in the body. It can

remove tightly bound electrons from atoms, which may result to damage to DNA and other vital cellular components. The severity of these biological effects depends on the amount of radiation exposure, the duration of exposure, and the type of radiation.

Table 4.1 Biological effects of short-term radiation on humans

Dose (Rem)	Biological Effects
0-25	No detectable effect
25-100	Temporary decrease in white blood cells count
100-200	Nausea, vomiting, long-term decrease in white blood cells
200-300	Vomiting, diarrhea, loss of appetite, listlessness
300-600	Vomiting, diarrhea, hemorrhaging, eventual death in some cases
Above 600	Eventual deaths in nearly all cases

4.1.2 Direct DNA Damage and Potential Mutations

Ionizing radiation can directly damage DNA, the genetic array in every cell. When radiation passes through the body, it can break the chemical bonds in DNA strands, leading to mutations or cell death. Cells have repair mechanisms, but if the damage is too severe or frequent, the DNA may not be repaired correctly. This can result in mutations that may cause cells to grow uncontrollably, leading to cancer.

- (i) Mutations: Changes in DNA can affect how cells function. While not all mutations are harmful, some may lead to severe consequences, like cancer or genetic defects that can be passed on to future generations. Based on degree and duration of exposure, the biological effects of radiation can be classified into acute and Long-term health effects
- (ii) Acute Health Effects: Radiation Burns and Radiation Sickness
High doses of radiation over a short period can cause acute radiation syndrome (ARS), commonly known as radiation sickness. ARS occurs when the body receives a high dose of radiation in a short amount of time, such as during a nuclear accident.
- (iii) Radiation Burns: Intense exposure can cause severe burns to the skin, as seen in individuals exposed to radioactive materials or those near nuclear reactor accidents.
- (iii) Radiation Sickness: Symptoms of radiation sickness can vary based on

the level of exposure but often include nausea, vomiting, fatigue, and hair loss. Severe cases may lead to damage to internal organs, bone marrow failure, and death.

(iv) Long-term health Risks: Increased Risk of Cancer

Prolonged or repeated exposure to lower doses of radiation can lead to long-term health risks. The most concerning of these is cancer. When ionizing radiation causes mutations in cells, those cells can become cancerous over time.

4.2.2 Lung Cancer from Radon Exposure:

Radon, a radioactive gas that naturally occurs from the decay of uranium in the earth's crust, can accumulate in homes and buildings. Long-term exposure to radon is the second leading cause of lung cancer, especially for non-smokers.

4.2.3 Leukaemia and Other Cancers from High Radiation Doses:

Individuals exposed to high doses of radiation, such as survivors of atomic bombings or nuclear accidents, have an increased risk of developing leukemia and other cancers. The effects can appear years or even decades after the initial exposure.

4.3 Case Studies of Radiation Disasters

Throughout history, there have been several significant radiation disasters that highlight the devastating effects of uncontrolled radiation exposure. These events have not only caused immediate harm but also led to long-term health and environmental consequences.

(i) Chernobyl (1986): Long-Term Effects on Human Health and the Environment

The Chernobyl disaster is one of the most infamous nuclear accidents. It occurred in April 1986 at a nuclear power plant in Ukraine, then part of the Soviet Union. During a safety test, a reactor exploded, releasing large amounts of radioactive material into the atmosphere. The health and environmental consequences were severe and continue to this day. About 28 plant workers and emergency responders died within a few weeks from acute radiation exposure. Thousands more suffered from radiation sickness, burns, and organ damage. Hundreds of thousands of people were exposed to dangerous levels of radiation. The incidence of thyroid cancer, particularly among children, increased dramatically in the years following the disaster due to the release of radioactive iodine. Other cancers, including leukemia, and cardiovascular diseases have

been linked to radiation exposure from Chernobyl (UNSCEAR, 2007).

The area surrounding Chernobyl, known as the Exclusion Zone, remains largely uninhabitable. Radioactive fallout contaminated the soil, water, and ecosystems. Animals and plants in the region have shown mutations and other harmful effects due to long-term radiation exposure.

(ii) Fukushima (2011): Health Effects of Radiation Exposure and Community Displacement

The Fukushima nuclear disaster occurred in March 2011 after a massive earthquake and tsunami hit Japan, causing multiple reactors at the Fukushima Daiichi nuclear plant to fail. Radioactive materials were released into the air, water, and soil, leading to widespread contamination and the evacuation of tens of thousands of people. The radiation levels in the immediate aftermath were significant, though not as high as Chernobyl. While no immediate deaths from radiation exposure were reported, the long-term effects are still being studied. There has been an increase in cases of thyroid cancer among children exposed to radiation but there has been debate over whether these cases are directly linked to the disaster.

4.3.1 Effects of radiation disaster

(i) Community Displacement: More than 150,000 people were forced to leave their homes, many of whom have never returned. The psychological and social impacts of displacement—stress, depression, and disruption of social networks—have been profound and long lasting.

(ii) Environmental Impact: Radioactive contamination from Fukushima spread to the Pacific Ocean, raising concerns about the safety of marine life and fisheries. Although the levels of radiation have decreased over time, some areas near the plant remain off-limits due to lingering contamination.

In addition to the direct health effects, radiation exposure has serious implications for the environment. Radioactive contamination can persist for decades, affecting ecosystems, wildlife, and natural resources.

(iii) Radioactive Contamination of Soil and Water

When radioactive materials are released into the environment, they can contaminate soil and water sources, creating long-term hazards.

- (iv) **Soil Contamination:** Radioactive isotopes like cesium-137 and strontium-90 can become trapped in the soil, where they pose a risk to both plants and animals. These isotopes can be absorbed by crops, which then enter the food chain, potentially affecting humans.
- (v) **Water Contamination:** Radioactive materials can leach into rivers, lakes, and groundwater, making them unsafe for drinking or agricultural use. The contamination of water sources can spread radiation over large areas, affecting both human populations and wildlife.
- (vi) **Impact on Wildlife and Ecosystems:** Radiation affects wildlife and ecosystems in similar ways to humans, though the effects may take longer to manifest. In areas like Chernobyl and Fukushima, scientists have observed mutations in plants and animals, reductions in biodiversity, and disruptions to reproductive cycles.
- (vii) **Mutations and Health Effects:** Studies around Chernobyl have shown increased rates of mutations in animals such as birds, insects, and mammals. These mutations can lead to physical deformities, reduced fertility, and shorter life spans.
- (viii) **Ecosystem Disruption:** Radiation exposure can disrupt entire ecosystems. For example, in heavily contaminated areas, some species may die off or suffer from reduced populations, while others may thrive in the absence of human activity. This can lead to changes in the balance of predator and prey species, altering the natural ecosystem.

Radiation on the long run is an invaluable tool in medicine and technology but can become dangerous when exposure is uncontrolled. The biological effects of ionizing radiation, from DNA damage to cancer, highlight the need for careful management of radiation sources. The case studies of Chernobyl and Fukushima demonstrate the severe and long-lasting consequences of radiation disasters, not only for human health but also for the environment. By understanding the risks from past disasters, we can better protect our world from the harmful effects of radiation in the future.

5.0 Navigating the Risks: Radiation Safety and Regulation

Although radiation is beneficial in various fields of medicine, industry, and clean energy production, its potential health risks require strict safety measures.

Radiation safety is a concern for humans in many departments, including medicine (radiology, interventional cardiology, and surgery), industries (mining, agriculture, space exploration, well-logging etc), research (academic and

scientific applications) and nuclear plants. It involves adhering to principles that minimize exposure and adopting regulations designed to protect both workers and the public. Any radiation exposure poses a potential risk to humans

5.1 Radiation Protection Principle

Radiation protection is defined by the International Atomic Energy Agency (IAEA) as "The protection of people from harmful effects of exposure to ionizing radiation, and the means for achieving this". Radiation protection aims to reduce unnecessary radiation exposure with a goal to minimize the harmful effects of ionizing radiation.

The basic understanding of the science behind the damaging effects of radiation is crucial in evaluating the different strategies to protect humans and the environment.

The overarching goal of radiation protection is to manage exposure levels and minimize health risks without hindering the benefits. These principles are based on a few fundamental concepts among which is the '**As Low As Reasonably Achievable**' ALARA principle.

5.1.1 ALARA Principle:

The ALARA principle is the cornerstone of radiation protection. The fundamental of radiation protection is the avoidance or reduction of dose using the simple protective measures of time, distance and shielding.

- (I) Time:** Reducing the time of an exposure reduces the effective dose proportionally. The less time spent near a radiation source, the lower the exposure. Limiting exposure time is especially important in settings like hospitals, research facilities, and nuclear power plants. For example, technicians operating X-ray machines or workers in nuclear plants are trained to limit the duration of their exposure to radiation.
- (ii) Distance:** Increasing distance from the source reduces dose due to the inverse square law. The farther from the source of radiation, the lower the exposure. This is because radiation intensity decreases with distance. In situations where time and exposure cannot be reduced, maintaining a safe distance is a vital protective measure.
- (iii) Shielding:** Sources of radiation can be shielded with solid or liquid material, which absorbs the energy of the radiation to reduce the radiation to a safe level for humans. The shielding materials may be concrete or lead shield which is 0.25mm thick for secondary radiation and 0.5mm thick for primary radiation. Lead aprons are commonly used

to protect patients from unnecessary exposure during X-rays or CT scans. In industrial applications, thick concrete walls may surround nuclear reactors to prevent radiation from escaping into the environment.

By adhering to ALARA principles, industries and healthcare providers can continue to use radiation while keeping exposure levels within safe limits.

