



UNIVERSITY OF LAGOS
Inaugural Lecture Series 2014

TOPIC:

**HOPES AND FEARS: THE QUANDARY
OF LIVING WITH RADIATIONS**

By
PROFESSOR M. A. AWEDA

5/1/20

L
36

L25

.96

2014

**HOPES AND FEARS:
THE QUANDARY OF LIVING WITH
RADIATIONS**

An Inaugural Lecture Delivered at the University of Lagos
Main Auditorium on Wednesday, 5th November, 2014

By

PROFESSOR M. A. AWEDA
B.Sc., M.Sc., Ph.D, BNS, MNAMP, MSFPH, MAAPM
Professor of Radiation Biology

Department of Radiation Biology, Radiotherapy;
Radiodiagnosis and Radiography (RBRRR)
Faculty of Clinical Sciences
University of Lagos

University of Lagos Press and Bookshop Ltd

© M. A. Aweda, 2014

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system or transmitted in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise without the permission of the author.

Published 2014

By

University of Lagos Press and Bookshop Ltd
Unilag P.O. Box 132,
University of Lagos,
Akoka, Yaba-Lagos,
Nigeria.

ISSN 1119-4456

Preamble

Vice Chancellor, Professor Rahman Adisa BELLO;
Deputy Vice Chancellor (Academics and Research),
Professor Babajide ALO;
Deputy Vice Chancellor (Management Services), Professor
Duro ONI;
Registrar and Secretary to Senate and Governing Council, Dr.
Mrs. Taiwo Folashade IPAYE;
My Provost of the College of Medicine, Professor Folashade
Tolulope OGUNSOLA;
My Dean, Faculty of Clinical Sciences, Professor Foluso Egun
Afolabi LESI;
Deans of other Faculties;
Members of Senate;
Gentlemen of the Press;
All invited Guests; and
Distinguished Ladies and Gentlemen.

I want to commence my inaugural lecture by acknowledging and appreciating God Almighty, my God, my Lord, my Saviour, the Adeda, the Aseda, the **AWEDA**, the Ameda and the Eleda, the Creator of Heavens and the Earth. To Him alone be all the glory, honour, might and power forever.

I seize this opportunity to express gratitude to our amiable, virile and indefatigable Vice Chancellor, Prof. Rahamon Adisa Bello for this opportunity to share some of my experiences and achievements in the pursuit of my academic career this 5th day of November, 2014. Sir, please accept my appreciation. This inaugural lecture is the 266th of its type in the history of the University, the 10th in the current academic year and the **first** in the history of the Department of Radiation Biology, Radiotherapy, Radiodiagnosis and Radiography (RBRRR).

Background

I came from a poor family, my late lovely parents, Mr. Johnson AWEDA and Mrs. Comfort AWEDA, who laboured hard and denied themselves of pleasures and comforts in order to send me to school. How I wish they were alive today to witness and praise God for their labour and sacrifices. My father was a peasant farmer and a disciplinarian; he had to struggle hard to get money and send me to school. I was always with him working on the farm all through my youthful days, especially during holiday periods. Right from my youth, I developed an inquisitive mind, always asking questions and wanting to know or finding reasons for whatever happened around me and how it happened. As a child, out of inquisitiveness, I dismantled things like wristwatch, clock, radio, domestic appliances etc because I wanted to know their contents and study how they worked. So, I got beatings and corporal punishments from my father for not being able to reassemble and make them work again. This attitude made me inclined to studying Science and Physics in particular upon entering secondary school. Physics and Mathematics were my favourite subjects and with this I nursed the idea of becoming an Aeronautic Engineer. The rare occasions I saw airplanes flying over our village were always a mystery to me and the idea of venturing into the mystery was exciting. Unfortunately, I did not have the opportunity to pursue the dream. Hence, at the university level, I studied Nuclear Physics while at Ph. D. Level; I specialised in Applications of Physics in Medicine (Medical Physics). Physics as the study of natural physical phenomena, covers many specialised fields varying from acoustics, nuclear, astronomy, astrophysics, medical physics, geophysics and vacuum sciences to mention but a few. Physics therefore is a field that offers challenging, exciting and productive careers.

God as a perfect Physicist

The Almighty God, the Creator of the Heavens and the Earth is the Greatest of all Physicists. He established and

has been applying physical theories and concepts before the foundation of our World, i.e. more than hundreds of billions if not trillion years ago. This was the period between Gen. 1:1 and Gen. 1:2, the period before the Luciferian flood that destroyed all the then living creatures as a result of sin, which rendered the then earth without form and void (Gen. 1:2).

Studies of radioactivity processes for dating and determination of the ages of archeological and fissile materials together with the Holy Bible make us to know that some living beings, including man, had existed for billions if not trillions of years before the Luciferian flood. Recent scientific findings using modern techniques in Geophysics, Geochemistry and Geobiology have confirmed the existence of Precambrian life. The Greatest Physicist (God) knows Thermodynamics and Entropy, He knows Optics and the interactions between electromagnetic radiation and the retina, as well as the use of crystalline (eye lens) to focus incident radiation on the retina for clear vision. God, the greatest lower and upper atmospheric Physicist alone can explain the flow of wind currents in opposite directions at the same time the winds blowing over the red sea formed walls of water, exposed the sea bed and permitted the Israelites to walk across safely on dry land. The same winds changing directions thereafter blew back on the sea caused the Egyptian army to drown. He has been in the management of the laws of floatation before Archimedes developed his principles, but man has not yet discovered the principles behind the floating of the blade of an axe on water, or how Jesus Christ and Simon Peter were able to walk on the sea like solid ground. The Creator of the vast outer space is an Astronaut, who needs no rocket to fly or satellite to visualise or localise. He does not need special attire to dive into the oceans' depths. He indeed is an Awesome God. After creation about 8,000 years ago, He commissioned the exploration and exploitation of the earth and the entire creatures to man for beneficial uses. Since then great discoveries and inventions have been made, which we

today describe as scientific and industrial advancements. Physics as a subject has always played an outstanding role in technological developments. For example, all engineering specialties evolved from Physics. We all employ physical concepts in everyday life and without Physics; our lives would come to a standstill. This generation cannot think of a day we lived without cell phones, computers and even minor things like calculators and electronic watches. The list is endless. I wonder whether my great grand children will know what a book is going by the rate at which almost everything we do is becoming electronic. E-mail has replaced letter writing on writing pad, e-medicine and telemedicine are fast gaining popularity. More and more people are depending on the Global Positioning System (GPS) for direction. Hospitals have grown with the materialisation of microsurgeries. Deaf people can now live normally with hearing aids. Shopping is not complete without bar code readers. Physics has its tentacles in all areas of life and has made technology alive.

