UNIVERSITY OF PORT HARCOURT

RADIATION - THE GOOD, THE BAD AND THE UGLY IN OUR ENVIRONMENT

An Inaugural Lecture

79th Series

By

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DEDICATION

This inauguration lecture is dedicated to God Almighty. He who is able to do immeasurably more than all we ask or imagine, according to his power that is at work within us. To him be the glory forever and ever. Amen

ACKNOWLEDGEMENT

I hereby appreciate the management of the University of Port Harcourt ably led by the Vice Chancellor Professor J. A. Ajienka for this opportunity given to me to present this inaugural lecture.

Special appreciation to my dear wife and friend, Seroghene and my children- Fejiro, Aghogho, Rukevwe and Urinrin that have been very prayerful and supportive in my academic sojourn.

Thanks to my mentors – Profs. J. O. Ebeniro and I. O. Owate and to my supervisor at my B.Sc and M.Sc programmes- Prof. O.E Abumere (Dean, Faculty of Science). The staff and students of Physics and Mathematics & Statistics Departments have been wonderful, and encouraging. God bless you all abundantly.

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instilled in me the virtues of discipline, integrity and hard work, I remain grateful.

Finally, all glory, honour and thanksgiving be unto God, the Alpha and Omega, El-shadai, Adonai and Ancient of days forever and ever.

Prof. G. O. Avwiri, mnip.

1.0 PREAMBLE

Protocol

The Vice Chancellor
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Our Unique Uniport Students
Members of the Press
Ladies and Gentlemen

Introduction

It is indeed a great honour, joy and high sense of humility that I stand here today to join in the roll call of scholars to deliver the 79th inaugural lecture of this University and the second in the Department of Physics. Professor I. O. Owate, an erudite Professor of Physics, delivered the first inaugural Lecture from the Department of Physics in January 2011. He afforded me the privilege to read his citation and also encouraged me to deliver my inaugural lecture within the year 2011.

In defining the task before a Lecturer in the presentation of an inaugural lecture, Ogunye (1981) proposed three forms which are:-

(i) to concentrate on the development of the department, if the lecturer is also the occupant of the chair to which the leadership is attached;
(ii) to focus on the Professor's own work within the general framework of his discipline, and ;
(iii) to be on a dry general topic where the Professor considers that he has something fresh and stimulating to tell his audience.

Mr. Vice-Chancellor sir, my approach in this lecture will be a combination of forms (ii) and (iii) above i.e. to focus on the recent international development in the field of radiation and present my modest contributions in the study of ionizing radiation safety in our environment (Nigeria).

On March 11, 2011, the news of the earthquake in Japan was heralded all over the world with high level of devastation to the environment with a consequent destruction to the power unit of Japan's nuclear facility known as FUKUSHIMA DAIICHI Plant. The consequent issues at stake were numerous on the Japanese Government. It was reported that the earthquake, tsunami, and the radiation leakage, presented Japan's government with the biggest challenge in a generation. This accident also cost the former Japan Prime Minister (Mr. Naoto Kan his dear job on 26th August, 2011. Recently, on September 10, 2011, Japan's Trade Minister resigned over the radiation gaffe crisis from the Fukushina Plant. Also, the radiation released from the plant, which became a threat to the neighbouring countries attracted worldwide interest. Furthermore, reducing the radiation level to permissible level is still an issue still begging for attention of Radiation Safety Officers, the International Atomic Energy Agency (IAEA) and various radiation agencies of the United Nations (UN).

2.0 RADIATION

Radiation refers to the emitted energy that travels as electromagnetic waves. Parker (1989) defined radiation as the emission of streams of particles such as electrons, protons, high-energy photons or an emission of a combination of these. There are two types of radiation; ionizing and non-ionizing radiation. Figures 1 and 2 below show the major classification of radiation and the positions of various components in the electromagnetic spectrum.

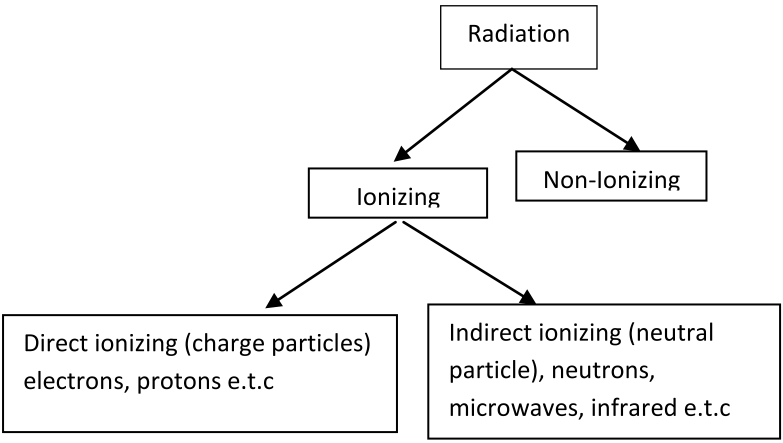

Figure 1: Classification of Radiation

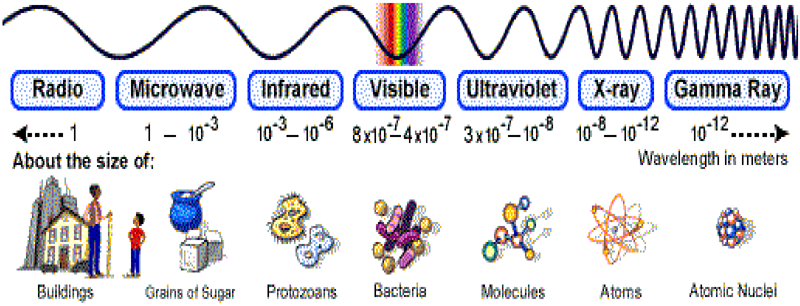

Figure 2: Components of the Electromagnetic spectrum

2.1 NON-IONIZING RADIATION

The non-ionizing radiation refers to any form of electromagnetic radiation that does not possess enough energy to knock off an electron from the atoms or molecules it comes in contact with. They include radio waves, microwaves, infrared, visible light and the ultra violet rays. Sources include GSM (Global System of Mobile Telecommunication) masts and phones, electrical high-tension wires, solar radiation etc. Non-ionizing radiation has been linked with dielectric heating, where living tissues are heated by rotation of polar molecules induced by electromagnetic field. Also, research from Greece found a direct casual relationship between mobile phone radiation and DNA damage (Achudume et al, 2010). There has been no strong linkage between non-ionizing radiation and cancer (Wikipedia, 2007).

2.2 IONIZING RADIATION

Ionizing radiation refers to that form of radiation that is emitted from a radioactive substance that has the ability to knock off electrons from the atom it interacts with. The emitted rays from this form of radiation include alpha rays (α), beta rays (β), gamma rays (γ) and x-rays. Ionizing radiations are very harmful since they have the ability to penetrate a living cell and to damage the chemicals there-in.

2.3 PROPERTIES OF IONIZING RADIATION

The essential properties of the ionizing radiation are discussed below:

i) Alpha Particles (α)

Alpha particles contain 2 protons and 2 neutrons (helium nucleus). They are the least penetrating among the ionizing radiations and can be stopped by thin sheet of paper or by 5 cm of air at a pressure of 760 mmHg. They have a frequency of 1.45 x 10^{21}Hz. They also have the highest ionizing radiation potential among the three characteristic radiations emitted by a typical radioactive substance (10^5 ion-pairs per cm in air at S.T.P). The energy equation below illustrates the energy released in an alpha emission of Polomium-210.

$$ {}^{210}_{84}Po \rightarrow {}^{206}_{82}\mathrm{Pb} + {}^{4}_{2}He + \mathrm{Energy} $$

A radioactive substance that emits α-rays can be used as a tracer. The exact position of an underground pipe can be located if a small quantity of radioactive liquid is added to the liquid being carried by the pipe.

ii) Beta Particles (β)