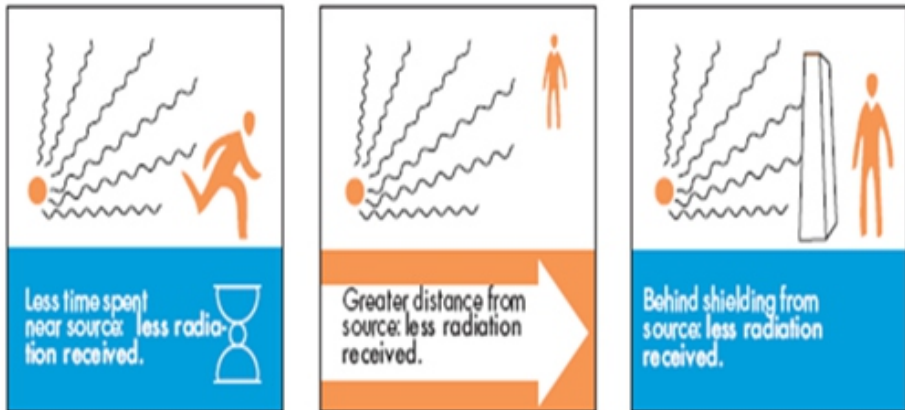


Figure 13: ALARA Principle

5.1.2 Regulation of dose uptake

The ICRP uses the following overall principles for all controllable exposure situations.

- (i) Justification: No unnecessary use of radiation is permitted, which means that the advantages must outweigh the disadvantages.
- (ii) Limitation: Each individual must be protected against risks that are too great, through the application of individual radiation dose limits.
- (iii) Optimization: This process is intended for application to those situations that have been deemed to be justified

5.1.3 Interlock Systems

A radiation safety interlock system is a device that automatically shuts off or reduces radiation emission rate from radiation-producing equipment (gamma or X-ray equipment or accelerator).

The purpose of a radiation safety interlock system is to prevent worker exposure and injury from high radiation levels. For applications involving high-energy radiation sources, a system with interlock keys can control access or prevent

entry into a radiation treatment room or during accelerator operations.

5.1.4 Administrative controls

Administrative controls generally supplement engineering controls (shielding and interlock systems). Administrative controls include signage, warning systems, and written operating procedures to prevent, reduce, or eliminate radiation exposure. Operating procedures typically include both normal operating procedures and emergency procedures (i.e., those for spills, leaks, and emergency evacuation).

- (i) Each radiation area must be conspicuously posted with a sign or signs with the radiation caution symbol (Figs 14a-d). For instance, the words: Caution Radiation Area (29 CFR 1910.1096(e)(2) indicate areas where a major portion of the body could receive a dose in excess of 5 mrem per hour, or in any 5 consecutive days a dose in excess of 100 mrem.
- (ii) Each high radiation area must be conspicuously posted with a sign or signs with the radiation caution symbol and the words: Caution High Radiation Area (29 CFR 1910.1096(e)(3) Fig 14b. Indicating areas where a major portion of the body could receive a dose in excess of 100 mrem per hour.
- (iii) Each airborne radioactivity area must be conspicuously posted with a sign or signs with the radiation caution symbol and the words: Caution Airborne Radioactivity Area (29 CFR 1910.1096(e)(4) (Fig 14c)
- (iv) A sign with the wording Caution Radioactive Material (29 CFR 1910.1096(e)(5)) is required in each area or room in which radioactive material is in use or stored, and which contains any radioactive material (Fig 14d)



Figure 14a: Ionizing radiation sign indicating a body receive a dose in excess of 5 mrem per hour



Figure 14b: Radiation symbol indicating a major portion of the body could receive dose in excess of 100 mrem per hour



Figure 14c: Radiation sign indicating airborne radioactivity area



Figure 14d: Radiation symbol indicating radioactive materials in use or stored

5.1.5 Warning Systems

Warning systems are integrated into the design of radiation-producing equipment or devices and can also be used with radioactive materials. Such warning systems will set off an audible alarm to warn workers that a radiation hazard exists or a visible light warning signal whenever ionizing radiation is being emitted.

5.1.6 Dose Limits: Regulatory Oversight

To ensure safety of humans and the environment, various international and national organizations set dose limits for both occupational and public exposure to radiation. These limits are crucial for guiding safe practices in medical, industrial, and environmental contexts.

5.1.6.1 ICRP and National Safety Authorities

The ICRP is one of the leading bodies that establish radiation safety guidelines worldwide. They provide recommendations on dose limits for workers and the public, which are adopted by national regulatory authorities as follows:

- (i) **Occupational Exposure:** For those who work with radiation regularly, such as radiologists, nuclear plant workers, and researchers, the ICRP recommends an annual dose limit of 20 millisieverts (mSv) averaged over five years, with no single year exceeding 50 mSv (ICRP, 2007). National authorities often adopt these guidelines, with adjustments based on local regulations and specific industries.
- (ii) **Public Exposure:** For the public, the dose limit is significantly lower, set at 1 mSv per year for continuous exposure. This limit ensures that people living near nuclear facilities, receiving medical treatments, or being exposed to naturally occurring sources like radon gas are adequately protected.

The ICRP's guidelines also emphasize the importance of justification (any

decision that involves exposure to radiation must be beneficial) and optimization (exposure should be kept as low as possible while still achieving the desired results).

5.6.1.2 Medical Safety Protocols

Medical safety protocols are designed to protect both patients and healthcare workers from unnecessary exposure while still allowing the effective use of radiation for medical purposes.

Reducing unnecessary exposure in medical diagnostics medical imaging technologies such as X-rays, CT scans, and nuclear medicine rely on radiation to produce detailed images of the body. However, protocols are in place to minimize exposure, ensuring that patients receive only what is necessary for accurate diagnosis.

- (i) **Lead Aprons and Shields:** During imaging procedures like X-rays or CT scans, patients are often provided with lead aprons or shields to protect parts of the body that are not being scanned. For example, a lead apron may be placed over the abdomen to protect reproductive organs from unnecessary exposure.
- (ii) **Minimizing Repeat Scans:** One of the best ways to reduce radiation exposure is by avoiding unnecessary repeat scans. Radiologists and technicians are trained to ensure that scans are performed correctly the first time, using the minimum radiation dose necessary to obtain a clear image. Advanced technologies also now allow for dose modulation, where the scanner automatically adjusts the dose based on the part of the body being examined.
- (iii) **Radiation Monitoring for Medical Staff:** Healthcare workers who operate radiation equipment wear dosimeters, small devices that measure the amount of radiation they are exposed to over time. This helps ensure that their exposure remains within safe limits and allows for corrective actions if exposure levels are too high.

By carefully following these safety protocols, healthcare providers can limit the risks of radiation exposure while still providing effective and accurate care.

5.6.2 Public Awareness and Education

One of the key aspects of radiation safety is ensuring that the public is informed about the potential risks and protective measures. Public education initiatives help people understand everyday radiation sources and how to minimize their exposure.

(I) Risks of Indoor Radon

Radon is the largest contributor of natural sources to the exposure of members of the public, contributing up to half of the total exposure from all sources (UNSCEAR, 2008). Most exposure to radon and terrestrial gamma radiations resulted from living indoors. Long-term exposure to radon, particularly in poorly ventilated areas, can significantly increase the risk of lung cancer.

(ii) Public Education on Radon:

In many countries, public health organizations encourage homeowners to test for radon levels, especially in basements or ground-floor living spaces. Simple radon testing kits are available, and if levels are found to be high, measures like improving ventilation or sealing cracks in the foundation can reduce exposure.

(iii) Environmental Radiation and Safety

Public awareness campaigns also focus on other environmental sources of radiation, such as those resulting from nuclear power plants or industrial activities. Safety drills and emergency preparedness plans are critical in areas near nuclear facilities, ensuring that people know what actions to take in the event of a radiation emergency.

Educating the public about these risks and providing clear guidelines on how to mitigate them is a key step in ensuring overall radiation safety.

5.6.3 The International Atomic Energy Agency (IAEA)

The International Atomic Energy Agency (IAEA) plays a leading role in setting global standards for nuclear safety. The IAEA works with countries around the world to ensure that nuclear energy is used safely and responsibly. Its initiatives include:

- (a) Nuclear Safety Guidelines: The IAEA establishes international safety standards for the construction and operation of nuclear facilities. These guidelines are designed to prevent accidents and minimize the release of radioactive materials.
- (b) Disaster Response: In the event of a nuclear disaster, the IAEA coordinates global responses to minimize the impact on human health and the environment. They provide technical assistance to affected countries and facilitate international communication and aid.

5.6.4 Preventing Radiation-Related Disasters

Many countries have adopted stringent safety measures in the wake of nuclear disasters like Chernobyl and Fukushima. These include:

(i) Strengthening Reactor Designs:

Modern nuclear reactors are built with multiple layers of safety measures to prevent accidents. These include improved cooling systems, reinforced containment structures, and fail-safe mechanisms that automatically shut down the reactor in the event of a malfunction.

(ii) Emergency Preparedness:

Countries with nuclear facilities are required to have comprehensive emergency preparedness plans in place. This includes clear evacuation routes, radiation monitoring systems, and public communication strategies to ensure that residents are protected in case of an emergency.

(iii) Public education and global initiatives play a crucial role in navigating the challenges of radiation safety, ensuring that both individuals and communities are informed and protected potentially harmful effects.

Public fears of radiation stem from misunderstandings. People are unaware of the fact they are exposed every day to natural sources of radiation, like radon gas and cosmic rays, or the fact that medical radiation is tightly controlled and regulated to minimize risk.

6.0 My contributions

Vice-Chancellor sir, the profession known as health physics came into existence in 1942, when a group of physicists were working on the first nuclear reactor and noticed deterioration in the health of project workers and the general public due to emission from the reactor. As a result, they took on the responsibilities of coping with the radiation hazards using different methods and so health physicists were born.

Sir, my research in the last 2 decades focused on the protection of people from harmful effects of exposure to ionizing and non-ionizing radiation (Natural and/or Manmade).

The following summaries a selection of my scholarly contributions to the fields of *Radiation and Health Physics*, with a specific focus on environmental radioactivity, radon exposure, food safety and toxicology and medical physics.

A. Environmental radioactivity

In the course of my research in the field of environmental and mining radiation, it was observed that studies on radionuclide concentrations in mines have been extensively studied in Nigeria but mining activities have not been subjected to radiological regulatory control and so there is generally little or no awareness

and knowledge of the radiological hazards and exposure levels to NORMs in mining areas.