Medical Physics

I had my first and Master's degrees in Nuclear Physics. My Ph D degree was to be in Nuclear Physics for which I was awarded scholarship. While preparing to commence the programme, I had the opportunity to access and pursue the degree in Medical Physics. I had earlier read with interest, about Medical Physics in libraries and publications where I got the idea that the job of a Physicist might not after all be restricted to classroom as it was in those days. Medical Physics is the study and applications of physical phenomena and concepts in the different specialties of Medicine. I decided to convert from Nuclear to Medical Physics while pursuing my Ph. D degree because of the versatility, diversity, immense opportunities and potentials the profession offers. After all I would not be limited to just proving theorems and doing calculations but be engaged in the practical (clinical) applications of the different Physics theories that I have been learning over many past years.

The different applications of Physics in Medicine include but not limited to:

Radiotherapy (Radiation Oncology) Physics

Medical physics has been and is still the pioneering subject in radiation oncology. Today, 50-65% of all cancer patients receive radiation therapy in the course of their treatments. The technological advancements in cancer management, especially with radiotherapy have been made possible largely by the science of Medical Physics. Radiation oncology of the future will demand on the continuing support and contributions of qualified Medical Physicists. Medical Physicists possess the knowledge and skills required to provide precise and safe use of radiations essential for good quality cancer management. Radiotherapy principles of practice could be expressed in the words of W. E. Power (1922–2001) as:

***Put The (radiation) Dose Where The Tumour Is
If You Don't "See" "It" You Can't Hit "It"
If You Don't Hit "It" You Can't Cure "It"
Don't Plunder Normal Tissues
Record And Evaluate Your Results.***

Diagnostic Medical Physics

Throughout the past century, Medical Physicists have been at the forefront of the development of the dynamic field of medical imaging. Early detection of breast cancer and other diseases relies heavily on precise diagnostic imaging. The imaging modalities used for diagnosing diseases, namely; mammography, computerised tomography (CT), magnetic resonance imaging (MRI), ultrasound, single photon emission computerised tomography (SPECT) and positron emission tomography (PET), have been developed, tested and standardised by Medical Physicists, working closely with diagnostic radiologists. Medical Physicists were the first to develop standards which have now resulted in improved quality of mammographs with reduced radiation dose. The improvements today allow earlier detection, an important criterion for success in the fight against diseases. Exploring

and viewing the internal organs of human body without surgery is one of the medicine's most important achievements in Radiodiagnosis. The use of x-ray radiography, gammagraphy, CT, fluoroscopy, angiography, MRI etc are used to detect bone fractures, diagnose diseases, and develop treatment techniques for various illnesses. The use of the different types of radiations makes all these imaging techniques possible.

Nuclear Medicine Physics

Nuclear Medicine is a technique involving intravenous, oral or nasal injection of radiation emitting, unstable elements in form of suitable radiopharmaceuticals for either diagnostic or therapeutic purposes. The fabrication of such radioactive elements from nuclear reactors, the separation and purification before radiopharmaceutical preparation are the jobs of physicist.

Both therapeutic and diagnostic nuclear medicine procedures use naked radiation emitting elements. Hence, radiation protection of patients and safe administration of the radiopharmaceuticals and the protection of the environment and the public are crucial. SPECT and PET are the modern forms of gammagraphy often used in not only diagnostic imaging but for treatment planning as well in some advanced radiotherapy techniques.

Who is a Medical Physicist and what does he do?

A Medical Physicist is a health professional with background education in Physics and specialist training in the concepts and techniques of applying physics in medicine, competent to practice independently in any of the specialties of medical physics. A Medical Physicist is engaged in:

Consultation

Medical Physicist gives scientific and clinical advice which has a direct bearing on the management of patients. He applies scientific methods to maintain the effectiveness, quality and safety of diagnostic and therapeutic techniques.

He introduces and advances on new procedures for the benefit of the patients. These activities take the form of consultations with physician colleagues. In radiation oncology departments, consultation is indispensable in the planning of patient treatments for cancer, using either external radiation beams (Teletherapy), implantation of radiation emitting isotopes inside the body (Brachytherapy) or oral, nasal or intravenous administration of radioactive materials as in Nuclear Medicine. Some other indispensable services include the accurate measurement of radiation output from radiation generating facilities employed in cancer therapy, patient treatment simulation and planning using a computerised system, precise calculation of the administered radiation dose to patients, safe management and use of radiation sources and the protection of staff and patients against the deleterious effects of radiations. In the specialty of Nuclear Medicine, Physicists collaborate with physicians in the procedures utilising radionuclides for delineating internal organs and determining important physiological variables, such as metabolic rates and blood flow. Additional and important services are rendered through investigation of equipment performance, organisation of quality control of the imaging and treatment facilities, design of radiation installations and control of radiation hazards. The Medical Physicist contributes in form of clinical and scientific advice and resources to solving the numerous and diverse problems that arise continually in many specialised areas of medicine.

Research and Development

Medical Physicists play vital and often leading roles in medical research. Their activities that cover wide frontiers include cancer, heart disease and mental illnesses. In cancer, they work primarily on diagnosis and treatments involving radiation, development and application of new high energy machines and the development of new techniques for precise calibration and calculation of radiation doses. Computer development has in no small measure contributed to the improvement of radiation dose calculation

for patient treatment and visual display of treatment information. Heavy particle radiation therapy is an area of active research with promising biological advantages over traditional photon and electron treatments. In heart diseases, Medical Physicists work on the measurement of blood flow and oxygenation. In mental illnesses, they work on the recording, correlation, and interpretation of bioelectric potentials. Medical Physicists are also involved in the development of new instruments and the technology for use in diagnostic radiology. These include the use of magnetic and electro-optical storage devices for the manipulation of x-ray images, quantitative analysis of both static and dynamic images using digital computer techniques, radiation methods for the analysis of tissue characteristics and composition, and the areas of CT and MRI for displaying detailed cross-sectional images, sagittal, coronal etc views of the anatomy and the development of new techniques for enhancing image quality.

Teaching

Often, Medical Physicists apart from hospital services, have faculty appointments at Universities and Medical Colleges, where they train future Radiodiagnosis, Nuclear Medicine and Radiotherapy residents, Physicians, medical students, Radiographers, Radiation Oncology Nurses, Medical and Biomedical technologists and technicians, who operate and maintain the different radiation-emitting devices and equipment used for diagnosis and treatment. They also conduct courses in Medical Physics on the different aspects of radiation protection, biophysics and radiobiology for a variety of graduate and undergraduate students.