Beta-particles are the mono-negatively charged particles. They are more penetrating than alpha particles. They can travel through 3mm sheet of aluminum or up to 1m of air at a pressure of 760mmHg. These particles are less ionizing than α-particles, they produce 10^{-2} - 5 x 10^{-3} of the ionization generated by particle per cm of their path in air (10^3 ion-pairs per cm in air at atmospheric pressure). **β** - ray has a frequency of 2.4 x 10^{20}Hz. An example of energy equation of β-decay is as follows:

$$^{232}_{90}Th \rightarrow \quad ^{232}_{91}Pa + {}^{0}_{-1}e + \text{Energy}$$

iii) Positrons (β^+)

This is another type of β- decay. In this process the particles emitted are positively charged beta particles called positrons. A positron has the same mass as an electron, but carries a charge of +e. The disintegration process for (β^+) decay is:

$$^{A}_{Z}P = {}_{Z-1}^{\ \ A}D + {}^{0}_{+1}e$$

It is important to note that the emitted positron does not exist within the nucleus but rather is created when a nuclear proton is transformed into a neutron. In the process, the proton number of the parent nucleus decreases from Z to Z-1 and the nucleon number remains the same. There is therefore, a transmutation of one element into another (Cutnell and Johnson, 1995).

iv) Gamma Rays (γ)

These are the most penetrating among the three forms of radiations, passing through several centimeters of lead. They are electromagnetic in nature and have wavelength shorter than that of light. Table 1 gives other characteristics of gamma rays. The thickness of a metal sheet can be monitored during manufacturing by passing it between a γ-ray source and a suitable detector. The thicker the sheet of metal, the greater its absorption. Gamma rays are not charged particles hence cannot cause ionization directly, but when they interact with matter they cause the ejection of electrons from the atom thereby ionizing it. Table 1 gives other characteristics of the various types of radiation.

2.4 X-Rays

X-rays are short wavelength electromagnetic radiation (typically about 10^{-10} m), discovered by Rontgen in 1895 (Muncaster, 1982). Some properties of X – rays are:-

(1) X – rays travel in straight lines from their sources and are not deflected by electromagnetic fields, hence they are not charged particles.
(2) They produce photoelectric effect on certain metals, and like electrons, produce secondary x-rays from metals.
(3) They ionize gases through which they pass.
(4) They are electromagnetic waves, having the same nature as light waves; they differ only in wavelength or frequency.
(5) X-rays penetrate matter to an extent governed by the density of the materials, hence, their use in some diagnostic work in medicine.

Table 1: Summary of the Properties of Ionizing Radiations [*Source*: Muncaster (1982)].

Property	**α-Particles**	**β-Particles**	**γ-Particles**	**x-ray**
Nature	Helium Nucleus	Fast electron	EM radiation	EM radiation
Charge	3.2×10^{-19} C	$- 1.6 \times 10^{-19}$C	0	0
Mass	6.4×10^{27} kg	9.1×10^{-31}kg	0	0
Velocity	~0.06 C	~0.98C	C	C
Energy	~6 MeV	~1 MeV	~0.1 MeV	< ~0.1 MeV
Frequency	1.4×10^{21} Hz	2.4×10^{20}Hz	1.45×10^{20} Hz	3.0×10^{20} Hz
Iron pair/cm of	$\sim 10^{5}$	$\sim 10^{3}$	~10	-
Penetration	~5 cm of air	~500 cm of air ~0.1 cm of A1	~4 cm of lead	< ~4 cm of lead
Matter	Straight	Tortuous	Straight	Straight
Ability to fluorescence	Yes (strong)	Yes	Yes (weak)	Yes
Ability to affect a photographic plate	Yes	Yes	Yes	Yes

3.0 SOME SOURCES OF IONIZING RADIATION

Some common sources of ionizing radiation are shown in Figure 3 below.

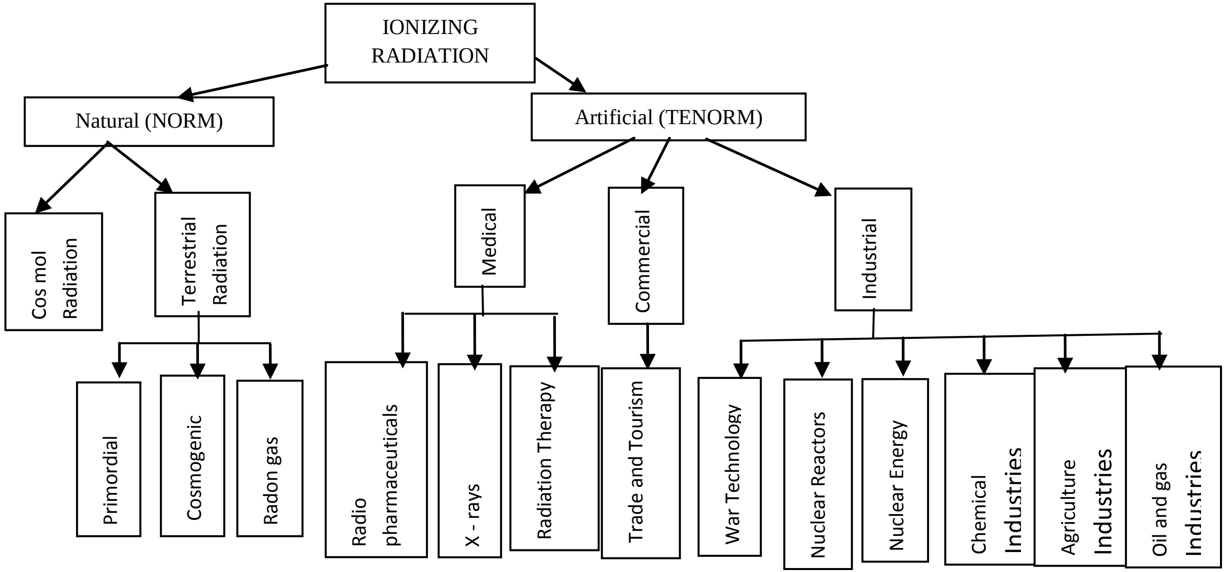

Figure 3: Some sources of Ionizing Radiation

3.1 Research Laboratories

Research laboratories are sources of highly collimated and very soft radiation phenomena usually affecting the hands if placed in the useful beam. They use substances such as cesium, barium and plutonium which pose occupational and population hazards. Nuclear research laboratories and centers of energy research utilize nuclear sources which are major contributors of ionizing radiation.

3.2 Medical laboratories

Medical institutions and hospitals use substances that are radioactive under controlled conditions. Exposure of patients to radiographic examination (fluoroscopic procedures, dental diagnosis, and routine exposure to x-rays), radioisotope procedures and radiation therapy have contributed to increase in radiation levels of patients and many occupational workers. Other sources include treatment using drugs containing iodine 131, phosphorus – 32 and carbon 14 (Chen et al., 2006).

3.3 Cement and Mining

The activities of the solid mineral mining industries can cause increase in radiation in the environment. During drilling and breaking of soils and rocks for production of cement and other allied products, cadmium and radon which are radioactive encapsulates in the rocks are released into the air. The waste minerals from mining operations, known as tailings, contain several radioisotopes that are harmful to human health and the environment. Such radioisotopes from ash, alumina, etc are mixed in new constructions (Buracu, 1978).

3.4 Fertilizer Industries

In fertilizer manufacturing, compounds like potassium chloride (KCl) and potassium sulphate (K_2S0_4) contain abundant natural potassium that possess isotopes like ^{40}K that are radioactive. A fertilizer plant which produces potassium bearing products is likely to have a stockpile of potassium compound and these products when stored in large quantities can also contribute to increase in background radiation levels of the environment (Ebong and Alagoa, 1992). The massive usage of fertilizers in agriculture has the tendency to increase the radionuclide level of both the soil and the environment.

3.5 Tobacco

Polonium -210 has been found in the tobacco of cigarettes. Also, according to World Health Organization, radiation from tobacco smoke is the biggest cause of death worldwide, just between hunger and malaria, having killed 100 million people in the 20th century (Kilthau, 1996). Furthermore, consumption of tobacco products results in the absorption of nicotine and radioactive isotopes in varying amount into bloodstreams of the user (Rajewsky and Stahlhofen, 1996). The obvious health and radiation hazards associated with cigarettes and related products have necessitated the Federal Ministry of Health to warn smokers of the dangers of smoking with the slogan ‘smokers are liable to die young”. Vice Chancellor Sir, may I propose that the Government should impose “smokers tax” to further discourage smokers.