(i) The concentration and distribution of natural radionuclides in marble around Igbeti marble mines, was investigated to evaluate the health effects which the marble samples may possess (Ademola et al. 2008). The study was carried out using gamma-ray spectrometry with NaI (TI) detector. The measured values of the activities of ^{226}Ra , ^{232}Th and ^{40}K in the marble samples were found to lie in the ranges 2.0–2.7, 0.3–1.2 and 5.7–7.3 Bq/kg, respectively. The samples were also found to have radium equivalent activity in the range 3.4–4.6 Bq/kg, external hazard indices of 0.009–0.012 and internal hazard indices of 0.014–0.019. The estimated representative (Igr) hazard index was 0.028. The measurements show that marble samples from Igbeti mine have low level of natural radioactivity and therefore the use of these types of marble in construction of dwellings is safe for inhabitants.

(ii). [Tantalite is the main source of tantalum, a metal known for its corrosion resistance and high melting point. It is a valuable material in electronics and aerospace applications.](#) Ademola and Obed, (2012) carried out a study on gamma radioactivity levels in soil samples in four tantalite mining sites in Upper-Ogun area, South-Western Nigeria using NaI (TI) detector. The measured values of the activities of ^{40}K , ^{226}Ra and ^{232}Th ranged from 123.7 ± 3.8 – 1372.3 ± 8.6 , 16.8 ± 1.6 – 71.1 ± 2.53 and 3.0 ± 0.7 – 31.9 ± 1.0 Bq/kg, respectively. The radium equivalent activity in the range 74.2–121.0 Bq/kg and the annual effective ranging from 70.3 ± 13.5 to 100.8 ± 42.8 μSv with a mean of 87.5 ± 18.6 $\mu\text{Sv/y}$. This value is about 25% higher than the world average of 70 μSv (UNSCEAR, 2000) and is also higher than the average of 62.9 μSv for South-Western cities in Nigeria (Farai et al., 2006). From the results obtained, it was revealed that the distribution of radionuclide was not uniform. Also, no artificial radionuclide was detected in any of the measured soil samples.

(iii) Ademola, et al. (2014) carried out the activity concentrations of natural [radionuclides](#) in soil samples from the gold mining area in Itagunmodi, Ilesa, Osun State using gamma [spectrometry](#) method. In the research, Itagunmodi was divided into five divisions. Four divisions (A – D) in the gold mining site and one division (E) in an undisturbed land where people live about 10 km from the mining site. This was done so that the activity concentrations in the mining site can be compared to the living area.

Radiological hazard from the mining sites showed that the average activity

concentrations of ^{238}U , ^{232}Th and ^{40}K were 55.3 ± 1.2 , 26.4 ± 2.7 and 505.1 ± 7.1 Bqkg^{-1} , respectively while in the normal living areas it was respectively 8.8 ± 1.9 , 17.5 ± 2.7 and 102.8 ± 12.1 Bqkg^{-1} . The mean annual effective dose in the mining site was $81.3 \mu\text{Sv}$ which is about 16% higher than the world average of $70 \mu\text{Sv}$ as shown in Table 1; meaning that there is high level of the natural radionuclides in the mining areas than the worldwide average

Table 1: Mean absorbed dose rate (*D*) and effective dose (*E*) estimated for the mining and living areas in Itagunmodi.

Locations	<i>D</i> (nGyh ⁻¹)	<i>E</i> (μSv y ⁻¹)
A	60.5 ± 6.1	74.2 ± 3.8
B	67.8 ± 4.2	83.1 ± 5.1
C	66.7 ± 6.3	81.8 ± 6.7
D	70.1 ± 3.5	86.0 ± 4.5
Mean (mining areas)	66.3 ± 4.1	81.3 ± 5.0
E (mean living areas)	20.4 ± 2.1	25.1 ± 1.5

World Average54.0 70.0

(iv) **Ademola** et al. (2017) assessed the natural radioactivity levels in cement samples commonly used for construction in Lagos and Ogun state, Nigeria.

The activity concentrations of natural radionuclides ^{238}U , ^{232}Th and ^{40}K in the cement samples used for construction in Lagos and Ogun State Nigeria was measured using standard method involving gamma spectrometry of a well-type NaI(Tl) detector. The average activity concentrations of ^{238}U , ^{232}Th and ^{40}K determined in the samples were 2.16, 7.82 and 114.3 Bq/kg respectively. The mean absorbed dose rate, the mean annual effective dose, excess lifetime cancer risk and annual gonadal equivalent dose in the samples analyzed were 9.59 nGy/h , 17.66 $\mu\text{Sv/y}$, 67.99 $(\text{MPY})^{-1}$ and 69.07 $\mu\text{Sv/y}$ respectively. The results obtained indicated that cements produced in this part of the country are safe and considered to have negligible radiological impact on the health of the individuals exposed to them.

(v) The activity concentration of naturally-occurring radioactive materials present in the soil, vegetables, and food crops and their transfer factor (TF) in

some high background areas of northern parts of Oyo state, Nigeria, were measured using gamma spectrometry (**Ademola, 2019**). The study area, is naturally endowed with varieties of mineral deposits; tantalite, aquamarine, marble and dolomite which contributed enormously to the economic progress of the region. These stones are of granite type and may contain a relatively high concentration of natural radioactivity. The area is also known as the food basket of Oyo state because the land is rich and is suitable for agricultural purposes. So with mining activities ongoing in these areas, there is the possibility of high background radiation, which may be transferred to food crops cultivated in the areas through root uptake and deposition of dust on plant leaves and stems.

Farmlands within 2–3 km distance to the mining sites were sampled. Soil, food crops (yam, cassava, and maize), and vegetables (tomato, okra, wild lettuce, and coriander leaf) samples were collected from farmlands in the study area.

The average concentrations of ^{226}Ra , ^{228}Ra , and ^{40}K in soil samples were within the limit of the world average except for ^{40}K which was slightly higher. The average concentrations of ^{226}Ra , ^{228}Ra , and ^{40}K in vegetables and food crops were found to be lower than the values obtained in similar research in Nigeria. Wild lettuce and cassava had the highest concentration of radionuclide among others investigated in the study area.

The soil-to-plant TF for ^{226}Ra , ^{228}Ra , and ^{40}K measured in vegetables are higher than the values obtained in food crops but were within the world average. Therefore, consumption of these vegetables and food crops may not pose any radiation hazard to the consumers and the general population. It is therefore recommended that similar research be carried out at interval to detect the concentration of radionuclides in soil as well as in food crops and their TFs calculated for radiological and dosimetric purposes as the use of fertilizer in farming is on the increase worldwide which may affect the quality of the products adversely in terms of radionuclides migration into the food crops.

(vi). **Ademola A.K (2018)** studied the concentration of natural radionuclides and heavy metals in 12 different brands of chalk products commonly used in schools and colleges in Oyo State, Nigeria to estimate the hazard risks that may occur from the ingestion of chalk dust through inhalation. In the study, NaI(Tl) spectrometry was used to determine radionuclides and FAAS was used for heavy metal analysis.

The annual effective dose rate obtained and the annual gonadal dose equivalent (AGDE) were found to be less than the recommended values of the International

Commission on Radiological Protection. The fatal cancer risk estimated from the ingestion of radionuclides through inhalation of chalk dust is lower than 2.5×10^{-4} which is standard. The heavy metals analysis results show that (Pb) and Calcium (Ca) are present at high concentration in all the chalk samples. The study revealed that the general public is safe from the radionuclide impact of the chalk-dust but the presence of Pb and Ca from Calcium sulfate or calcium carbonate in the chalk samples is harmful as its deposition in the lungs may cause interstitial pneumonia with multiple bullae throughout the lungs, including the lower lobe. Hence the users and the general public must be aware of the health effect of exposure to these toxic metals from the chalk dust.

(vii) Radiological Risks from Natural Radionuclides in Surface Soil of Agbara Industrial Area, Ogun State, Nigeria were investigated using A 7.6 x 7.6 cm² NaI (TI) manufactured by Bicron Electronics Ltd, USA. The absorbed dose rate, effective dose and cancer risk was estimated using standard models. The contamination factor and Pollution level Index of the soil samples were also estimated.

The mean concentrations of ²³²Th and ⁴⁰K were above the world average. The absorbed dose rate and the effective dose were found to be higher than the recommended level. The estimated Cancer risk is high in the area, indicating a high probability of developing cancer from inhalation of soil gas in the long term. The results of the contamination showed that the area is contaminated with Th-232 and K-40. The pollution level index indicated a drop in the quality of soil for agricultural and building purposes.

The soil is moderately polluted with ²³²Th and ⁴⁰K. The Pollution Level Index indicates a drop in soil quality in about 50% of the areas covered. Cancer risk from inhalation of dust from the soil is high in the area.

B. Radon Researches in the Environment

It is a well-known fact that inhalation of alpha particles from ²²²Rn and its associated decay products cause morbidity in humans and it is recognized as a worldwide problem and a significant risk factor for lung cancer.

(i) **Obed et al. (2010)** conducted a survey of Rn using passive type radon monitors (CR-39) in offices in Nigeria oldest university campus in order to estimate the effective dose to the occupants over a period of 3 months.

CR-39 was exposed for 3months in offices selected randomly in the University. The detectors were removed and processed. Based on the processing, the

arithmetic mean and standard deviation of the ^{222}Rn concentrations were obtained as 293.3 and 79.6 Bq/ m³, respectively. The values of radon concentration obtained were below the upper value of the ICRP reference level of 1500 Bq/m³ for workplaces. The mean annual effective dose to the public from Rn was calculated to be 1.85 mSv/y. The result obtained is higher than the mean value of 0.049 mSv/y that was estimated to be the effective dose due to soil radioactivity in Ibadan. Therefore, the risk from radon is found to be higher than that from (outdoor) terrestrial radiation.

The commonest combination as covering materials for the walls, ceilings, and floors were considered and they are paint, paint, and carpet (A); paint, paint, and ceramic tile (B) paint, paint, and linen (C), respectively. The average radon concentration in offices with combinations (A) and (C) were about the same, while that for offices with combination (B) was a little higher. A person working in an office with combination (B) receive an average annual effective dose that is higher (by a small amount 0.04 mSv) than one working in an office with combinations (A) and ©.