Significance of the role of a Medical Physicist

As a result of his rigorous training, competency and his wealth of experience, one can count on a qualified Medical Physicist to:

- Meet the challenge of cost effective health care by dealing with the headaches and costs of regulations,

- reducing expenses in equipment purchase and maintenance and preventing costly law suits.
- Perform radiation procedures.
- Preventing patient over- or under-exposures.
- Limiting employee exposures to radiation.
- Bringing the latest advances in technology into your department.
- Ensure excellence by maximising effectiveness of new equipment, balancing faster and more detailed imaging for optimal quality.
- Continuous Quality Improvement.

Medical Physics is a vital part of the cost effective health care of the future. Every day, the pressure on healthcare professionals to make the industry more cost effective is increasing. In the coming century, as the society and the government deal with the financial realities of an aging population, this pressure will intensify and Medical Physics can play a key role in this area. Involving a qualified Medical Physicist in your organisation's programs can produce billable services, save money on equipment negotiation and prevent mistakes that can eventually cost millions and even billions of naira.

Avoiding litigation: Involvement of a medical physicist can provide added protection against costly litigations. In the areas of both diagnosis and treatment, a good quality control program maintained by a qualified medical physicist can prevent equipment wrong calibration or dose miscalculation that could result in multi-million and even billion lawsuits.

Avoiding regulatory headaches: In addition, Medical Physics program can avoid the pain and cost when dealing with the ever increasing regulation of today's health care. A violation of the Nigeria Nuclear Regulatory Authority (NNRA) regulations is not only costly, but the bad publicity can often lead to a loss of income. Wading through the realms of

complicated, convoluted NNRA regulations can be expedited by the involvement of a Medical Physicist.

Evaluation and selecting high cost equipment: Once your equipment is purchased, Medical Physicist evaluates how well the equipment meets the specifications by performing rigorous acceptance testing and commissioning. Some institutions lose money by scheduling machine replacement on a regular basis even when the equipment is operating properly. Involvement of a Medical Physicist in continuous quality improvement and maintenance results in the reliable operation and extended life of your equipment. Be sure the future of your institution is secure in the hands of a qualified Medical Physicist.

Radiations and their interactions with biological tissues

Radiation is a process of transmitting energy through space. Such radiation can consist of waves or particles. This radiation occurs in a wide spectrum of energies, with visible band situated at about the middle of the electromagnetic spectrum as shown in fig. 1. A radiation is classified as ionizing when it possesses sufficient energy to bring about changes in the electronic structure of the atom it is incident on. Examples are ultraviolet (uv), x- and γ -rays. A non-ionizing radiation does not have sufficient energy to produce significant changes in the structure of the atom, but absorption of such radiation causes increase in atomic and molecular excitation, rotational and vibrational energies. Examples are infra-red, microwave, radiofrequency radiations.

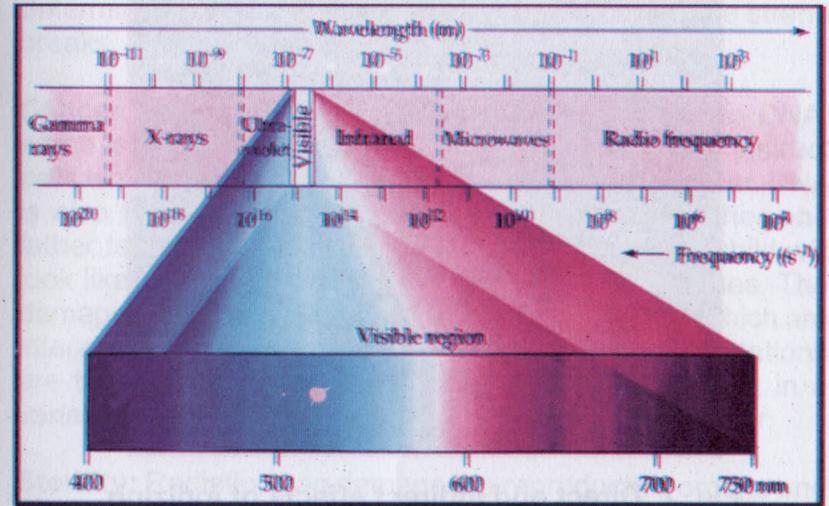


Fig. 1: Electromagnetic spectrum

Radiation in form of particles also can be ionizing if it possesses enough energy. Such particles may be neutral or charged. Coherent or elastic interaction describes radiation interactions which do not involve significant energy transfer from the radiation to matter. Examples are Rayleigh and Thompson interaction processes. In inelastic interactions, exchange of significant amount of energy between the radiation and matter is involved, and the exchanged energy produces modifications in the atoms and molecules. Examples are: Photoelectric, Compton, Pair Production and Photonuclear interaction processes. Incoherent interactions with biological materials involve impartation of radiation energy to the atoms, molecules and cells. Consequently, cellular functions may be temporarily or permanently impaired as a result, these interactions or the cell may out rightly be destroyed.

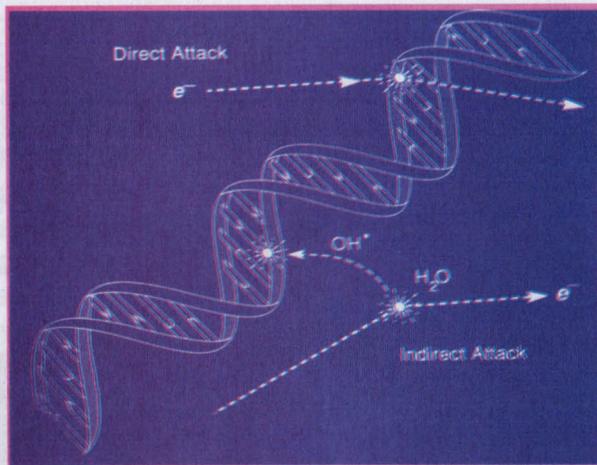


Fig. 2: Direct and indirect effects of ionizing radiation on DNA

The mechanisms of radiation damage in biological tissues are principally in two ways; direct and indirect interactions with the deoxyribonucleic acid (DNA) in the cell nucleus. Direct mechanism involves the incidence of the photon on the DNA and interactions produce one or more ruptures, modification, deformation or denaturing of chemical bonds. This may lead to a break, double or multiple breaks in the strand of the giant DNA molecule at different positions on the long molecule. The indirect mechanism involves the radiation interactions with bound and free water molecules and by consequence, causing hydrolysis and production of radicals described as Reactive Oxygen Species (ROS) (Fig. 2). These radicals, which are very reactive chemically include hydrogen H° , O° , OH° , $O_2H_2^\circ$, OH_3° , and aqueous electron e^-_{aq} . These radicals in turn cause chemical reactions that lead to breaks in the strands of DNA molecules. The severity of the injury depends on the type (quality) of the radiation, the absorbed radiation dose, the rate at which the dose is absorbed and the radiosensitivity of the tissues type. The quality of the radiation and the dose

determine the number of the single, double or multiple strand breaks.