3.6 Petroleum industry

The activities in the petroleum industry involve exploration, exploitation, drilling, production, logging etc. Some of these activities utilize explosives made of uranium, radium, strontium and other radioisotopes (Manadham 1991). During drilling, three primary radioactive sources which are logging, stabilization and calibration sources are identified. These sources emit gamma rays and neutrons into the atmosphere thus increasing the radiation level, thereby endangering the lives of personnel and staff on oil platforms and the immediate environment (Stoca et al 2000).

3.7 Telecommunication and power lines

The rapid growth of the cellular communication (GSM) in the developed and developing countries has resulted in installation of large networks of base transceiver stations (BSTs) and GSM masts (base stations). Today, clusters of them are visible in school premises, churches, bank premises and even University campuses for economic reasons.

The use of radio frequency (RF) field emitting devices such as mobile phones, microwave ovens, base stations, and other broadcast facilities has led to a widespread human exposure to RF field's radiation. This remarkable growth in the GSM technology has raised public concerns about possible associations between RF radiation and adverse health side effects. A number of authorities have conducted detailed reviews and surveys on the potential health risk associated with exposure to RF fields (Royal Society of Canada, 2003, British Medical Association, 2001, Zmirou, 2001 and Achudume et al., 2010). International standards established for the control of human exposure to radiations from GSM base stations and GSM phones are presented in Table 3. However, the present state of scientific research and knowledge has not substantiated scientific evidence of health effects associated with mobile phones and their base stations.

Table 3: International Standards

Organization	**GSM base station**	**GSM phone**
Federal Communication Commission (FCC)	0.57mw/cm^2 (0.13w/kg)	1.0mw/cm^2 (0.22w/kg)
International Commission of Non-ionizing Radiation Protection (ICNIRP)	0.40mw/cm^2 (0.09w/kg)	0.90 mw/cm^2 (1.98w/kg)
National Radiological Protection Board (NRPB,1998)	0.57mw/cm^2 (0.13w/kg)	0.10mw/cm^2 (0.22w/kg)
International Standard RF Range	0.20 to 1.20mw/ cm^2	NA

Bamidele (2009) measured the radiation levels around electric power lines environment. The result obtained shows that the average radiation levels around power lines of 330kV, 132kV and 11kV lines range from 13.85 x 10^{-8}Gy/hr to 18.14 x 10^{-8} Gy/hr. This range is less than 20 x 10^{-8}Gy/hr which according to IAEA is the minimum standard of ionizing background radiation that can cause health hazard.

4.0 SOME EFFECTS OF IONIZING RADIATION

Effects are observed when ionizing radiation strikes living tissues and damaged the molecules of cellular matter. Cellular function may be temporarily or permanently impaired from the radiation or the cell may be destroyed. Some of the effects of ionizing radiation are discussed below.

4.1 Erythema:

This is an increased redness of the skin caused by capillary dilation. Erythema is one of the earliest known reactions to radiation. Large amount of radiation may cause injury or kill cells giving rise to dilation of blood and lymph vessels. Figure 4 depicts an example of erythema.

Figure 4: Erythema

4.2 Skin Cancer:

Cancer can be caused by the use of diagnostic and therapeutic procedures involving x-rays and from prolonged exposure to the cosmic rays due to ozone depletion (Ballinger, 1990). This exposure starts by reddening of the skin and later developes into cancer of the skin. The skin is the most exposed part of the body and it is radiosensitive. The extent of skin injury varies from reddening to ulceration and sloughing. The development of injury is characteristically slow. The maximal damage is usually not evident until weeks after irradiation. Months later, permanent effects consisting of thinning of the skin, scaring of the underlying connective tissues and dilation of coetaneous blood vessels may gradually appear. This sequence of change is called radiation dermatitis.

Figure 5: Skin Cancer

4.3 Genetic Effects

Genetic effects occur only when reproductive cells are irradiated by x-ray and other radioactive substances. Radiation affects the estrogen to forestall the effects of menopause and prevent spontaneous absorption in the female reproductive organs, produce a permanent damage to germ plasm which results in genetic mutation that affects the embryo causing miscarriage and sometimes deformity or death.

4.4 Atrophy of the Kidney

Atrophy is the wasting or shrinking of a cell, tissue or organ after it has developed completely and achieved its full size. Exposure to radiation can cause the kidney and urinary tract to waste or shrink which leads to fatal loss of renal functions.

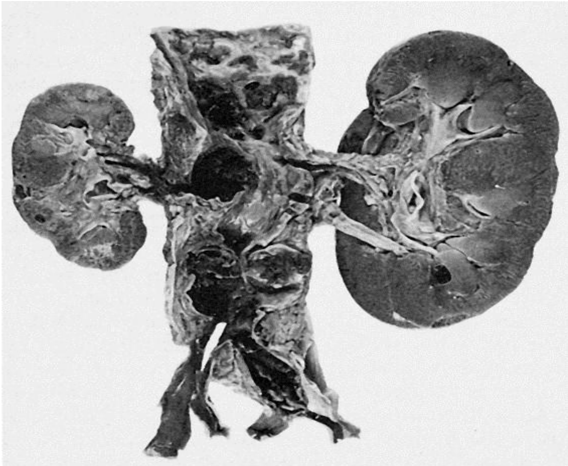

Figure 6: Atrophy of the Kidney

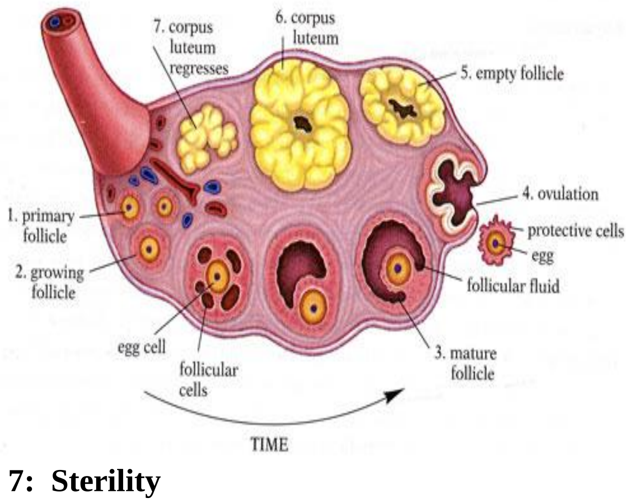

Figure 7: Sterility

4.5 Sterility

Sterility is a situation where species are unable to produce offspring. Since the developing germ cells (gonads) are highly radiosensitive, their irradiation may results in sterility. In humans, permanent sterilization requires an amount of radiation that is lethal when absorbed by the entire body.

4.6 Bone and Teeth

Irradiation with few hundred roentgens to bone and tooth forming cells in infancy or early childhood can cause disturbances of dentition and skeletal growth. In contrast, mature bones and teeth are relatively radio resistant. Large amounts of radiations may accumulate from locally deposited radioisotopes or from the treatment of cancer. This produces demineralization and necrosis of the bone that can lead to fractures, loosening of the teeth, bone cancer and other complications.

Radiographic changes due to radiation therapy.

Figure 8: Bone and Teeth

4.7 Cataracts

They are opacities on the surface of the eye's lens. It is usually due to denaturing of the protein that makes up the lens.

This denaturing of the lens can be caused by radiation. It obscures the transmission of light, thus, such individuals do not see with the lens. If the cataract is big enough, it leads to blindness. The retina is usually not affected by radiation. Cataracts can be treated by surgical removal of the cataract.

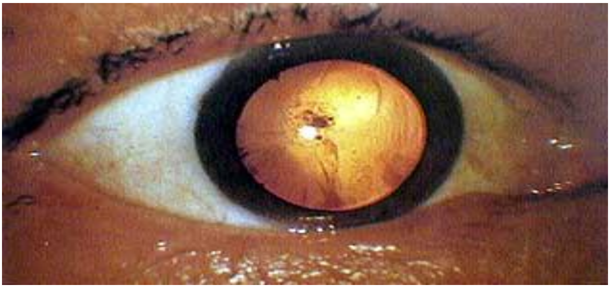

Figure 9: Cataracts

4.8 Leukemia

Leukemia is a progressive growth of abnormal leukocytes (white blood cells) found mainly in the bone marrow due to long term exposure of radiation. It occurs when an individual takes in strontium - 90 which tends to deposit on the bone marrow. The high rate of leukemia among the Japanese survivors of the atomic bomb detonated at Hiroshima and Nagasaki at the end of World war 11 drastically demonstrated the role of high – dose radiation in causing leukemia (Lichtman, 2008).