(ii) An indoor radon survey was carried out in 77 dwellings randomly selected in 10 districts in Oke-Ogun area of Oyo state, South-western Nigeria using CR-39 detectors (poly allyl diglycol carbonate) to determine the annual effective dose and excess lung cancer risk (Obed et al., 2011) The CR-39 detectors were placed in the bedrooms and living rooms and exposed for 6 months. Annual radon concentrations in the dwellings were found to range from 77 to 627 Bq/m³ with mean vales of 255 ± 47 and 259 ± 67 Bq/m³ in living rooms and bedrooms, respectively. The dose received by dwellers lies below the 10 mSv/y. The frequency distribution of radon in all the locations in the dwellings is shown in Figure 1.

It was found that 77 % of the houses monitored showed radon concentration between 0 and 200 Bq m⁻³, 19 % showed concentration between 200 and 400 Bq m⁻³ and 2.3 % showed concentration between 400 and 500 Bq m⁻³. This large variation of the indoor radon activity between different dwellings is due to the different ventilation rates, nature of the soil underneath and particularly the geological formations.

The values of annual effective doses thus calculated for radon inhalation by the inhabitants were found to vary in the range 1.9–15.7 mSv with a mean of 6.4 ± 2.8 and 6.5 ± 3.1 mSv in living rooms and bedrooms, respectively. The effective dose and the excess lung cancer risks were estimated as 6.5 mSv and 25.2 (MPY)⁻¹,

respectively. According to UNSCEAR, the worldwide average dose due to inhalation of radon and its decay product is 1.15 mSv/y, while the internal and external exposure to all natural radiation sources amounts to 2.4 mSv/y. Therefore, the dose received by the dwellers is about three times higher than the natural one

(iii) Radon measurements by nuclear track detectors in secondary schools in Oke-Ogun region, Nigeria was carried out to complete radon measurement in the area (Obed et al., 2011). Radon measurements were performed in 35 secondary schools using 70 solid state nuclear track detectors (SSNTDs) for 3 months during the rainy season from May to July 2008. The period between May and July is characterized with heavy rainfall in south western, Nigeria and during this period, windows and doors are usually closed and the radon readings are expected to be at their highest. After etching and processing with digital microscope, the radon concentration was determined at the Radioactivity Laboratory, Department of Physics, University of Trieste, Trieste, Italy. The overall average radon concentration in the surveyed area was $45 \pm 27 \text{ Bq m}^{-3}$. The arithmetic mean concentration was below the ICRP intervention limit for work places. The results indicated no radiological health hazard. The variation of radon concentration levels with the floors (Figure 2) confirmed the influence of soil as the main source of indoor radon

It was concluded that radon concentration levels in homes are more than in the school due to:

- (i) Ventilation in school building
- (ii) Total time spent in school is lower than the time spent at home

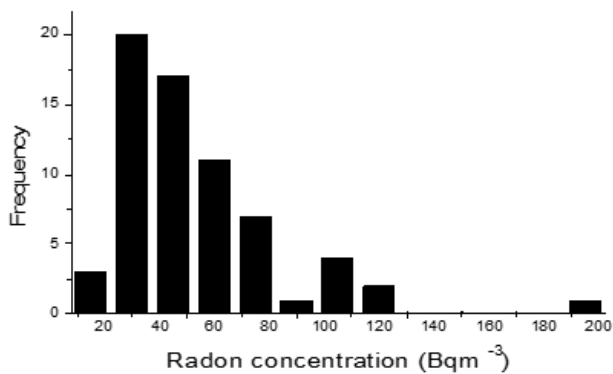


Figure15: Frequency distribution of radon concentration schools

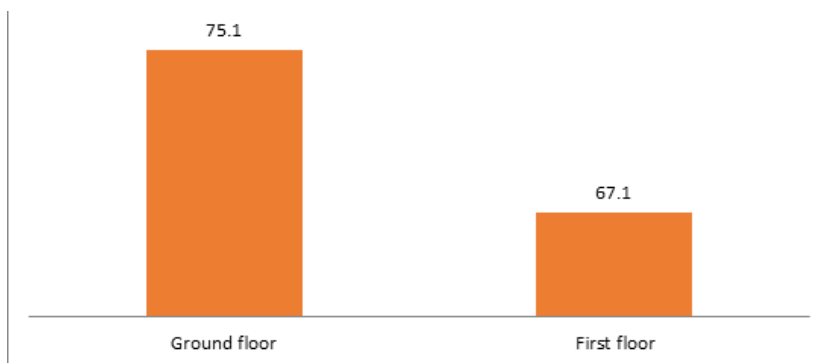


Figure 16: Comparison of radon concentration in floor levels

(iv) Measurement of concentration of radon gas was investigated in Bells University of Technology campus in Nigeria to determine the health risk of the workers in the community (**Ademola** et al., (2015). Seventy- eight offices were statistically selected for the measurement from all the Colleges. Measurements were performed using passive radon dosimeters comprising (CR-39) solid state nuclear track detector, for a period of six months.

The detectors were chemically etched, tracks were counted and radon concentrations were statistically determined. The mean radon concentration and the effective dose obtained in this work were 18.8 Bq/m^3 and 0.02 mSv/y , respectively. The mean value for excess lung cancer risk was estimated to be 0.08 (MPY)^{-1} . When the results were compared with the published data and international references, the results obtained in the study were found to be within the safe limits. The variation in indoor radon activity in different offices was due to different ventilation rates and the geological formation of the soil underneath the different offices.

(v) **Ademola** and Obed (2016) carried out a study to investigate an association between indoor radon concentration and radium (^{226}Ra) in the underlying soil in the corresponding houses sampled for the study. The concentration of natural radioactivity in soil and indoor radon concentration in 116 corresponding houses, were measured.

The indoor radon measurement was carried-out using Nuclear Track detectors (NTDs) CR-39 (Poly ally diglycol carbonate) manufactured by Track Analysis Systems Ltd. (Bristol, UK). The radioactivity measurement was performed with a well calibrated 7.6 cm by 7.6 cm NaI (TI) detector manufactured by Bicron and calibrated using a reference standard gamma source (No. 48722-356) by

Atlantic Inc., Atlanta, GA, USA.

A correlation analysis was performed with the results obtained, between the specific $^{238}\text{U}/^{226}\text{Ra}$ content in soil (X) and the measured indoor radon concentration (D) in the surveyed houses. The model yielded a correlation factor of 0.702

$$D = 6.205X + 20.91$$

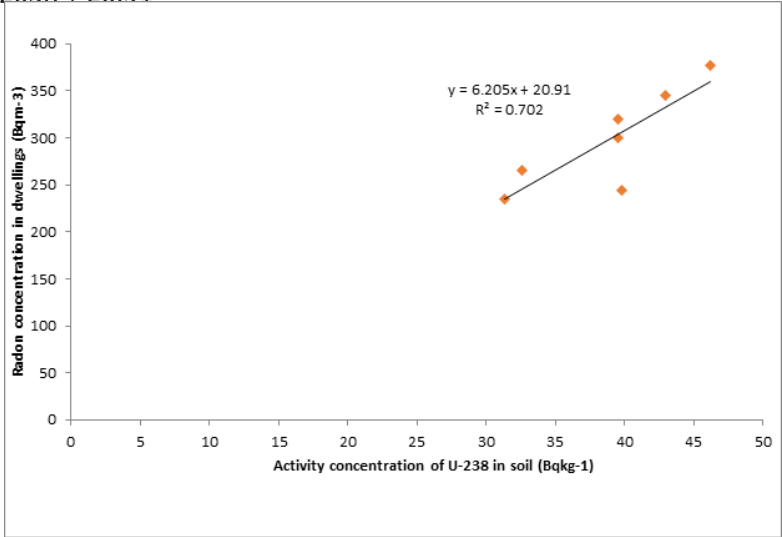


Figure 17: Correlation of Radium-226 in soil to Radon-222 in air

This finding is in good agreement with those of other studies in literature (Al-Jarallah, 2001, Saad et al, 2014, Salih et al. 2014) which drew attention to soil as a major source of indoor radon accounting for 70.2% of the total radon concentration in the houses surveyed. Other contributors are water, domestic gas, building material and covering materials like paint, wall paper etc

(C) Radon in water

(i) Jidele et al, (2021) investigated the concentrations of radon and some potentially toxic elements in drinking water in Ota; an industrial hub of south-western Nigeria. Twenty (20) water samples (ten each at residential (S1- S10), and industrial (T1-T10) areas respectively) were randomly collected. 0.5L of water sample from each area was collected in a clean bottle, sealed with masking tape to prevent escape of radon from the water and transported to laboratory where radon concentration was measured using RAD-7 and Atomic Absorption Spectrometer for potentially toxic elements.

Radon concentration in the samples varied from 2.3 to 34.5 Bq L⁻¹, with a mean of 7.7 Bq L⁻¹. The committed annual effective doses due to the ingestion of radon varied from 0.017 to 0.252 mSv/y with mean dose of 0.056 mSv/y. It was observed that 15% of the samples have radon concentration above the action level recommended by the United States Environmental Protection Agency.

The mean concentration of potentially toxic elements in the water samples were 0.02, 0.014, 0.048, 0.010 and 0.003 mgL⁻¹ for Cd, Pb, Se, Cr and As, respectively. The concentrations of Pb, Se and As were higher than the WHO permissible limit. This study revealed high concentration of some potentially toxic elements in water of the study areas which may have some delirious effects on the consumers.

(ii) Dosunmu et al. (2022) measured radon concentration and estimate excess lifetime cancer risk in water-well samples along Iwaraja-Ifewara faults Southwestern, Nigeria

In this study, drinking water from underground water wells were selected in towns along Iwaraja-Ifewara fault line in southwestern, Nigeria. Twenty (20) water samples were collected within 50 m to 150 m at the fault line. RAD-7 was used for the radon concentration measurement. Radiation doses due to ingestion and inhalation of radon were determined as well as excess cancer risk.

Radon concentration in this study ranged from 5.0 to 400.1 Bq/l with a mean value of 45.78 ± 85.93 Bq/l. Radon concentration obtained is higher than US EPA recommended limit of 11.1 Bq/l in 70% of the samples. The excess lifetime cancer risk (ECLR) due to inhalation from the water samples was found to be higher than the world average. Therefore, it is recommended that deep wells should be dug far from the fault lines, and systematic measurements of radon level be carried out before consumption of the water especially in Iwaraja.