Cancer induction: Radiation may cause damage to DNA, which is the molecule that carries the information to instruct cells what to do; hence, the radiation can induce cancer. DNA is also the information that is passed on from mother and father to their child. It is what determines what the child will look like as well as his future susceptibility to diseases. The damage to the DNA can result in genetic mutations, which are alterations to genes contained in the DNA. These mutations are then passed along to the children and can result in a variety of disorders, including an increased risk for cancer.

Sterility: Radiation can damage the reproductive organs and cause temporary or even permanent sterility. Patients who undergo radiation treatments and individual exposures involving the pelvic region are at risk of permanent infertility. Infertility which is radio-induced is influenced by the amount of radiation and the age of the person exposed.

The hopes of living with radiations

Right from the day of creation, man has been using radiation in form of visible light. Early and even modern man uses the radiation from the sun to dry objects. Recently, there has been a revolutionary increase in the uses of radiations for diver's purposes such as GSM, blue tooth, Wi-Fi, television, radio, teledetection to mention but a few examples. As earlier said, our grand children may not know or have an idea of paper books going by the rapid technological development, just as e-library is fast chasing away the usual physical library. All these advanced technologies make use of Radiowave, RF, MW and radar (non-ionizing) radiations. Due to space constraint, we shall only briefly discuss few of the numerous applications of radiation in Medicine.

Applications in Medical Diagnostic Imaging

Both ionizing and non-ionizing radiations find applications in medical diagnosis and therapy. Shortly after discovery in 1895 by William Conrad Roentgen, x-rays was found to possess ability to penetrate objects, hence, the use in imaging the internal structures of man for diagnostic purposes. Fig. 3 shows the first radiograph ever taken, which is the right hand of Mrs. Reontgen. Today, there has been a great revolution in medical imaging thanks to isotopic and non-isotopic radiations. Modern imaging facilities use injected radioisotope in the form of suitable radiopharmaceuticals, non-ionizing RF and x- radiations. Thermography, which is the image of the skin heat distribution based on infra-red radiation emission, is a technique that is not very popular in routine clinical practices, but has a high diagnostic potential. While MRI using RF field, whose principle is based on nuclear spin has been highly developed, the technology of the same principle but based on electron spin (Zeumatography) is yet to be developed to produce good enough image quality.



Fig. 3: The first radiograph of the right hand of Mrs. William Conrad Roentgen (1895), showing her wedding ring

Applications in External Beam Therapy (EBT)

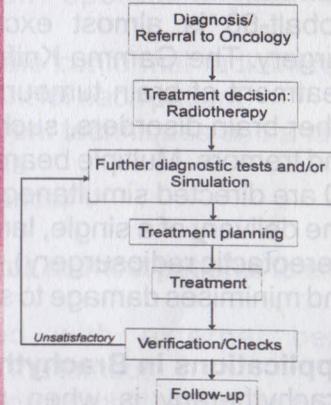
Cancer management techniques are surgery, chemotherapy, hormonotherapy and radiotherapy. External beam radiotherapy is when radiation dose is delivered from outside the patient using x-rays, γ -rays, high energy electrons or heavy ions. Radiotherapy techniques include the three brachytherapy methods: intracavitary, interstitial and permanent seed implants. Interstitial brachytherapy in breast cancer management is an alternative for radical mastectomy with less mutilation and less edema of the arm. Fig 4 shows the major clinical indications for external beam therapy and the workflow in the disease management. Fig. 5 shows the typical total body irradiation (TBI) and tangential beam setups for breast treatment.

Major indications for radiotherapy

- Head and neck cancers
- Gynaecological cancers (e.g. Cervix)
- Prostate cancer
- Other pelvic malignancies (rectum, bladder)
- Adjuvant breast treatment
- Brain cancers
- Palliation

(a)

Fig. 4: (a) Principal indications for radiotherapy and (b) Workflow in radiotherapy



(b)

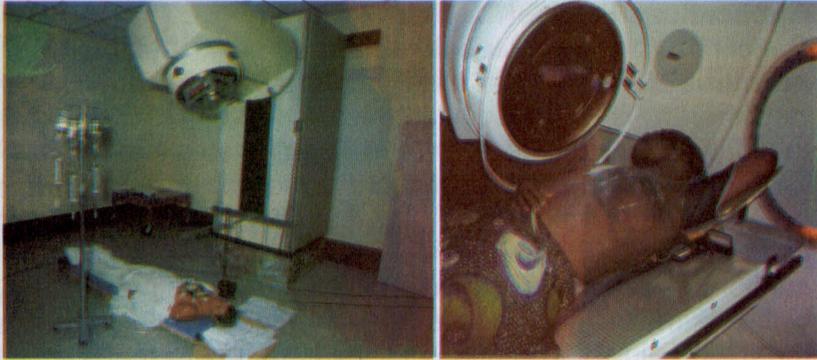


Fig. 5: Typical setups during (a) Total body irradiation (TBI) and (b) tangential LINAC positioning for managing breast cancer patient post-mastectomy

Gamma Knife

Cobalt-60 is almost exclusively used for Gamma Knife surgery. The Gamma Knife is a nonsurgical approach to the treatment of brain tumours, blood vessel abnormalities and other brain disorders, such as Parkinson's disease, epilepsy and tremors. Multiple beams of gamma radiation from Cobalt-60 are directed simultaneously at a specific point in the brain. The delivery of a single, large dose of radiation (referred to as stereotactic radiosurgery), is executed with extreme precision and minimises damage to surrounding healthy tissues.