4.9 BIOLOGICAL EFFECTS OF LOW LEVEL RADIATION AND IONIZING RADIATION

Two main factors enhance the effect of ionizing radiation in biological system. These factors are:

(1) The deposition of radionuclide in the organism followed by energy absorption by a specific organ.

(2) The overall distribution of energy in the organization which lead to ionizing and excitation processes. This shows that, if radiation passes through an organism without dissipating any energy on it, then no biological effect would be caused. The effects of non-ionizing radiation are shown below in the Table 4.

Table 4 : Effects of Non –ionizing Radiation

Source	**Wave length**	**Biological Effects**
Ultraviolet germicidal irradiation	100nm - 280nm	Skin erythema, inflammation of cornea (photokeratitis).
Black light, sunlight	315nm - 400nm	Eye-photochemical cataract ,skin-Erythema
Lasers, sunlight, fire Light bulbs	400nm - 780nm	Skin photo-ageing, skin cancer; eye Photochemical and thermal retina injury
Lasers, remote controls	780nm - 1.4µm	Eye thermal retina injury Thermal cataract; skin burn
Lasers, long distance Telecommunications	1.4µm - 3µm	Eye – corneal burn, cataract: skin Burn
Far-infrared laser	3µm – 1nm	Eye – corneal burn, cataract: heating of body surface
Some mobile /cell Phones, microwave ovens, cordless phones, motion detectors	1nm – 33cm	Heating of body surface
Power lines	>3km	Accumulation of charge on body surface. Disturbance of nerve and muscle responses
Strong magnets	Infinite	Magnetic – vertigo/nausea

4.10 FACTORS THAT DETERMINE THE EXTENT OF RADIATION EFFECT

The effect of radiation on the human body depends mainly on the dose of radiation taken, duration of radiation, type of radiation and the sensitivity of the part of the body exposed to it (ICRP, 1977, UNSCEAR, 1988, Ike, 2008). According to Ike (2010), other factors are:

(i) Total dose
(ii) Type of cell
(iii) Type of radiation
(iv) Age of individual
(v) State of cell division
(vi) Part of body exposed
(vii) General state of health of the individual
(viii) Tissue volume exposed
(ix) Duration or length of time of exposure to the person.
(x) Route or channel of exposure

5.0 THE INTERNATIONAL NUCLEAR AND RADIOLOGICAL EVENT SCALE

The International Nuclear and Radiological Event Scale (INES) is a tool for promptly communicating to the public in consistent terms the safety significance of reported nuclear and radiological incidents and accidents, excluding naturally occurring phenomena, such as radon. The scale can be applied to any event associated with nuclear facilities, as well as the transport, storage and use of radioactive materials and radiation sources. The primary purpose of the INES Scale is to facilitate communication and understanding between the technical community, the media and the public on the safety significance of events. The aim is to keep the public, as well as nuclear authorities, accurately informed on the occurrence and potential consequences of reported events. Figure 10 shows the International Nuclear and Radiological Event Scale.

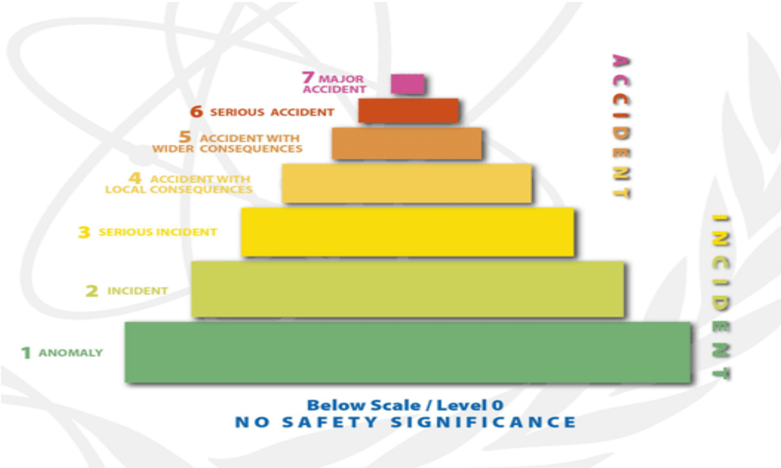

Figure 10: The International Nuclear and Radiological Event Scale

The INES uses a numerical rating to explain the significance of nuclear or radiological events similar to ratings for earthquakes or temperature. INES applies to any event associated with the transport, storage and use of radioactive materials and radiation sources. Such events can include industrial and medical uses of radiation sources, operations at nuclear facilities or the transport of radioactive materials. Events are classified at seven levels: Levels 1–3 are "incidents" and Levels 4–7 "accidents". These levels consider three areas of impact: people and the environment, radiological barriers and control, and defence in depth. The scale is designed so that the severity of an event is about ten times greater for each increase in level on the scale. Events without safety significance are called “deviations” and are classified below Scale/Level 0.

6.0 REVIEW OF NUCLEAR AND RADIATION ACCIDENTS

A nuclear and radiation accident is defined by the International Atomic Energy Agency (IAEA, 2008) as *"an event that has led to significant consequences to people, the environment or the facility. This has the ability of increasing the background ionizing radiation with its attendant hazards and effects. Examples include lethal effects to individuals, large radioactivity release to the environment, or reactor core melt"*.

The prime example of a major nuclear accident is one in which a reactor core (the power house of a nuclear energy plant) is damaged and large amounts of radiation are released, such as in the Chernobyl disaster in 1986.

The likelihood and potential impact of nuclear accidents has been a topic of debate practically since the first nuclear reactors were constructed. It has also been a key factor in public concern about nuclear facilities (Romana, 2009). Many technical measures to reduce the risk of accidents or (should one occur) to minimize the amount of radiation released to the environment have been adopted. Despite the use of such measures, there have been many accidents with varying impacts as well as near misses and incidents. Sovacool (2011) has reported that globally there have been 99 accidents at nuclear power plants from 1952 to 2011. There have been comparatively few fatalities associated with nuclear power plant accidents.

Table 5 shows nuclear power plant accidents with multiple fatalities and/or more than US$100million in property damage, 1952-2011.

Table 5: Nuclear power plant accidents 1952-2011(Sovacool ,2011)

Table 5: Nuclear power plant accidents 1952-2011(Sovacool ,2011)

S/no	Date	Location	Description	Deaths	I-131 Release in 1,000 Ci	Cost (in millions 2006 $US)	INES level
1	January 3, 1961	Idaho Falls, Idaho, US	Explosion at SL-1, National Reactor Testing Station.	3	0.08	22	4
2	April 26, 1986	Pripyat, Ukraine	Steam explosion and meltdown (Chernobyl disaster)	53	7000	6,700	7
3	February 20, 1996	Waterford, Connecticut, US	Leaking valve forces shutdown Millstone Nuclear Power Plant Units	0		254	3
4	September 2, 1996	Crystal River, Florida, US	Balance-of-plant equipment malfunction forces shutdown and extensive repairs at Crystal River Unit 3	0		384	3
5	September 30, 1999	Ibaraki Prefecture, Japan	Workers at the Tokaimura uranium processing facility	2		54	4

			added too many buckets of uranium directly into a precipitation tank, causing it to go critical, killing two, and exposing one more to radiation levels above permissible limits				
6	February 16, 2002	Oak Harbor, Ohio, US	Severe corrosion of control rod forces 24-month outage of Davis-Besse reactor	0		143	3
7	August 9, 2004	Fukui Prefecture, Japan	Steam explosion at Mihama Nuclear Power Plant kills 4 workers and injures seven more	4		9	1
8	March 11, 2011	Fukushima, Japan	Cooling failure in 4 reactors following an earthquake, tsunami and multiple fires at the Fukushima I Nuclear Power Plant	?	2400	7	7(provisional)