(iii) Ground and surface water within Ojo local government area of Lagos state were investigated for radon concentration to ascertain its safety for consumption. Sixteen groundwater and surface-water samples (wells, boreholes, and sachets) were collected from six different locations within the study area. The water samples were collected in 75cl plastic bottles sterilized with distilled water to avoid contamination. Water samples were then taken to the laboratory for the analysis of radon levels using a RAD7, produced by the DurrIDGE Company in the USA.

The radon level in the water is higher than the safe limits of 11.1 Bq/L, as per EPA

regulations, except for two sample points from the studied areas. The total annual effective doses from ingestion and inhalation were higher than the safe limit (0.1 mSv/y) that is recommended by the World Health Organization and the European Union Commission (Mostafa Mostafa et al., 2022).

The results of this study underline the importance of the development and updating of databases regarding radon levels in drinking water in Nigeria.

(D) Radioactivity and heavy metals in dumpsites and health hazard

Human activities generate wastes and industrialization and population increment in most cities in Nigeria results in changing the composition and quality of waste generated. Soil from waste dumpsites contains heavy metals and naturally occurring radionuclides in significant amount. Therefore, Hazardous waste can cause pollution, damage to health and even death.

(i) Investigation of the activity concentrations of NORMs in the representative soil samples from ten (10) industrial dumpsites in Ota was carried to estimate the absorbed dose rates and the effective dose from exposure to natural radionuclides and heavy elements (Ademola et al., 2014)

A total of 10 samples were collected from each dumpsite at a depth of about 20-30 cm at various locations. The samples were processed following the standard procedures and placed in a plastic container hermetically sealed for 30 days for secular equilibrium to take place. The analysis of radionuclide concentrations was performed by gamma ray spectrometry with sodium iodide detectors. The main material used in the determination of the elemental composition of the samples was the Flame Atomic Absorption Spectrophotometer.

The results of this study revealed that the average outdoor gamma radiation due to the activity concentrations of the radionuclides from the samples from are lower when compared with the results obtained for normal living areas in the same region. Ra-226 was not detected in all the samples and others were within the safe limit. However, no matter how small radiation exposure could be, it has effect on human being and exposure to this radiation must be reduced.

The results of heavy metal concentrations in the soil show the presence of heavy metals with cadmium and copper having concentrations above their natural range in the soil. These metals are regarded to be toxic at higher concentrations. Therefore, it is imperative to monitor heavy metal accumulation in soil samples before inhabitants can cultivate the land around the dumpsites for agricultural purposes to prevent the transportation of these metals into human system.

(ii) **Ademola** et al. (2015) studied the natural radionuclide and heavy metals in some major dumpsites in Lagos and Ogun State to evaluate the hazards they may have on the public.

Five popular waste dumpsites in the two states (Olusosun, Ojo, Igando, Ogijo and Agbara) were selected for this study. Ten (10) soil samples were collected from each dumpsite. The radionuclide analysis was performed using 7.6 x.7.6 NaI(Tl) spectrometer and the potentially toxic metal were analyzed using Flame Atomic Absorption Spectrophotometer

The mean activity concentrations of ^{226}Ra , ^{232}Th and ^{40}K in the samples were 23.1 ± 2.5 , 35.1 ± 2.1 and 318.9 ± 27.4 Bq/ kg, respectively in Ojota, 32.1 ± 6.1 , 44.2 ± 16.0 and 377.4 ± 9.0 Bq/ kg in Ojo, 18.2 ± 4.8 , 28.4 ± 3.1 and 340.9 ± 12.1 in Igando, 26.3 ± 9.0 , 38.1 ± 1.1 and 531.1 ± 23.0 in Agbara and 15.3 ± 3.6 , 22.3 ± 1.7 and 840.9 ± 42.0 in Ogijo. It was shown that ^{40}K concentrations in this area were higher than the world average.

The analysis of the heavy metal concentrations indicated the presence of Cadmium, Zinc and Copper in the soil samples and their concentrations were above the natural range in the soil. Cu is also found in soil sample from Ojo Scrap yard in high concentration. These metals are toxic at higher concentrations and may cause severe problem with prolonged exposure.

It is concluded that the practice of cultivating the land around the dumpsites for planting vegetables and legumes by farmers must be discouraged to prevent the transportation of these toxic metals into human system.

(iii) This study measured indoor radon in some buildings in the vicinity of dumpsites in Lagos, Nigeria to estimate the health hazard to the residents and/or scavengers (Olaoye et al., 2021).

Indoor radon was measured with CR-39 detectors (SSNTD) in some buildings in the vicinity of dumpsites in Lagos, Nigeria. Eight (8) dumpsites (4 dormant and 4 active dumpsites) were chosen for this study. Detectors were exposed in 50 houses randomly selected within 0 and 100m away from the dumpsites. The detectors were exposed for 3 months. They were then retrieved and etched. Tracks were counted using a semi-automatic system with a DCE camera mounted on a microscope and connected to a PC.

In active dumpsites, mean radon concentration was 169.8 ± 31.9 Bqm-3 while in the dormant it was 234.5 ± 46.9 Bqm-3. The comparison of radon concentrations in the residential building showed that buildings within 0-50 meters have the

highest radon concentration, although some buildings within 50 and 100 meters also showed high values which may be due to poor ventilation, building material, and water usage in the buildings. Mean radon concentrations were 235.5 and 166.5 Bqm-3 for buildings within 50 meters and buildings beyond 50 meters, respectively. The annual effective dose and cancer risk 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), respectively.

The study revealed that the concentration of radon in the buildings varied with distance, ventilation and type of dumpsites. It was concluded, that the residents of building in the vicinity of the dumpsites irrespective of distance may be at risk of contracting lung cancer due to continuous radon exhalation from the dumpsite

(E) Radiation in medical diagnostics

Radiation-based techniques underpin modern medical diagnostics and treatment. Ongoing research seeks to optimize dose delivery and image quality while minimizing patient exposure and side effects. My contribution in the applications of radiation in clinical diagnostic practices to ensure patient and public safety are:

(I) Entrance Skin Dose (ESD) in Routine Diagnostic X-ray Examinations in Southwestern Nigerian Hospitals was calculated in adult patients undergoing six routine X-ray projections (Chest PA, Chest LAT, Skull AP, Skull LAT, Abdomen AP, Pelvis AP) across several hospitals (**Ademola et al., 2006**).

Exposure parameters (tube potential and current-time product) and patient demographics (age, weight and height) were collected from each hospital for the six routine x-ray projections considered. Entrance skin dose (ESD) was estimated using standard mathematical model and the results were compared with international reference dose levels (IAEA, NRPB, CRCPD, and Malaysia standards).

The result of this study showed a wide variation in patient doses both within and between hospitals, the mean ESD values were mostly below international reference levels, except for skull projections (AP and LAT), which exceeded basic safety standards.

The study revealed that factors contributing to dose variation include radiographic technique, equipment performance, type of X-ray generator, and image processing systems.

This study provides baseline ESD data for Nigerian hospitals, aiding future dose optimization efforts and highlights the need for standardization and quality control in radiographic practices in developing countries. It is also important to develop a local diagnostic reference levels (DRLs) to improve patient radiation safety.

(ii) Pediatric diagnostic radiography requires careful balance between image quality and radiation protection, as children are more sensitive to ionizing radiation than adults. Ademola et al. (2013) evaluated the pediatric radiation doses specifically Entrance Skin Doses (ESDs) and effective doses during common diagnostic X-ray exams (chest, skull, abdomen, pelvis) in five Nigerian hospitals.

The study surveyed Entrance Skin Doses (ESDs) and effective doses for common chest, skull, abdomen, and pelvis X-ray examinations across five Nigerian hospitals, using standardized measurements and DoseCal software.

Analogue X-ray units (film–screen speed 400) were used for quality-controlled for kVp accuracy, filtration and darkroom performance. Data were collected for 450 patients (15 per projection per hospital) across four age bands (0–1, 1–5, 5–10, 10–15 years). Records of patients' size (weight, height, thickness) and exposure parameters (kV, mAs, focus-to-skin distance) was taken and ESD was calculated using Davies et al. 1997

$$ESD = BSF \times mAs \times \frac{Output_{(80Kv,10mAs)}}{FSD^2} \times ? \frac{KV}{80}^2$$

With backscatter factors from National Radiation Protection Board and tube outputs measured by a calibrated ion chamber. Effective dose was derived using NRPB dose-conversion coefficients.

The result of this study is presented in Table 2

Table 2: Result of Entrance Skin Dose in different projections

Projection	Dose
Chest PA (1 –5 yr)	111
Chest LAT (1 –5 yr)	170
Skull AP (1–5 yr)	660
Skull LAT (1–5 yr)	570
Abdomen AP (1–5 yr)	310
<u>Pelvis AP (1–5 yr)</u>	<u>570</u>

The median of the estimated ESDs were compared with NRPB/EC guidelines. It was found that the ESDs are lower for all projections **except** Chest PA and Chest LAT, which exceeded recommended values (70–120 μGy) for 5-year-olds. The **effective doses** were in line with published literature, indicating low overall radiation burden.

The study concluded that pediatric ESDs for chest, skull, abdomen and pelvis in all the hospitals generally fall within reported international ranges. Chest projections (PA and lateral) have ESDs above reference levels, revealing inconsistent optimization across centers. Overall radiation risk to both patients and staff is low, but variability highlights the need for protocol adherence.

(iii)Ademola, 2017 conducted a study on the effects of Tube Potential (kVp) and Current-Time Product (mAs) on Entrance Skin Dose in Chest Post-Anterior (PA) radiography, which is the most widely performed radiograph in Nigeria. The Entrance Skin Dose (ESD) delivered to patients at 80, 100 and 120 kVp was determined using mathematical algorithms in six hospitals in Ogun States, South-Western, Nigeria

Radiographic parameters (kVp, mAs, FSD, Filter thickness and field size) were collected for adult patients undergoing Chest PA in six major hospitals. Patients with 80, 100 and 120 kVp were selected and their corresponding mAs were recorded. The data selected were used to compute Entrance Skin Dose (ESD) using mathematical algorithms according to Aroua et al, 2002. The Focus to Skin Distance (FSD) in all the hospitals surveyed was 1 meter and the added filter is 3 mm Al

$$\text{ESD} = K \frac{\{U (kV)\}^2}{\{100\}^2} \frac{3}{FA (mm)} Q(\text{mAs}) \frac{1}{\{FSD (m)\}^2} \quad (2)$$

Where U is the Tube potential normalized at 100 KVp, Q is the Current –time product and FSD is the Focus-to-Skin Distance. K is an empirically determine constant specifying radiological unit and it is taken to be $0.1 \text{ mGym}^2/\text{mAs}$.