Applications in Brachytherapy

Brachytherapy is when radiation dose delivered is from radioactive sources implanted in the patient close to the tumour. Brachytherapy systems are classified according to dose rates;

0.4 – 2 Gy/hr	low dose rate
2 – 12 Gy/hr	medium dose rate
> 12 Gy/hr	high dose rate (ICRU report no 38)

Low dose rate is fast becoming unpopular, giving way to high dose rate. Radiation sources could be in form of microspheres, rigid wires or needles. Ir-192 and Co-60 are

most popular in high dose rate (HDR). Employed radioisotopic sources are of high activity of several 100s of GBq. Both β^- and γ - radiations are emitted by the radioisotopes hence encapsulation with Pt or W material is required to filter the β^- particles. Dimensions of encapsulated sources are typically 5mm-10mm long by less than 1.5 mm diameter, depending on the type of the facility. To make optimal use of HDR technique for breast conservation, it can be used solely for early stages or with external beam therapy (EBT) boost. Clinical application of HDR is accompanied with physical, psychological, economic, dosimetric and clinical benefits over other methods. These include:

- very flexible radiation dose delivery
- radiation source positioning determines the treatment success
- management depends on operator's skill and experience
- in principle, it allows for ultimate 'conformal' radiotherapy
- highly individualised treatment for each patient
- allows for use of many different techniques and a large variety of equipment and tools
- used typically for localised cancer
- often relatively small tumour
- often good performance status as most patients tolerate the operation
- sometimes pre-irradiated with external beam radiotherapy (EBT) to shrink the tumour
- often treated with combination brachytherapy and EBT boost

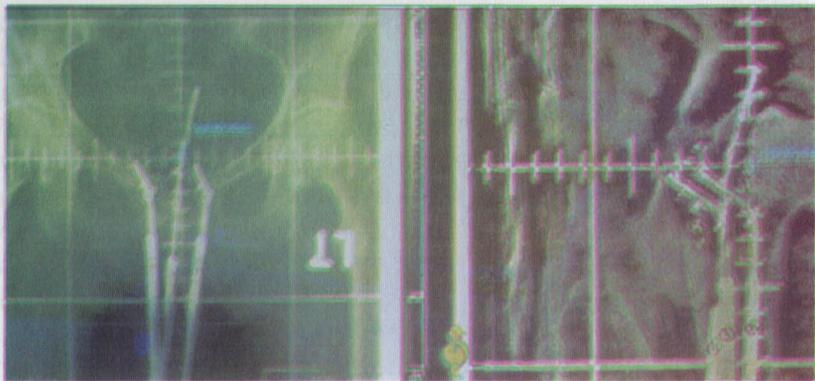


Fig. 6: Antero-posterior and lateral radiographic projections showing radioactive sources in the 2 ovoid and the uterine sleeves during an intracavitary brachytherapy

Brachytherapy Procedure

Special applicators are used to facilitate exact and parallel placement of stainless steel needles or flexible tubes in interstitial brachytherapy. The positions are such that needles are 1.0 cm apart, either in a single plane for small lesions or more often in a double plane. 3-D implant is rarely required (only in case of large tumours). The active portion of the needle does not come closer to skin surface than 1.0 cm.

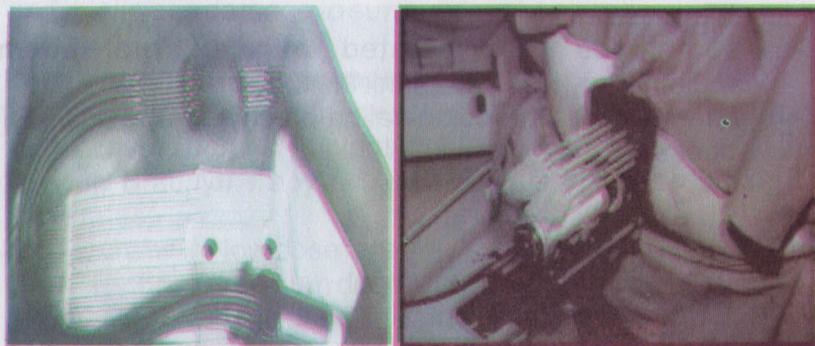


Fig. 7: Typical interstitial brachytherapy implants for managing (a) breast and (b) prostate cancers

The needles are fixed with buttons/clips to avoid further movement. Orthogonal radiographs, simulator, CT or MR images are taken for dosimetry purposes after adjustment of applicator positioning has been made where necessary. Applicators are such that the centers of implanted sources will form equilateral triangles or squares plan view in a three plane arrangement (in PARIS system of application). They are then connected to the HDR facility for loading with sources. Live sources are remotely applied from the HDR machine. Sources are withdrawn after the pre-calculated time by the Medical Physicist has elapsed. Calculation of the spatial distribution of radiation dose and the duration of source dwell time in the patient required for delivering prescribed dose is done by the Medical Physicist. Necessary care (dressing) of wound by nurses follows immediately after treatment. The patient may after then be referred to a designated room for few minutes of rest if she wishes, before leaving the clinic for the day.

Advantages of HDR brachytherapy

No need of anesthesia for insertion of sources because they are small due to high activity. Treatment times last for 15-20 min, treating most ambulatory patients as outpatients, thereby eliminating expensive overnight hospital costs. No prolonged bed rest involved and no risk of deep vein thrombosis or pulmonary emboli. Each machine allows treatment of 16-20 patients within the 8 hour-working day. Dose optimisation capability in HDR allows for improved isodose distribution with respect to the shape of the tumour volume than LDR. More stable positioning is used. Reduced positioning uncertainty between localisation and the completion of treatment due to better immobilisation of applicators is achievable. It allows better documentation: HDR machine can print out detailed treatment parameters rather than relying on the diligence of the person inserting the sources to write in a chart and provides better radiation protection for all health care workers as most facilities are remote after loading. The form of treatment room provides sufficient shielding and safety of the environment and the

members of the public are assured. The procedure results in less mutilation than mastectomy, post-treatment cosmetics are generally good. The same HDR facility is suitable for gynecological intracavitary procedures. The only disadvantage is the cost of changing the sources every 3 months for ir-192 and Co-60 every 6 years.

Application of non-ionizing radiation in cancer management

Non-ionizing radiations have also found applications in cancer management. RF field today has been developed and clinically applied in tumour ablation and thermocoagulation, especially liver tumours. MW tumour ablation is currently undergoing intensive research in our laboratory.

Applications in agriculture and food irradiation

Food irradiation technique has been known and used in many developed countries to preserve agricultural (perishable) produce. Exposure of the produce to high radiation doses provides a system of preservation without chemicals and without any known side effects on consumers. This is of immense economic advantage as it allows availability of fruits all round the year and also prevents wastage during the season.