Table 6 : Reported Radiation accidents (Sovacool, 2009)

S/no	Radiation Accident	Effects
1	1952 - AECL Chalk River Laboratories, Canada	Partial meltdown, about 10,000 Curies released
2	Sept. 1957 – Mayak nuclear waste storage tank explosion at Chelyabinsk	Two hundred plus fatalities, believed to be a conservative estimate; 270,000 people were exposed to dangerous radiation levels. Over thirty small communities had been removed from Soviet maps between 1958 and 1991
3	July 1961 – Soviet submarine K-19 accident.	Eight fatalities and more than 30 people were over-exposed to radiation
4	March 1984 – Radiation accident in Morocco,	Eight fatalities
5	August 1985 – Soviet submarine K-431 accident.	Ten fatalities and 49 other people suffered radiation injuries.
6	September 1987 – Goiania accident.	Four fatalities and 249 other people received serious radiation contamination
7	December 1990 – Radiotherapy accident in Zaragoza.	Eleven fatalities and 27 other patients were injured.
8	April 1993 - accident at the Tomsk-7 Reprocessing Complex	The explosion released a cloud of radioactive gas. (INES level 4
9	1996 – Radiotherapy accident in Costa Rica.	Thirteen fatalities and 114 other patients received an overdose of radiation.
10	April 2010 - Mayapuri radiological accident, India,	One fatality
11	March 2011- Fukushima I nuclear accidents, Japan	Current event
12	March 2011- Fukushima Daini Power Station	radioactive discharge

The nuclear and radiation accidents are classified into various types including:

(1) Loss of coolant (Fukushima Power Station, Japan).
(2) Criticality or power excursion (Chernobyl accident, Soviet Union),
(3) Decay heat accident (Three Mile Island, Pennsylvania, US),
(4) Equipment failure (Białystok , Poland),
(5) Human error (Manhattan Project, Canadian),
(6) Lost source accidents (Goiânia , Brazil) and
(7) Other accidents that defy classification.

7.0 RADIATION ACT AND NUCLEAR AGENCIES IN NIGERIA

Ionizing radiation with its many useful domestic and industry applications has several health hazards as presented in section 4. Governments at the international and national levels have the major role of creating adequate environment and regulatory agencies/organizations that help to maintain standards, training of radiation workers, regulate and establish radiation standards so as to protect the environment thus making it safe for sustainable development. Governments should also take extraordinary measures to protect occupational radiation workers and the public from excessive exposure to radiation.

In Nigeria, apart from the enabling Act, there are two major agencies with several subsidiaries responsible for the radiation safety of our environment.

7.1 Nuclear Safety and Radiation Protection Act, CAP NI42, LFN 2004

The Act is concerned with the regulation of the use of radioactive substances and equipment emitting and generating ionizing radiation. In particular:

- Section 4 provides authority to make regulations for the protection of the environment from the harmful effects of ionizing radiation.
- Sections 15 and 16 make registration of premises and the restriction of ionizing radiation sources to those premises mandatory.
- Section 37 (1) (b) allows an inspector to verify records of activities that pertain to the environment.
- Section 40 clarifies that the same regulations guiding the transportation of dangerous goods by air, land or water should also apply to the transportation of radioactive substances.

7.2 Nigerian Nuclear Regulatory Authority (NNRA).

There are four basic mandates of this agency. They are:

1. To Set Requirements and Ensure Compliance, the NNRA:

- Sets and documents clear requirements, using a process that includes consultation;
- Cooperates with other organizations and jurisdictions to foster the development of consistent regulatory requirements;
- Indicates acceptable ways to meet regulatory requirements;
- Promotes compliance with regulatory requirements;
- Verifies that processes and programs satisfy regulatory requirements;
- Enforces requirements using a gradual but consistent approach; and
- Uses appropriate industry, national or international standards.

2. To Base Regulatory Action on Levels of Risk, the NNRA

- Regulates persons, organizations and practices that are subject to the Act in a manner that is consistent with the risk posed by the regulated practice;
- Recognizes that risk must be considered in the context of the NNRA's mandate under the Act

3. To Make Independent, Objective and Informed Decisions, the NNRA

- Performs objective assessments of information submitted by licensees, interveners and others;
- Recognizes the role of professional judgment;
- Maintains a consistent regulatory process;
- Learns from experience and the experiences of others, and strives for continuous improvement.

4. To Serve the Public Interest, the NNRA

- Carries out its mandate in the interest of Nigerians;
- Communicates openly and transparently with stakeholders in an objective fashion while respecting Nigeria's access to information and privacy laws;
- Provides stakeholders with the opportunity to be heard in accordance with the prescribed rules of procedure;
- Consults with stakeholders when establishing priorities, developing policies, and planning programs and services;
- Interacts with foreign nuclear regulators and appropriate national and international organizations, and cooperates with other jurisdictions; and
- Operates in an effective and efficient manner.

7.3 Nigeria Atomic Energy Commission (NAEC)

NAEC's primary goal entails the provision of the pathway to explore, exploit and harness atomic energy for peaceful applications in the quest for the socio-economic development of Nigeria. This, expectedly, would be done in conformity with the economic policies of the Federal Government. Those objectives that are relevant to the attainment of this goal are listed as follows:

(i) To streamline, harmonise, promote and coordinate research and development activities for capacity building and infrastructure development in nuclear technology.
(ii)To fast-track and catalyze the process of development and deployment of nuclear power plants for electricity generation in Nigeria, in partnership with the private sector.
(iii) To put in place a comprehensive manpower development programme which includes: (a) Development and introduction of core training programmes in nuclear science and engineering in selected institutions of higher learning in Nigeria to generate the critical mass of the needed manpower for the nuclear industry. University of Port Harcourt is involved in the actualization of this mandate.

(b) Develop, network and create opportunities for fellowships and advanced training in nuclear science and technology in international organizations and institutions with advanced facilities in other countries with similar objective to use nuclear technology for peaceful applications only.

(c) To develop the requisite legal framework for the use of nuclear power plants in Nigeria within a strict regulatory regime as specified by the Nigerian Nuclear Regulatory Authority (NNRA), and in due compliance with the three universal cardinal planks of safety, security and safeguards.

(d) To liaise with the International Atomic Energy Agency (IAEA), the Preparatory Commission to the Comprehensive Nuclear Test Ban Treaty Organization (CTBO), other international organizations and countries with similar vision for the implementation of the national programmes.
Other allied and cooperating agencies in Nigeria are:
ANA - Atomic Nuclear Agency
FEPA - Federal Environment Protection Agency (now Fed.

Min. of Environment)

NIRPR - National Institute of Radiation Protection and Research

FEDA - Federal Environmental Development Agency

International Agencies

At the international level, agencies and commissions have been established for the World radiation safety. They are conservative, flexible and based in solid scheme, so providing adequate protection and data against all known health effects of any form of radiation either ionizing or non – ionizing radiations (Ike, 2010). Some of these agencies and commissions in which Nigeria has cooperation signatures include:

IAEA - International Atomic Energy Agency.
AERB - Atomic Energy Regulatory Board
IARC - International Agency for Research on cancer
IACRS - Inter Agency Committee on Radiation Safety
ICRU - Inter Committee on Radiation Units and Measurements
ICRP - Inter Commission on Radiation Protection
ICNIRP - Inter Committee on Non-ionizing radiation protection
NCRP - Natural Council on Radiation Protection
UNSCEAR - United Nations Scientific Committee on effect of atomic Radiation
USNRC - United States Nuclear regulatory Commission
WHO - World Health Organization.

8.0 SOME APPLICATIONS OF RADIATION

Mr. Vice- Chancellor Sir, it will interest you to know that despite the associated hazards radiations are useful for the enhancement of technology and socio-economic improvement. Some specific applications are presented below.

8.1 Medical Applications:

- Blood therapy – blood counting, blood type, time rate of destruction
- Radiation therapy – Treatment for cancer, bone marrow etc
- Irradiation of joints (rheumatoid arthritis)
- X-rays for bones, heart and brain tumors
- Stimulation of medical instruments and equipment
- Anemography – breast treatment
- Radiology - treatment of injuries and dresses with EM waves

8.2 Industrial Application:

- Pathogenic reduction of diseases
- X-ray crystallography in pipeline welding, cutting etc
- Nuclear energy and researches
- Radio-carbon dating
- Oil and Gas activities – rig operation
- Radio-isotopes are used to eliminate static elements.