Results indicated that patients' dose reduction, could be achieve by appropriate combination of both kVp and mAs. The tube potential determines the proportion of high-energy photons in an X-ray beam, which are selected for each examination. The optimum choice depends on the part of the body being image, the size of the patient and type of information required.

Therefore, dose reduction can be achieved at low kVp (70-90 kVp) as well as at

high potential (125 kVp) by careful selection of appropriate current-time product.

Estimation of dose based on exposure data assumed no responsibility to film-screen speed and processing techniques. Dose variation mainly depends on technical parameters (such as kVp, mAs, filter thickness and focus-to skin distance).

(iv) Abodunrin et al. (2022) investigated the shielding properties of Nigerian Building and Road Research Institute interlocking compressed stabilized earth bricks as shielding material for x-ray in diagnostic radiological facilities.

Preparation of the bricks involved the application of a mix design that attained the desirable density and compressive strength. Bricks samples with thickness 100 mm, 200 mm and 300 mm were prepared based on the concept of compressed stabilized earth bricks for the NBBRI interlocking semi-automated brick making machine at 20 MPa efforts.

Irradiation was carried out with narrow beam geometry using Siemens Mobilett II portable x-ray machine and the transmitted exposures were measured with and without the shield using RDS-30. Tube parameters for the measurement comprised of 50 kVp, 70 kV p, 90 kV p and 102 kVp at 10 mAs tube current. The values selected were within the diagnostic range and a constant source-to-detector distance of 62 cm was maintained. The percentage transmissions for each brick thickness at different x-ray energies were determined.

The data obtained for the linear attenuation coefficient, mass attenuation coefficient, Half Value Layer and x-ray examinations undertaken showed that NBBRI interlocking compressed stabilized earth brick samples are not suitable as primary x-ray shielding in diagnostics facilities. It may however offer adequate protection in low workload diagnostic facilities as secondary barrier.

(F) Radioactivity and toxicology in food (Vegetables, fish, meat and nuts)

(I) Cultivation of vegetables is common around Ibese and Ewekoro cement factories in Ogun State, Nigeria. Residents cultivate food crops (vegetables) around the open spaces in the areas and irrigate their farms with wastewater from the industries.

Absorption of natural radionuclides and heavy metals from the waste, sludge, and dust is a possible way of contamination of the soil, which may adversely affect the quality and safety of the food produced. The assessment of Natural Radionuclides and Some Toxic Metals in Vegetables Cultivated around Ibese and

Ewekoro Cement Industries in Ogun State, Southwest Nigeria was carried out.

This study by Ademola et al. (2021) measure NORMs and some toxic metals in five types of vegetable; *Telfairia occidentalis* (Pumpkin/Ugu), *Corchorus olitorius* (Jute leaf/Ewedu), *Solanum Lycopersicum* (Tomatoes), *Amaranthus hybridus* (Green Vegetable/Tete), and *Talinum fruticosum* (Water leaf) grown around two cement industries in Ogun state using a sodium iodide detector for radionuclides and atomic absorption spectrometer for heavy metals.

It was found that *Telfairia occidentalis* had the highest radionuclide levels than other vegetables. Committed doses and cancer risks from ingestion of vegetable are below UNSCEAR limits, indicating no radiological hazard.

Heavy metal concentrations, however, showed potential risks, with hazard indices (1.29–2.21) exceeding 1, particularly for *Solanum lycopersicum*. This study supports firm regulations for food safety near industrial sites.

(ii) Poultry farming is a highly profitable and non-capital-intensive agricultural project. It is becoming one of the highest investments in agriculture in Nigeria. In a study by Ademola and Gbadeyanka (2021), we assessed natural radionuclides (^{40}K , ^{232}Th , ^{226}Ra) in chicken feeds and meat from five Lagos poultry farms and evaluated the health risks from consumption of chicken. The production of self-produced feeds by the Farmers that include addition of some minerals to stimulate growth was the reason behind this research.

Ten broiler and 30 feed samples (10 each of Starter, Grower, and Finisher feeds) used in feeding chicken were collected from five selected poultry- farms in Lagos State, Nigeria. They were prepared using standard procedure and analyzed using a NaI(Tl) detector after attaining secular equilibrium.

Chicken meat showed mean concentrations of $49.0 \pm 25.8 \text{ Bq kg}^{-1}$ (^{40}K), $24.9 \pm 12.2 \text{ Bq kg}^{-1}$ (^{232}Th), and $32.9 \pm 16.2 \text{ Bq kg}^{-1}$ (^{226}Ra), and concentration in feeds were all below UNSCEAR limits. Doses ($<70 \mu\text{Sv y}^{-1}$), cancer risks, and hazard indices (<1) indicated low risk. The mean values of the transfer coefficient (TC) were also below 1 for ^{40}K but higher than unity for ^{226}Ra in Finisher feeds, and ^{232}Th in Starter feeds.

The starter and finisher feeds were moderately contaminated. So, feeding chicken with these feeds may expose the consumers to the danger of over-exposure to ^{226}Ra and ^{232}Th . The study provides baseline data, offers a replicable methodology, and supports firm feed regulations.

(iii) Chicken meat is a major source of animal protein and is in high demand. To meet up with this high demand, feeds are produced with the addition of some minerals, plants, and crops. When broilers are fed on these fortified feeds, they develop faster. Therefore, the probability that the broiler may contain a high concentration of heavy metals is high.

In another study by Ademola and Gbadeyanka (2021a), the concentration of some heavy metals in the feeds used in five randomly selected poultry in Lagos was assessed using Flame Atomic Absorption Spectrometer (FAAS). Their hazard was determined in the chicken meat, liver, and gizzard.

Lead concentration was observed to be higher than the permissible limit in about 95% of the feeds. Cd concentration was also found to be higher in about 33% while the concentrations of other metals were below permissible limits in chicken meat and organs. Cd was not detected in the liver and gizzard while other metals had their concentrations within the permissible limit.

Hazard Quotient (HQ) of metals shows that Cu in the chicken meat, Cd in the liver and Zn and Cu in the gizzard were below unity.

Hazard Indices (3–10) in the study indicated potentially fatal risks from long-term consumption of the chicken samples.

(iv) Monitoring of toxic environmental contaminants is of primary importance for adequate risk assessment of human exposure. Ademola and Olurin (2018) assessed the natural radionuclides and heavy metals contaminants in milk candy samples obtained from three states in the south-western Nigeria. Eight samples of milk candy that were common in the local markets at the time of the study in Oyo, Ogun and Lagos were collected and analyzed for natural radionuclides (^{40}K , ^{232}Th and ^{238}U) and heavy metals (Pb, Cr, Cd, Fe, and Ni). The nutritional composition of the candies was also investigated.

The analysis was carried out using gamma-ray spectrometer with NaI(Tl) detector for radioactive analysis and Flame Atomic Absorption Spectrophotometer for heavy metal analysis. Proximate analysis was carried out to determine the nutritional contents (ash content, crude protein, carbohydrate, moisture content, energy and ether extract) of the milk candies using gravity and Kjeldahl methods.

The activity concentrations of ^{40}K , ^{232}Th and ^{238}U and the effective dose estimated in the samples were lower than the recommended values.

Analysis of heavy metals in the samples showed that Pb, Cr, Cd, Fe, and Ni were present in the samples and comparison with standard permissible limits showed that Pb concentration was higher than the standard in 6 of the samples.

The proximate analysis indicated higher crude protein, ash content, and energy

compared to the raw milk. This shows that milk candy can supplement protein and energy deficiency in the body. Therefore, milk candy consumption may be considered safe because of its high amount of nutrient than raw milk.

The study supports global food safety research, offers a robust methodology, and calls for Pb monitoring in our environment.

(v) The study of natural radioactivity (^{226}Ra , ^{232}Th , ^{40}K) and heavy metals (Pb, Cd, Fe, Cu) in eight powdered milk samples from Oke-Ogun, Nigeria was investigated by Ademola et al., (2014) to assess health risks due to their widespread use in food products.

Eight milk samples were analyzed for radionuclides using a gamma-ray spectrometer with a NaI(Tl) detector after 30 days of sealing for equilibrium. Heavy metals were measured via Flame Atomic Absorption Spectrophotometry after acid digestion. Health risks were evaluated using the Annual Effective Ingestion Dose for radionuclides and the Hazard Index (HI) for heavy metals, based on a 13 kg y^{-1} milk consumption rate.

Radionuclides (^{226}Ra and ^{232}Th) were below detection limits (BDL) while ^{40}K ranged from BDL to $195.0 \pm 9.5\text{ Bq kg}^{-1}$ (mean: $39.6 \pm 12.6\text{ Bq kg}^{-1}$). The total ingestion dose was $<33.7\text{ }\mu\text{Sv y}^{-1}$, below the 1 mSv y^{-1} safety limit.

Mean concentrations of HM were 0.029 mg kg^{-1} (Pb), 0.034 mg kg^{-1} (Cd), 2.298 mg kg^{-1} (Fe), and 0.255 mg kg^{-1} (Cu), all within safe limits. HI values (Fe: 0.212, Cu: 0.025, Pb: 0.005, Cd: 0.300) were <1 , indicating no health risk.

The powdered milk is safe for consumption, with radionuclide and heavy metal levels below international safety thresholds. Fe was highest but beneficial, while Pb traces may stem from production contamination.

(vi) Ademola and Omoboyede (2018) examined the natural radionuclide and heavy metal contents of five commonly consumed medicinal plants in southwestern Nigeria in order to determine their radiological implications as well as their toxicity levels

Five commonly consumed medicinal plants in south-western Nigeria, were collected from different local markets in the six states of the region and determined using gamma spectrometry with high purity germanium detector and flame atomic absorption spectrophotometer.