The fears of living with radiations

We live with radiations every day of our lives. Radiations are ubiquitous as they are naturally present in our environment, under the ground, in the air we breathe, in the food we eat and the water we drink, in the building, utensils and furniture materials, in the cloth we wear and indeed, in the different tissues that make up our bodies. The higher you go from the earth surface, the higher the concentration of the radioactive materials. Similarly, the deeper you go under the ground, the higher the concentration of radiation-emitting materials. These sources of radiation exposure to man are primordial, they existed before the creation of the earth and man, animals, plants and indeed, all creatures have always been exposed to radiations of celestial and terrestrial origin. The

intensity distribution varies from place to place on the earth surface and beneath depending in part, on the type of soil. Fortunately, the level of radiation exposures due to these natural background sources is not likely to produce any deterministic health hazards. Determination of Radon gas concentration is a common exercise in environmental radiation protection because the radioactive noble gas, being a daughter product of radioactive Radium that exists naturally under the ground in some places, is an emitter of alpha particles during the decay process. Alpha particles are highly damaging to tissues they have contact with.

There are a number of man-made sources of radiation exposure as well. These are due to human activities such as medical uses of radiation generating facilities, industrial activities such as mining, exploration and exploitation of minerals, due to activities in nuclear industries, in the production of radioactive materials for medical and industrial applications and uses of radiation sources in research centers. The most likely sources of man's exposure to radiation are summarised in fig.8. Man is therefore unavoidably exposed to radiations continuously and every second of his life, before his birth till death. Exposure to radiations therefore constitutes a threat to human health, hence the fears of living with radiations.

The commonest type of ionizing radiations man may be exposed to are the ultra violet (uv), x- and γ -rays. They are generally highly energetic and highly penetrating in matters and they are used in disease diagnosis and treatment. Radiation doses from natural background exposures are generally low and do not produce acute and deterministic effects; rather they produce probabilistic or stochastic effects. The clinical, especially therapeutic applications of ionizing radiations use high energy radiations and high radiation doses are administered to patients. Table 1 and the list below are some of the common experiences of patients following radiotherapy treatments as a result of the effects of radiation exposures.

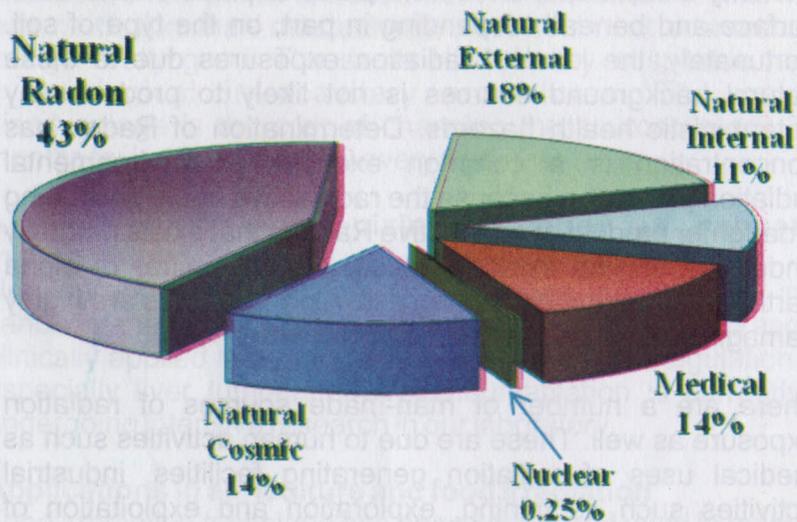


Fig. 8: Average radiation exposure from all sources: 2.8 mSv/year

Hair: The loosing of hair quickly and in clumps occurs with radiation exposure at 2 Sv or higher. Radiation therapy can destroy the hair follicles at the site of treatment, leading to hair-loss side effects in certain patients. Hair loss can be permanent depending upon how much radiation a patient receives.

Brain: Since brain cells do not reproduce, they cannot be damaged directly unless the exposure is 50 Sv or greater. Radiation kills nerve cells and small blood vessels and can cause seizures and immediate death.

Organ or tissue	Dose in less than 2 days	Deterministic effects	
		Type of effect	Time of occurrence
Whole body (bone marrow)	1 Gy	Acute Radiation Syndrome (ARS)	1 – 2 months
Skin	3 Gy	Erythema	1 – 3 weeks
Thyroid	5 Gy	Hypothyroidism	1st – several years
Lens of the eye	2 Gy	Cataract	6 months - several yrs
Gonads	3 Gy	Permanent sterility	weeks

Table 1: Some common deterministic effects of radiation exposures

Thyroid: The gland is susceptible to radioactive iodine. In sufficient amounts, radioactive iodine can destroy all or part of the thyroid.

Blood System: When one is exposed to around 1 Sv, the blood's lymphocyte cell count will be reduced, leaving the victim more susceptible to infections. Early symptoms of radiation sickness mimic those of flu and may go unnoticed unless blood count is done. Symptoms may persist for up to 10 years and may also have an increased long-term risk for leukemia and lymphoma.

Heart: Intense exposure to radioactive material at 10 to 50 Sv would do immediate damage to small blood vessels and probably cause heart failure and death directly.

Gastrointestinal Tract: The intestinal tract lining will cause nausea, bloody vomiting and diarrhea. This occurs when the victim's exposure is 2 Sv or more. Damages start by destroying the cells that divide rapidly in general. These include the bone marrow, GI tract, reproductive and hair cells and harms the DNA and RNA of surviving cells.

Reproductive Tract: Because reproductive tract cells divide rapidly, these areas of the body can be damaged for as low as 1.5 Sv and permanent sterility from 3 Sv and higher.

Some Side Effects of Therapeutic Radiation Treatments

LINAC and radioisotopic Cobalt-60 emit radiation and the side effects of exposure depend largely upon the absorbed dose and whether the exposure was internal (i.e. ingested or inhaled) or external (i.e. skin contact). These side effects may develop within hours or days of treatment (acute/sub-acute) or months and years later (delayed/late onset).

Acute/Sub-acute Side Effects: Fatigue is the most common side effect of Megavoltage radiation and can last for weeks, months or years. Many patients never regain their full energy, although, it is not clear that radiation therapy alone is responsible for this. Cerebral edema (swelling of brain tissue) occurs in all patients with varying degrees of severity. Some patients experience only a mild headache, while others experience more significant headache, profound dizziness, nausea, vomiting and even loss of consciousness. Localised hair loss may be noticed if the treated lesion is close to the scalp, skin irritation, scalp numbness, tingling, vision changes and decreased appetite have also been reported.

Radiation Necrosis: the death of brain tissue in response to radiation treatment can also create an inflammatory reaction with symptoms of cerebral edema and can trigger seizures and rarely, death.