8.3 Agricultural sector:

- Food pasteurization and irradiation
- Food preservation and sterilization
- Plant genetics for plant breeding
- Entomology and Pest control
- Fertilizer production and study of uptake of fertilizer in plants

8.4 Archaeology: Use of carbon dating for age determination of decaying materials.

8.5 Telecommunication: Thallium sulphate is used extensively in military command systems; radar and telegraphs.

8.6 Astronomy:-

- Radio astronomy
- Observatory, quasar
- Particles strap.

8.7 Use for Nuclear Energy generation

8.8 Nuclear Power:- for war (Ukraine, China, Iran etc.)

9.0 PATHWAYS OF RADIATION TO MAN

Mr. Vice- Chancellor Sir, permit me to show you some of the pathways through which radionuclides released into the environment from various sources find their ways to the soil, plants, water, air, aquatic organism and ultimately to man. As a result of the dispersion of these radionuclides to the environment, the International Atomic Energy Agency initiated the Monitory in Environment and Found (MEF) program (IAEA, 1989). Figure 11 shows the radionuclides pathway.

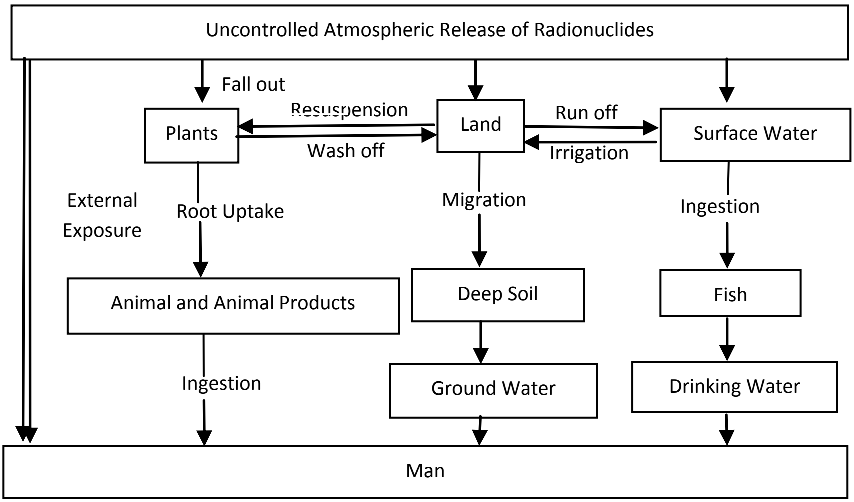

Figure 11: Major pathways of radionuclides to man (IAEA, 1989)

Furthermore, pathways through which man receive radioactive materials from solid minerals exploration and oil mineral exploitation and exploration sources which are classified as 'Technologically Enhanced Naturally Occurring Radioactive Materials (TENORMs)' are shown in Figure 12 below:

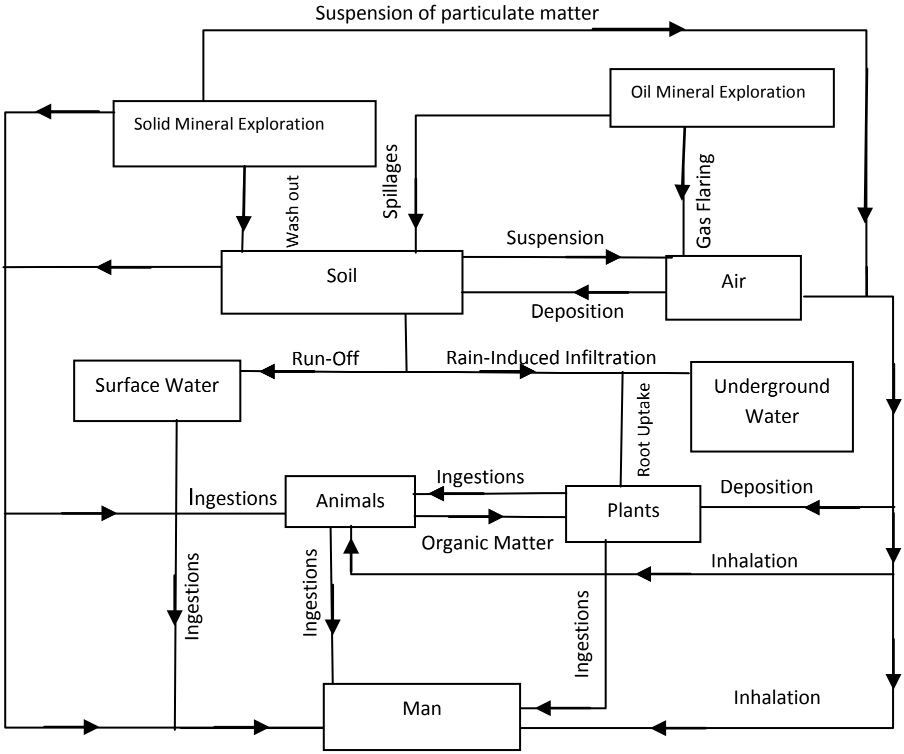

Figure 12: Major Pathways of TENORM to Man from Solid/Oil Mineral Exploration Source

Table 7 shows a list of radionuclide of major importance in the contamination of food and other environmental samples.

Table 7 : Radionuclides in Air, Soil and Food (IAEA, 1989)

Samples	Radionuclides
Air	^{131}I, ^{134}Cs, ^{137}Cs
Water	^{3}H, ^{89}Sr, ^{214}Bi, ^{90}Sr, ^{131}I, ^{134}Cs, ^{137}Cs, ^{40}K, ^{238}Th
Milk	^{80}Sr, ^{90}Sr, ^{131}I, ^{134}Cs, ^{137}Cs
Meat	^{134}Cs, ^{137}Cs
Other Foods	^{89}Sr, ^{90}Sr, ^{134}Cs, ^{137}Cs
Vegetables	^{89}Sr, ^{90}Sr, ^{95}Zr, ^{95}Nb, ^{103}Ru , ^{131}I, ^{134}Cs, ^{137}Cs, ^{141}Ce, ^{144}Ce
Soil	^{90}Sr, ^{134}Cs, ^{137}Cs, ^{238}Pu, ^{241}Am, ^{242}Cm, ^{238}U, ^{242}Th

10.0 CONTROL OF EXPOSURE TO RADIATION AND ALARA PRINCIPLE

Sources of radiation external to the body account for the radiation dose that can affect the individual due to exposure. Four basic principles and procedures are adopted as control and ways to limit radiation exposure. Figure 13 below shows the Illustration of some radiation control procedures.

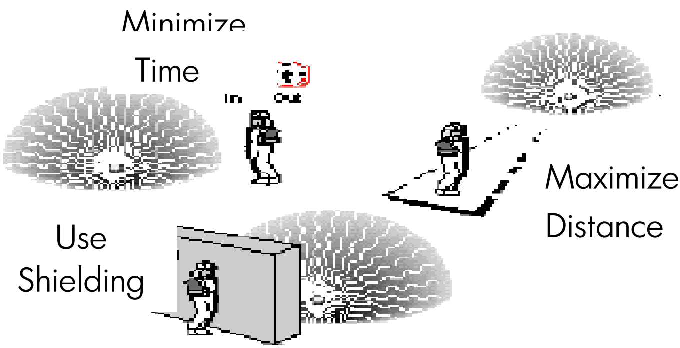

Figure 13: Illustration of Radiation Control

(a) Time

The amount of time spent near a source of ionization radiation is a major factor in the ionization process. Therefore, limiting or minimizing the exposure time will reduce the dose from the radiation source.

(b) Distance

To reduce the effects of radiation, closeness to a source should be minimized. Radiation intensity (R) decreases sharply with distance (r) according to the inverse square law i.e. $R \propto 1/r^2$. Therefore, the nearer a source of radiation the more effective of its action.