The activity concentrations in the samples are as presented in the Table 4 below
Table 4: The activity concentrations in the medicinal samples

Plant	A_K	A_U	A_{th}
Zobo (<i>Hibiscus sabdariffa</i>)	541.36±54.32	5.41±2.39	8.49±2.69
Turmeric (<i>Curcuma longa</i>)	635.57±60.45	3.15±2.08	3.04±1.99
Basil (<i>Occimum basilicum</i>)	658.36±6.18	1.73±1.95	3.17±1.82
Garlic (<i>Allium sativum</i>)	301.46±39.18	2.54±1.96	1.22±1.75
Ginger (<i>Zingiber officinale</i>)	329.20±41.40	2.14±1.81	1.95±1.65
World Average (UNSCEAR, 2000)	420	33	45

The mean annual effective dose in the samples is lower than the standard proposed by United Nation Scientific Committee on Energy and Atomic Research.

Also, the fatal cancer risk and hereditary cancer risk from ingestion of the plants lie within the safe limit as recommended by United State Environmental Protection Authority and World Health Organization.

The mean concentrations of the heavy metals in the samples were found to be within the safe limit except for Zn which is higher.

Total hazard index obtained for all the samples is higher than 1.0 but lower than 3.0. which implies that there is no probable hazard from the consumption of these plants. Therefore, the consumption of these plants is safe.

This study highlights the need for establishing policy, rules and regulations relating to processing and manufacturing of medicinal products in Nigeria.

(vii) Ademola and Morakinyo (2020) investigated the concentrations of Norms and some heavy metals from intake of Some Nuts and Seeds in South-Western, Nigeria.

In the study, five samples each of ten nuts and seeds (cashew nut, groundnut, walnut, Kola nut, moringa seed, bitter kola nut, African Star Apple seed, avocado seed, watermelon seed, and cocoa seed) commonly cultivated and consumed in the south-western state of Nigeria were selected for this study. The samples were collected from the farm sites and were packed with identification labels. Radioactive analysis of the samples was performed with NaI(Tl) spectrometry and the toxic metal with Inductively Coupled Plasma (ICP).

The concentrations of ^{226}Ra , ^{232}Th , and ^{40}K in the samples were found to be below the world average.

Concentration of metals in the samples descend as $\text{Fe} > \text{Zn} > \text{Cu} > \text{Cr}$. The Hazard Index of heavy metals is lower than 1 except for Cocoa which is higher than 1 due

to the high concentration of Cu and Fe.

It was concluded that there was no radioactive health risk involved in the consumption of nuts and seeds if consumed within the 42 g per day as recommended.

Cu and Zn were found to be higher than the recommended value in Cashew nuts and Walnuts. The nuts and seeds analyzed were contaminated with Cu, Zn and Fe and so must be taken with care so that consumers will not be exposed to excessive concentration of Cu and Fe which may have undesirable effects because high dose intake of Zn may cause tachycardia, vomiting, diarrhea, pancreatitis, and damage to the liver.

(viii) Fish consumption is on the rise in Nigeria and according to Food and Agriculture Organization (FAO), Nigeria fish consumption is estimated at 3.32 million metric tons while the domestic production is about 1.12 million metric tons. In order to meet the demand of the consumers, fish are imported into the country.

Ademola et al. (2021) measured natural radionuclides in eight types of fish consumed in Nigeria to determine the annual committed effective dose, daily intake of radionuclides, and carcinogenic risk from their consumption.

Eight types of fish were collected from three major cold rooms in Lagos for this study. After drying in the oven, the real fraction of the fish consumed was 0.7. The dried samples were then processed and taken to laboratory for analysis. A Sodium Iodide (NaI(Tl)) detector of $7.6 \times 7.6 \text{ cm}^2$ manufactured by Bicron with a Canberra multi-channel analyzer was used for the measurement.

The mean concentrations of Norms in the samples are within the safe limit. The mean total activity in the fish was estimated as $235.5 \pm 51.5 \text{ Bqkg}^{-1}$. It was also observed that Catfish and Tilapia; reared in Nigeria have lower activity concentrations than most of the others imported into the country. The Cancer Risk (CR) from the consumption of the samples is within the World Health Organization limit except for consumption of Herrings every day a week.

The Committed effective dose, daily and annual intake of radionuclide and cancer risk from the consumption of fish was estimated and found to be within the WHO recommended average.

6.0 Conclusion: Is Radiation a Friend or Foe?

Radiation is undoubtedly a Double-Edged sword that plays a critical role in advancing medicine, technology, and energy production, but it comes with

risks. When managed properly, radiation is a friend to humanity, enabling life-saving treatments, technological progress, and cleaner energy alternatives. However, when used irresponsibly or without sufficient regulation, it can be a foe, causing harm to human health and the environment.

To fully harness radiation's benefits while minimizing its risks, society must:

- (i) **Maximize Benefits:** Continue to develop and improve radiation technologies that serve humanity, particularly in medicine and clean energy production.
- (ii) **Control Exposure:** Strictly adhere to radiation protection principles, implementing robust regulations that limit exposure in both occupational and public settings.
- (iii) **Educate the Public:** Increase public awareness to dispel myths, ensuring that radiation is understood as a tool, not a threat, when used responsibly. Only through responsible use, continual innovation, and a commitment to safety can we ensure that radiation remains a trusted ally in the service of humanity.

Recommendations

- (i) The government should allocate more resources to establish and equip diagnostic and radiotherapy centers across the country with state-of-the-art equipment and technology that can rival developed country like China, USA, etc.
- (ii) Government should invest in the training of personnel to handle radiation and also develop researchers in that area. There should be a mandatory regular training for all workers working with radiation sources
- (iii) Regular workshop/conference should be organized on Local Government basis to educate and create interest in the public awareness about radiation hazard in their community
- (iv) Government to establish and/or enforce existing law on every aspect of radiation; mining, diagnostic, therapy, radon indoor, dumpsites, radioactive waste, e-waste, etc
- (v) It should be ensured that the established body/agencies e.g. (NNRA) align and harmonize national regulations with regulated bodies like IAEA, ICRP, UNSCEAR and USEPA
- (vi) Waste management should involve categorization of radioactive waste

and environmental monitoring involving particulate matter, radon, toxic metals in water, soil and other environmental samples

(vii) Establishment of emergency response team in case of radiation accident

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Middle page Pictures



Radon analysis Lab Ota: High-quality mono-chrome charge coupled device (CCD) TV camera connected to a PC-based image analyzer (Image-Pro Plus version 4.0) and computer.



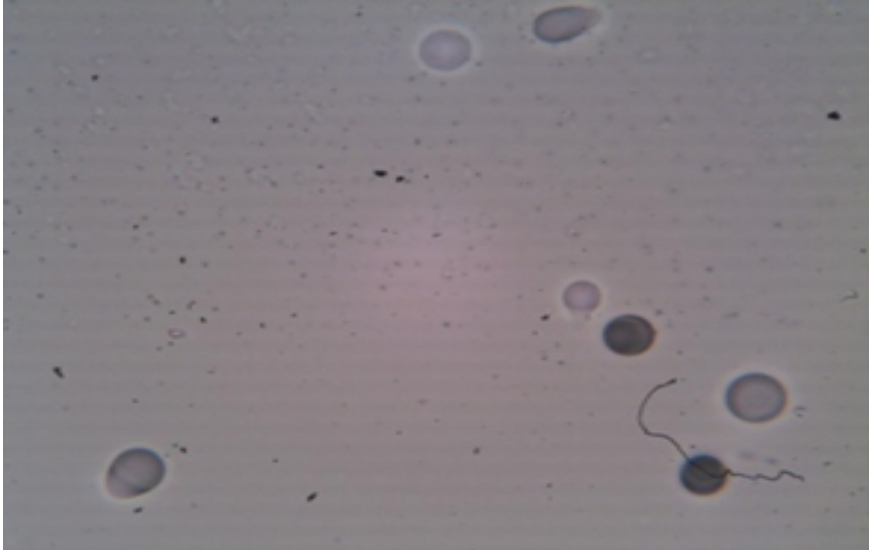
Radiation/ Radon Analysis equipment laboratory @BellsTech



At a workshop



My MRI team at ISMRM in Accra, Ghana



Tracks of alpha particles emitted by radon in a CR-39 detector



Sodium Iodide Thallium (NaI) spectrometer

As fears of a meltdown in Japan rise, so do the fears of radiation exposure. What does radiation do to the human body?

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Education and
Training
Government of
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	Q1 '18	Q1 '17	Q1 '18	Q1 '17
	in \$ mil.	in \$ mil.	in \$ mil.	in \$ mil.
Revenue	---	---	---	---
Operating	---	---	---	---
Nonoperating	---	---	---	---
Financial	---	---	---	---
Total	---	---	---	---

Keywords: *workplace spirituality, organizational commitment, organizational citizenship behaviors, organizational trust, organizational identification, organizational justice, organizational support, organizational commitment, organizational citizenship behaviors, organizational trust, organizational identification, organizational justice, organizational support*

[illegible]

Group	Yes (%)	No (%)
All respondents	100%	0%
Those who answered 'yes' to the question 'Do you have a good idea of what you are doing?'	100%	0%
Those who answered 'no' to the question 'Do you have a good idea of what you are doing?'	0%	100%