Skin Irritation: The most common side effect related to radiation therapy is skin irritation at the entrance of the beam. Cancer patients can notice that the treated skin appears unusually red (erythema) or dry and may begin to itch. Damage to the skin caused by radiation can also result in skin peeling or blistering, which may be uncomfortable. These common skin-related side effects of radiation therapy typically resolve on their own once treatment has ended, but can cause permanent skin discoloration or scarring in certain patients.

Stomach upset or difficulty in swallowing: If radiation therapy is given near the stomach or throat, patients can experience stomach upset as side effect. Other side effects may include: nausea, vomiting or diarrhea. Certain patients may also experience difficulty in swallowing.

Swelling: Patients receiving radiation therapy can develop unusual swelling of the hands or arms as a side effect of treatment. This type of swelling (lymphedema) often occurs if the lymph nodes are treated with radiation. Swelling of the hands or arms can be uncomfortable and may interfere with the ability to move these body regions normally. This common side effect of radiation therapy is typically temporary but may persist for up to two months after treatment has ended.



(a)

(b)

Fig. 9: The (a) front and the back views of the reported first skin-burn attributed to radiation in 1901 and (b) localised necrotic right hand

Death of the embryo or fetus: Effects observable in offspring born after one or both parents had been irradiated prior to conception include: malformation (teratogenesis), growth retardation, functional disturbance and cancer. The factors influencing the probability of these effects are absorbed dose for embryo or fetus and gestation status at the time of exposure.

Typical examples of the health detriments of ionizing radiation exposures

Wrong handling and maladministration of clinical radiations may lead to adverse effects detrimental to health such as skin burns, skin erythema, necrosis, moist and dry desquamation etc, some of which demonstrated in Figs. 9-11. Most early workers and researchers on ionizing radiations were victims of radiation hazards due to ignorance about the exposure consequences. Hence, great care is required in the various medical, industrial and research applications.



(a)

(b)

Fig. 10: (a) Skin Erythema and (b) Dry desquamation following Radiotherapy treatment



(a)

(b)

Fig. 11: (a) Moist desquamation following a treatment and (b) Necrosis following an exposure

Fig. 12 shows an example of tissue damage to a man who found a lost jewel-like Co-60 source on a walk way, picked it because it looked like a jewel and kept it in the right bottom pocket of his trouser for hours until he got home and displayed it on the table in the sitting room. Blistering was noticed the following day and more grievous damages ensued days after. The condition of the man later led to the surgical removal of the entire right thigh/leg and eventual death. These examples are emphasising the need for the involvement of a Medical Physicist in clinical and industrial uses and management of radiations.



Fig. 12: Effect of Co-60 source kept in back pocket of trousers for few hours

Living with non-ionizing radiations

Non-ionizing radiation is any type of electromagnetic radiation that does not possess sufficient photon energy to completely remove an electron from atoms or molecules. Absorption of such radiation can only produce excitation, i.e. the movement of an electron to a higher energy state with increased vibrational and rotational energies. Despite inability to cause ionization, exposures may lead to various biological effects for different types of non-ionizing radiation. Near ultraviolet (uv), visible light, infrared (i-r), microwave (MW), radiowaves and low frequency RF (longwave) are all examples of non-ionizing radiation (Table 2). Visible and near ultraviolet may induce photochemical reactions, ionize some molecules or accelerate radical reactions such as photochemical aging of varnishes. The light from the sun that reaches the earth is largely composed of non-ionizing radiation with the notable exception of some uv-rays.

The recent introduction of global system mobile communication (GSM) is now used by over 2 billion peoples worldwide and over 50 million in Nigeria. Today, there are many major operators of GSM, television and radio in Lagos state alone. These wireless technologies rely upon an

extensive network of fixed antennae or base stations, using information with radiofrequency (RF) signals. Over 1.6 million base stations exist worldwide and the number is increasing only on daily basis. In Nigeria, especially in Lagos State, it is common to see transmitting and receiving antennae of varying heights in close proximity to residential areas, offices, homes, public places such as motor parks, churches, schools, mosques etc. RF radiation which is an electromagnetic wave is generated by the movement of electric charges in a conductive metal object (antenna); propagate through space with the velocity of light. The power of the RF signal decreases as a function of inverse of the square of the distance between the transmitter and receiver. A base station communicates with transmitters/receivers which are within the area of coverage. The highest RF intensity lies within the main lobe of any given antenna. The essence of GSM, radio and television base stations is to improve coverage, quality and to increase the capacity of the communication technology. The use of microwave (MW) radiation is fundamental not only in modern communications systems such as mobile telephones but also in Nuclear Magnetic Resonance Diagnostic Imaging, hyperthermia and thermal ablation therapeutic techniques. The proliferation of MW applications has generated concerns about the safe use due to the suspected and experienced health hazards associated with exposures.

Table 2: Some effects of non-ionizing radiation exposures

E-M Band	Source	Wavelength	Frequency	Biological Effects
<u>UVA</u>	Sun	318 nm - 400 nm	750 THz - 950 THz	Eye – <u>Photochemical cataract</u> Skin – Erythema, pigmentation
<u>Visible Light</u>	<u>LASERS</u> , Sun, Fire, LED, Light Bulbs	400 nm - 780 nm	385 THz - 750 THz	Skin <u>photo-ageing</u> , Skin cancer; Eye – Photochemical & thermal retinal injury
<u>IR-A</u>	<u>LASERS</u> , remote controls	780 nm - 1.4 µm	215 THz - 385 THz	Eye – Thermal retinal injury, thermal cataract; Skin burn
<u>IR-B</u>	<u>LASERS</u> , long-distance telecoms	1.4 µm - 3 µm	100 THz - 215 THz	Eye – <u>Corneal burn</u> , cataract; Skin burn
<u>IR-C</u>	<u>Far-infrared LASERS</u>	3 µm - 1 mm	300 GHz - 100 THz	Eye – Corneal burn, cataract; Heating of body surface
<u>MW</u>	Mobile & cordless phones, MW ovens, radar, <u>Wi-Fi</u> etc	1 mm - 33 cm	1 GHz – 300 GHz	Heating of body tissue.
<u>RF</u>	Mobile & cordless phones, TV, FM, AM, SW etc	33 cm - 3 km	100 kHz- 1GHz	Heating of body tissue, Raised body temperature
<u>Low freq. RF</u>	power lines	> 3 km	< 100 kHz	Accumulation of body surface charge, Disturbance of nerve & muscle responses
<u>Static Field</u>	strong magnets MRI	infinite	0 Hz	Magnetic -vertigo/nausea, Electric - body surface charge