(c) Shielding

Shielding on source of radiation generally reduces the radiation levels around the radioactive source. In particular, shielding should be utilized for stored sources. Barriers of lead, concrete of water are used as shields from gamma ray, and neutrons. Some radioactive materials are stored or handled underwater or by remote control in rooms constructed of thick concrete or lined with lead. Shielding can also be designed using halving thickness, the thickness of material that reduces radiation by half.

(d) Containment

Radioactive materials are confined in the smallest possible space and kept out of the environment from the public reach. Usually, nuclear reactors operate within closed systems with multiple barriers which keep the radioactive materials contained. Rooms are designed to have reduced air pressure thus any leaks occur into the room and not out of it.

The ALARA Principle:

A philosophy of control of radiation dose called As Low As Reasonably Achievable (ALARA) has become an integral, functioning part of radiation protection programmes. This is an optimization principle that guides all users of radioactive materials and radiation producing sources.

11.0 MY CONTRIBUTIONS TO TENORM RESEARCH IN THE NIGER-DELTA ENVIRONMENT

The increasing level of ionizing radiation in the environment especially in the Niger-Delta is mainly due to contributions from the technologically enhanced NORM. Most research works and studies in radiation are domiciled in the scope of TENORM. Mr. Vice Chancellor Sir. My studies and contributions in the past decade are centered on the TENORM. Some are presented below:-

11.1 RADIATION IN OIL AND GAS SECTOR

According to Ikoku (2000), the impact of oil and gas activities on the physical environment are the general aspects that have generated the most controversy and debates among scholars, environmentalists, industrialists, politicians and communities. This is because each group evaluates the effects from different points of view over different time scales and with different objectives in mind. Highlights of some of our studies on the contribution of the exploration and exploitation of oil and gas to the ionizing radiation of the Niger-Delta are as follow:

Avwiri et al., (2007) studied the terrestrial radiation around oil and gas facilities in Ughelli region of Nigeria and reported a range of 12.00 ± 0.l μRh^{-1} (5.33 ± 0.35µSv/wk) to 22.00±2.lμRh^{-1} (9.79±0.16 µSv/wk) in the oil fields and 09.00 ± 1.0 to 11.00 ± 0.5 μRh^{-1} in the host communities. We concluded that though the radiation values are within international standards and are in consonant with other reported values in the country. However, the background ionizing radiation levels exceeded the normal background level. Also, the significant difference between the values of the company premises and the host community suggests impactation of the company's immediate environment.

Avwiri and Agbalagba (2007), surveyed the gross alpha and beta radionuclide activity in Okpare Creek situated in an oil field in Delta State and reported average alpha activities in the three classified zones as 1.03 ± 0.097, 4.26 ± 0.109 and 10.29±0.489 Bql^{-1} respectively, and beta activity in the three zones as 0.19 ± 0.100, 0.52 + 0.003 and 0.793 + 0.010 Bql^{-1} respectively. These values are far above the 0.1 Bq/l for alpha and 1.0 Bq/l for beta WHO maximum recommended level for the screening of drinking water (WHO, 2003).The results reflected the influence of the activities in the environment.
Avwiri et al., (2008) also assessed the natural radioactivity concentration and distribution in River Forcados, Delta State using exploranium - The-Identifier GR-135 model and reported the average specific activity values obtained for ^{40}K, ^{232}Th and ^{226}Ra as 113.9 ± 9.70, 12.80 ± 2.84, and 34.62 ± .7lBql^{-1} respectively. The values obtained are comparable to other reported values obtained elsewhere in Nigerian rivers and well below international standards, thus may not pose any serious radiological health hazards on the populace that uses the river.

Avwiri et al., (2008) estimated the occupational radiation profile of oil and gas facilities during and off – production periods in Ughelli oil field. We reported a maximum exposure rate of 26.00 ± 5.1μRh^{-1} obtained during production period and concluded that the elevated levels indicated a measure of radiation health hazard on the field workers and suggested regular monitoring, job rotation and reduction in radionuclide bearing input materials as precautionary measures.

11.2 TELECOMMUNICATION AND POWER LINES

In 2007, we were commissioned by the Governing Council of this University to study the 'effects of GSM Mast Antennas and the high tension electric cables on the environment of Delta Park '. The findings showed that the radiation level ranged between 0.03 $\mu W/cm^2$ to 0.288 $\mu W/cm^2$ while the SAR level ranges from 0.682 x 10-5 W/kg to 2.89 x 10-3 W/kg. The mean power density obtained is 0.023% of the FCC guideline, 0.015% of the NRPB permissible limit and 0.019% of the ICNIRP and Internal public exposure maximum permissible limit. Hence the RF values may have no impact or cause biological, epidemiological or physiological effects on the residents. However, mechanical failure of the mast could cause devastating physical effects. Therefore, building of mast in residential areas should be discouraged. Also, because of other hazards associated with high tension power lines, it is not advisable to live or carry out commercial activities under them.

A study of the radio-frequency radiation power density delivery of inactive and active cell operations of some makes and models of GSM mobile phones in Nigeria was carried out. The results showed that the specific absorbed rate (SAR) values were well below recommended maximum permissible limits and may not cause any immediate radio-frequency radiation health side – effects among the users of GSM handsets (Avwiri et al, 2009). However, Ladies and Gentlemen, knowing that the radiation effects depend partly on the duration of exposure, a continuous call or increase in call time especially long free night calls could lead to the risk of increased exposure to high SAR dosage which may result to future radiation health related problems. Thus, caution must be exercised by users of handset phones.

11.3 INDUSTRIAL SECTOR

The presence of an industry or factory can contribute to the elevation of the background ionizing radiation of the immediate environment. The effect/impact of industrial production on its host environment essentially depends on the nature of the input raw materials, effluents from the production process and the output products. Ebong and Alagoa (1992) studied the background radiation pattern of pre- and post-industrial activities of a fertilizer plant and reported an increase in the level of background radiation in the post-industrial activities.

Ebeniro and Avwiri (1998), studied the external environmental radiation in the Trans-Amadi industrial area and other sub-industrial areas of Port Harcourt and reported an average value of $0.014mRh^{-1}$. The result indicated some level of impactation of the environment and a significant elevation from the standard background radiation level for similar environment. Also, a determination of radionuclide levels in soil and water around cement companies in Port Harcourt revealed mean dose rate equivalent of 0.18 mSv/y❈ and 0.39 mS/y❈ for water and soil samples respectively. These results were lower than the International Communication on Radiological Protection (ICRP) maximum permissible levels but were higher than other non-impacted environments (Avwiri, 2005). Furthermore, Avwiri et al., (2005) surveyed the radionuclides concentration of soil, sediments and water in Aba River, Abia State and reported higher concentrations compared to previous studies already done (Jibiri et al, 1999, Tchokossa et al., 2011). This significant increase was attributed to the activities of the

Industrial Zone in Aba where the industries discharge their untreated effluents directly into the river. A similar work on the radiological impacts of natural radioactivity along Aleto River due to the petrochemical industry in Port Harcourt showed a significant level of elevation of the radionuclide at the point of discharge of effluents into the river (Avwiri and Tchokossa, 2006).

Assessment of the natural radionuclide in borehole water in some selected wells in Port Harcourt revealed that the mean specific activity and the resulting annual effective doses for ^{226}Ra, ^{228}Ra and ^{40}K were 3.51±2.22, 2.04 ± 0.29 at 23.03 ± 4.37 and 0.36 ± 0.12, 0.51 ± 0.02 and 0.05 ± 0.01mSY/y❋ respectively (Avwiri et al. 2006). The results of this survey are within the range obtained elsewhere. Generally, public places showed the highest activity concentration due partially to poor sanitation.

Recent studies of the radionuclide contents and background ionizing radiation of some selected dumped sites in Port Harcourt showed some reasonably high values of the radionuclide levels due to the various types of non-segregated wastes ranging from medical, domestic and industrial (Avwiri et al, 2011).

11.4 RADIATION IN CROPS AND FOODSTUFFS

Food production is a major occupation of most Nigerians. Therefore radionuclides in food stuffs are of radiological importance when assessing the contribution to the internal dose through the ingestion pathway and general risk assessment of radiation to a nation.