1. 2. 3. 4. 5. 6. 7. 8. 9. 10. 11. 12. 13. 14. 15. 16. 17. 18. 19. 20. 21. 22. 23. 24. 25. 26. 27. 28. 29. 30. 31. 32. 33. 34. 35. 36. 37. 38. 39. 40. 41. 42. 43. 44. 45. 46. 47. 48. 49. 50. 51. 52. 53. 54. 55. 56. 57. 58. 59. 60. 61. 62. 63. 64. 65. 66. 67. 68. 69. 70. 71. 72. 73. 74. 75. 76. 77. 78. 79. 80. 81. 82. 83. 84. 85. 86. 87. 88. 89. 90. 91. 92. 93. 94. 95. 96. 97. 98. 99. 100. 101. 102. 103. 104. 105. 106. 107. 108. 109. 110. 111. 112. 113. 114. 115. 116. 117. 118. 119. 120. 121. 122. 123. 124. 125. 126. 127. 128. 129. 130. 131. 132. 133. 134. 135. 136. 137. 138. 139. 140. 141. 142. 143. 144. 145. 146. 147. 148. 149. 150. 151. 152. 153. 154. 155. 156. 157. 158. 159. 160. 161. 162. 163. 164. 165. 166. 167. 168. 169. 170. 171. 172. 173. 174. 175. 176. 177. 178. 179. 180. 181. 182. 183. 184. 185. 186. 187. 188. 189. 190. 191. 192. 193. 194. 195. 196. 197. 198. 199. 200. 201. 202. 203. 204. 205. 206. 207. 208. 209. 210. 211. 212. 213. 214. 215. 216. 217. 218. 219. 220. 221. 222. 223. 224. 225. 226. 227. 228. 229. 230. 231. 232. 233. 234. 235. 236. 237. 238. 239. 240. 241. 242. 243. 244. 245. 246. 247. 248. 249. 250. 251. 252. 253. 254. 255. 256. 257. 258. 259. 260. 261. 262. 263. 264. 265. 266. 267. 268. 269. 270. 271. 272. 273. 274. 275. 276. 277. 278. 279. 280. 281. 282. 283. 284. 285. 286. 287. 288. 289. 290. 291. 292. 293. 294. 295. 296. 297. 298. 299. 300. 301. 302. 303. 304. 305. 306. 307. 308. 309. 310. 311. 312. 313. 314. 315. 316. 317. 318. 319. 320. 321. 322. 323. 324. 325. 326. 327. 328. 329. 330. 331. 332. 333. 334. 335. 336. 337. 338. 339. 340. 341. 342. 343. 344. 345. 346. 347. 348. 349. 350. 351. 352. 353. 354. 355. 356. 357. 358. 359. 360. 361. 362. 363. 364. 365. 366. 367. 368. 369. 370. 371. 372. 373. 374. 375. 376. 377. 378. 379. 380. 381. 382. 383. 384. 385. 386. 387. 388. 389. 390. 391. 392. 393. 394. 395. 396. 397. 398. 399. 400. 401. 402. 403. 404. 405. 406. 407. 408. 409. 410. 411. 412. 413. 414. 415. 416. 417. 418. 419. 420. 421. 422. 423. 424. 425. 426. 427. 428. 429. 430. 431. 432. 433. 434. 435. 436. 437. 438. 439. 440. 441. 442. 443. 444. 445. 446. 447. 448. 449. 450. 451. 452. 453. 454. 455. 456. 457. 458. 459. 460. 461. 462. 463. 464. 465. 466. 467. 468. 469. 470. 471. 472. 473. 474. 475. 476. 477. 478. 479. 480. 481. 482. 483. 484. 485. 486. 487. 488. 489. 490. 491. 492. 493. 494. 495. 496. 497. 498. 499. 500. 501. 502. 503. 504. 505. 506. 507. 508. 509. 510. 511. 512. 513. 514. 515. 516. 517. 518. 519. 520. 521. 522. 523. 524. 525. 526. 527. 528. 529. 530. 531. 532. 533. 534. 535. 536. 537. 538. 539. 540. 541. 542. 543. 544. 545. 546. 547. 548. 549. 550. 551. 552. 553. 554. 555. 556. 557. 558. 559. 560. 561. 562. 563. 564. 565. 566. 567. 568. 569. 570. 571. 572. 573. 574. 575. 576. 577. 578. 579. 580. 581. 582. 583. 584. 585. 586. 587. 588. 589. 590. 591. 592. 593. 594. 595. 596. 597. 598. 599. 600. 601. 602. 603. 604. 605. 606. 607. 608. 609. 610. 611. 612. 613. 614. 615. 616. 617. 618. 619. 620. 621. 622. 623. 624. 625. 626. 627. 628. 629. 630. 631. 632. 633. 634. 635. 636. 637. 638. 639. 640. 641. 642. 643. 644. 645. 646. 647. 648. 649. 650. 651. 652. 653. 654. 655. 656. 657. 658. 659. 660. 661. 662. 663. 664. 665. 666. 667. 668. 669. 670. 671. 672. 673. 674. 675. 676. 677. 678. 679. 680. 681. 682. 683. 684. 685. 686. 687. 688. 689. 690. 691. 692. 693. 694. 695. 696. 697. 698. 699. 700. 701. 702. 703. 704. 705. 706. 707. 708. 709. 710. 711. 712. 713. 714. 715. 716. 717. 718. 719. 720. 721. 722. 723. 724. 725. 726. 727. 728. 729. 730. 731. 732. 733. 734. 735. 736. 737. 738. 739. 740. 741. 742. 743. 744. 745. 746. 747. 748. 749. 750. 751. 752. 753. 754. 755. 756. 757. 758. 759. 760. 761. 762. 763. 764. 765. 766. 767. 768. 769. 770. 771. 772. 773. 774. 775. 776. 777. 778. 779. 780. 781. 782. 783. 784. 785. 786. 787. 788. 789. 790. 791. 792. 793. 794. 795. 796. 797. 798. 799. 800. 801. 802. 803. 804. 805. 806. 807. 808. 809. 810. 811. 812. 813. 814. 815. 816. 817. 818. 819. 820. 821. 822. 823. 824. 825. 826. 827. 828. 829. 830. 831. 832. 833. 834. 835. 836. 837. 838. 839. 840.

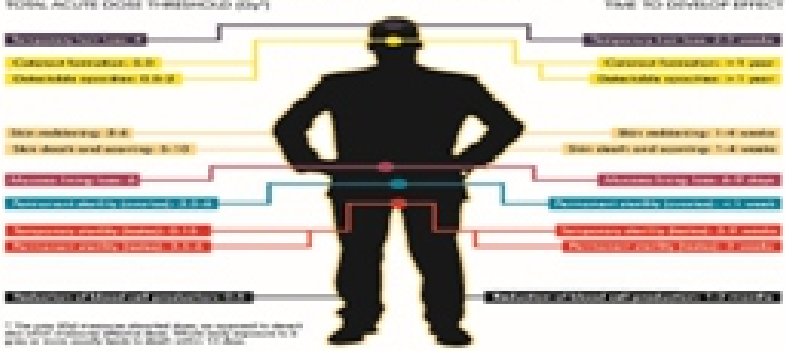


Diagram illustrating the process of genetic damage and mutation:

- GENETIC DAMAGE** (represented by a thumbs up icon) leads to **GENETIC MUTATION** (represented by a thumbs down icon).
- The process involves **GENETIC DAMAGE** (represented by a skull and crossbones icon) leading to **GENETIC MUTATION** (represented by a DNA double helix icon).

EMF/ELF Radiation Health Risks

Recent medical research has uncovered links between prolonged exposure to electromagnetic radiation and many health impacts.

Neurological Effects

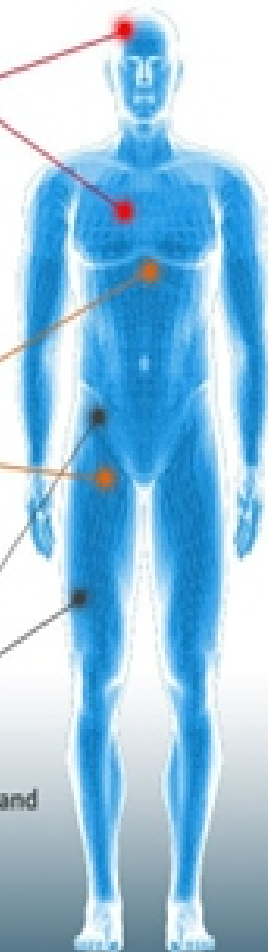
- Brain Tumor
- Alzheimer's Disease
- Cognitive Impairment
- Sleep Disturbance
- Reduction in Melatonin Production
- Acoustice Neuroma
- Lou Gehrig's Disease

Cellular Effects

- DNA Damage
- Leukemia
- Cancers, including Breast and Skin
- Infertility and decreased sperm motility
- Blood-Brain Barrier Disruption

Well-Being Effects

- Toasted Skin Syndrome
- Electromagnetic Sensitivity
- "Subliminal Stress", the reduction of blood and oxygen flow to vital systems



Source:

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Shape of etch-pit in the clear background of SSNTDs

INAUGURAL LECTURE SERIES.

(June 25, 2015 - September 24, 2025)

1. The 1st Inaugural Lecture titled: "Food Product Development, Quality Assurance and Nutrition: Whither the Humane Senses?" by Professor Olugbenga A. Ben Ogunmoyela of the Department of Food Sciences and Technology. June 25, 2015.
2. The 2nd Inaugural Lecture titled: "Crisis in Forest Conservation in Nigeria: Threats to Livelihoods and Human Survival" by Professor Gbadebo Jonathan Osemeobo of the Department of Biological Sciences. January 13, 2016.
3. The 3rd Inaugural Lecture titled: "Minerals, Metals & Materials: The Hidden Wealth of A Nation" by Professor Gabriel Oladipo Oluwadare of the Department of Biomedical Engineering. May 18, 2016.
4. The 4th Inaugural Lecture titled: "Fungal Impact on Man: From Waste to Health" by Professor Olubukola Kuforiji of the Department of Biological Sciences. March 8, 2017.
5. The 5th Inaugural Lecture titled: "Chemistry is Reaction: Reaction is Chemistry" by Professor Violette Nkechi Atasie of the Department of Chemical and Food Sciences. March 7, 2018.
6. The 6th Inaugural Lecture titled: "Man and Materials: The indivisible Entities" by Professor Ojo Sunday Fayomi of the Department of Mechanical Engineering. March 14, 2025.
7. The 7th Inaugural Lecture titled: "My Nigeria Food Story: Scarcity in the Midst of Plenty" by Professor Ngozi Ugo Arisa, Department of Food Science and Technology. September 24, 2025.
8. The Eighth (8th) Inaugural Lecture titled: "Radiation and Human Well-being: A Doubled-Edged Sword in our World – Balancing the Benefits and Risks" by Augustine Kolapo Ademola Professor of Radiation and Health Physics Deputy Dean, COLNAS. Wednesday, 8th October, 2025