In 2010, the study of soil-to-crop transfer factors (TF) of natural radioactivity and Its associated radiological health hazards indices in cultivated areas around a fertilizer factory in Onne, Rivers State was carried out (Avwiri et al, 2010). The results showed that the ranges of the TF of ^{40}K, ^{238}U and ^{232}Th from soil to cassava are 0.61 – 4.59 for ^{40}K, 0.36 – 1.82 for ^{238}U and 0.20 – 1.89 for ^{232}Th. Potassium-40 was observed to concentrate more in cassava. These values are quite higher in comparison with the study done by Tchokosa (2006) in Oil and Gas producing area of Delta State, the transfer factor values ranged from 0.1 – 0.98 for ^{40}K, 0.03 – 0.57 for ^{226}Ra and 0.41 for ^{228}Ra. These higher values could be attributed to the prolonged effluents from the fertilizer plant on the environment.

Also, assessment of processing effects on the level of radionuclides in some commonly cultivated foodstuffs around the Niger- Delta area was carried out. The results showed that food processing substantially reduced the radionuclides levels in the foodstuffs by a factor of 0.43; therefore, food should be properly processed before eating to reduce the radon gas inhalation from them.

11.5 RADIATION FROM SOLID MINERALS

Ezekwesili (2005), then Minister of Solid Minerals solicited for the diversification of the Nigerian economy to accommodate solid minerals mining so as to encourage sustainable growth and development of industrial production, revenue generation, employment creation and human capital development. Actualization of these goals has led to the increase in the exploration of solid minerals across the states of the country with their attendant environmental consequences.

Avwiri *et al.* (2010) studied the occupational radiation levels in solid mineral producing areas of Abia state. The results of the radiation exposure rate ranged between 14.7 µR/hr – 18.2

µR/hr which constitute an elevation over the host communities' normal background radiation level of 11.4 µR/hr. These measured radiation exposure levels could yield some future radiological health side effects to the miners, farmers and the environment.

12.0 CONCLUDING REMARKS

Mr. Vice Chancellor Sir, the safety of our environment obtainable by combating all sources of degradation must be a collective effort by all aspects of science and technology. The Niger Delta of Nigeria has been greatly afflicted by the blessing of oil and gas with its associated industrial activities. Today, the global community is agitated by the fluctuating level of ionizing radiation released from the FUKUSHIMA nuclear plant in Japan. Nigeria must not be left out in the global efforts to minimize the numerous effects of ionizing radiation through a focused scientific knowledge, technological expertise and international collaboration by the adoption of protocols and commission's reports on radiation protection.

Chairman Sir, I will like to recommend the followings:

- There should be regular and periodic radiological survey of the major industrial lay -outs in the country to curb the build – up of radiation levels and minimize the radiological risk of the populace.
- Regulatory agencies should check the indiscriminate discharge of untreated industrial effluents, domestic wastes and imported wastes, such as the dumping of 3500 tons of toxic waste suspected to be radioactive toxic waste at Koko, Delta State in 1988, into rivers and other receiving environments to reduce their radiological burden on the users and residents of such environments.

- In the course of oil exploration activities; oil spillages, gas flaring and indiscriminate disposal of contaminated sludge and scales from oil pipelines and equipment should be checked since researches have shown that oil contains naturally occurring radioactive materials capable of enhancing the background radiation level of the environment.
- The Federal Government's environmental regulatory body and other state environmental bodies should set regulatory standards that will help to check the environmental radiological impact of the activities of non-nuclear industries such as oil and solid mineral mining industries.
- The study of the background ionizing radiation of the environment should be included in Environmental Impact Assessment (EIA) and Post Impact Assessment (PIA) studies of industrial projects because of their significant contributions to the terrestrial radiation level of their host communities.
- The Federal Government of Nigeria should establish radiation monitoring stations in all the seaports, International airports and industrial areas/lay outs in the country to checkmate the illegal entrance of radioactive materials into the country thereby regulating the ionizing radiation level.
- Finally, in view of Japan's experience in the management of the recent radiation problem and the proposed phasing out of all nuclear power plants by developed countries like Germany, China, USA and Italy, I hereby call on the Federal Government of Nigeria to reconsider the proposed plan of generating electricity from Nuclear reactors in 2017 In a bid to solve the protracted power problems and explore other forms of energy that are safe and environmental friendly.

Thank you and God bless.

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CITATION OF PROFESSOR GREGORY ONOMAKERE AVWIRI

Prologue

> *"The fear of the LORD is the beginning of knowledge; but the fools despise wisdom and instruction" Proverbs 1:7.*

Birth

Professor Gregory Onomakere Avwiri, the university 79th Inaugural Lecturer was born at Oviorie-ovu to the family of Chief J. A. Avwiri of Oviorie- Ovu and Mrs. Titi Avwiri of Okpara lnland, Ethiope-East Local Government Area of Delta State on 9th September 1965.

Education

He started his academic voyage in 1971 at the Ovu Primary School 1, Ovu Inland. He was admitted to Ovu Grammer School, Ovu where he obtained the West African School Certificate in 1982 with a record of the highest number of credits in the examination. This endeared him to the Principal who employed him as an Auxiliary Teacher to teach Physics and Integrated science.

In 1984, he was admitted into the University of Port Harcourt and graduated in 1988 as the best graduating student in Physics/Electronic. After the mandatory NYSC at Government Secondary School, Wuse-Abuja, he enrolled for his M.Sc. (Solid State Electronics) at the University of Port Harcourt in 1989 and graduated in 1991. The search for a doctoral degree took him to the Rivers State University of Science and Technology in 1993 where he obtained a PhD in Environmental Physics.

Working Experience

Professor Avwiri joined the University of Port Harcourt as an Assistant Lecturer in 1991 and rose through the rank and file to the rank of Professor of Physics in March 2007. Since he joined the University, he has never missed a promotion exercise when due for it. He was a visiting Scholar to Delta State University, Abraka in 2003/2004 session. He is an Environmental Consultant to several companies and academic mentor to several of his colleagues with the philosophy of discipline, precision and excellence. He has graduated one PhD and four M.Sc. students. He currently supervises four PhD students, four M.Sc. students and several undergraduate students in the Department of Physics, University of Port Harcourt and Delta State University, Abraka. He was a member of NUC accreditation Team in 2009 and was a Panelist in the Federal Scholarship Board Committee of Federal Ministry of Education, Abuja in 2010.

Awards and Appointments

Professor Avwiri has received several awards. Notable among them is the best graduating student award prize in Physics/Electronic (Uniport) and Federal Government Scholarship for his M.Sc programme.

He has served in various capacities both in public service and Christian duties. Among many are SIWES Coordinator (Faculty of Science), Hall warden (Amino kano Hall and Postgraduate Hall), National Auditor (NICA), Head of Physics Department, Council Committee on Student Welfare, Senate Committee on Student Unrest, Senate Committee on the Criteria for selection of Emeritus Professor, Senate Committee on Inter-religious harmony on campus, Appointments & Promotion Committee (SPAT), Board of CORDEC, Board of Basic Studies and School of Graduate Studies, General Secretary PWSC, Chairman, Education Committee - Rivers Baptist Conference and Coordinator, University of Port Harcourt Research Fair. Because of his integrity and candor, he was appointed the Head of Department of Mathematics and Statistics of this University in 2009 to restore stability, decorum and orderliness to the department.

Family Life and Christian Activities

Professor Avwiri is happily married to Mrs. Eseroghene and they are blessed with four children, Fejiro, Aghogho, Rukevwe and Urinrin. He is a dedicated Christian, Preacher, Staff Advisor to many

Christian fellowships and members of various Christian organizations and mission groups.

Conclusion

Mr. Vice Chancellor Sir, Principal Officers of the University, Special Guests, Invited Guests, Staff and students, distinguished ladies and gentlemen, May I humbly present to you an academia, a scientist, a researcher of great repute, an achiever, a preacher and a lover of fairness, justice and equity for all mankind to deliver the 79th Inaugural lecture of the University of Port Harcourt.

Epilogue

> *"Let us hear the conclusion of the whole matter: Fear God and keep His commandments, for this is the whole duty of man. For God shall bring every work into judgment, including every secret thing, whether it be good or whether it be evil" – Ecclesiastes 12:13 – 14.*

Prof. A. A. Uwakwe