Consistent epidemiologic evidences of association between childhood leukemia and exposure to these radiations have led to their classification by the International Agency for

Research on Cancer as a “possible human carcinogen.” Concerns about the potential vulnerability of man to RF fields have been raised because of the potentially greater susceptibility of developing nervous systems and brain tissues that are conductive. This is particularly so in children because the RF penetration is higher due to the relatively smaller head size and because they will have a longer lifetime of exposure than adults. Some recent epidemiologic studies suggest an association between lymphatic and hematopoietic cancers and residential exposure to high-frequency electromagnetic fields (100 kHz to 300 GHz) generated by cell phone masts, radio and television transmitters. The risk of childhood leukemia has been reported to be higher than expected for distances up to 6 km from the radio stations. Childhood defects can result from genetic or epigenetic damage and from effects on the embryo or fetus, which may both be related to environmental exposure of the parent before conception or during the pregnancy. The heart and brain function are regulated by internal bioelectrical signals. Environmental exposures to artificial MW can interfere with fundamental biological processes in the body. In some cases, this may cause discomforts and diseases. Exposure to high intensity MW may cause detrimental effects on the testis, the eye and induce significant changes in the central nervous system (CNS). It can also affect cardiovascular and haematopoietic systems, utero-placental function, cutaneous perception and development through the thermal and non-thermal actions of MW. In animals, behaviour is controlled by the endocrine and the nervous systems and the complexity of the behaviour is related to the complexity of the nervous system.

Some Life Testimonies on the Adverse Health Effects of RF and MW Radiations

There have been many reported cases of the adverse effects of exposure to the telecommunication RF fields from cell phone masts in Nigeria and in Lagos in particular. Complaints varied from sleep disorder, migraine, nausea,

profuse bleeding from the nose and strange painful hitching skin rashes to death in children and adults alike. Figs. 13(a-d) show some testimonies of the adverse effects cell phone mast RF field exposure victims.

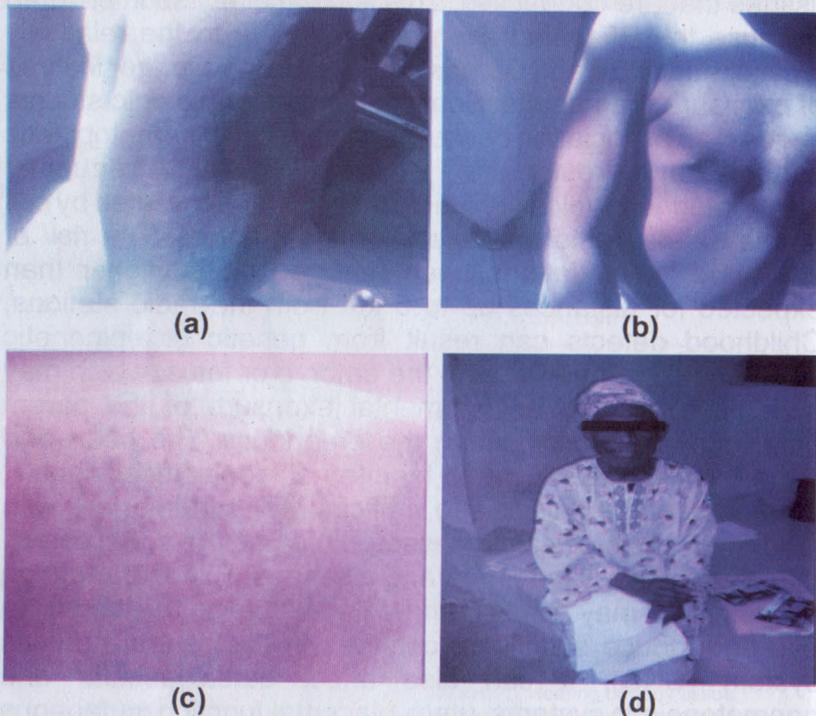


Fig. 13 shows adverse skin reaction all over the body of a (a) 5 year old girl (b) 2 year old boy, (c) Dr. O'Connor's painful skin rashes which itched and burned (d) Pa O. A. is another victim with several complaints including profuse nose bleeding.

Dr. (Mrs.) Eileen O'Connor's testimony was presented at the Emergency Conference on Human Health in an Electro-Technological World with theme "Are the Present ICNIRP EMF Exposure Recommendations Adequate?" Royal Society, Carlton House Terrace London. (27th November, 2007).

"In 2001 I was diagnosed with breast cancer. At the time when I was diagnosed, I was running a successful

commercial photographic business with my husband Paul, bringing up my two young children and renovating my home and was also training for the London Marathon. I visited my doctor on 5th November 2001 covered in a horrific skin rash from head to toe and a lump in my breast. The phone mast was 100 m from my home; I had been living next to the mast for over 7 years. The mast was also associated with health problems in many other people living in most of the other houses in the village. I was released from hospital on the day of the meeting, I'd had another suspicious breast lump removed, thankfully it turned out to be scar tissue. I wouldn't have missed this meeting for the world and was grateful to the scientists who attended in their own time."

Other experiences with Wishaw T-Mobile mast after a few years of operation revealed:

- Five ladies developed breast cancer
- One case of prostate cancer
- One bladder cancer
- One lung cancer
- Three cases of pre-cancer cervical cells
- One motor neuron disease, age 51, who also had massive spinal tumour
- Many people developed benign lumps
- Several cases of electro-sensitivity
- Three cases of severe skin rashes
- Many villagers suffering with sleep problems, headaches, dizziness and low immune system problems.
- Horses with blood problems, continuous treatment needed by veterinary doctors.

A powerful statement from an Ex-Government Military Scientist, Barry Trower shocked the audience when he said: ***"This Government, some of the Government Scientists and this Industry, will be held responsible for more deaths in peace time than any terrorist group in the World ever."***

Health improvement for Wishaw:

"One other important fact is that since the Wishaw Mast was removed in November 2003, many of the residents are reporting a restored feeling of well-being, improvement in sleep patterns and increased energy levels. Simple things like the headaches and dizzy symptoms have disappeared. There has been a baby boom in the village. We have seen a return of wildlife in the area."

Pa A. O.'s health is fast deteriorating. He has been diagnosed to be suffering from a disease suspected to be cancer from the effect of the radiation he is exposed to. From the X X X hospital, he was given a Medical report dated 18th January, 2011 with hospital card number X X X X that reads in part:

"This elderly man who is a subsistent farmer was brought into the accident and Emergency Unit of our hospital on 16/1/11 at 10:50pm with complaints of loss of consciousness associated with convulsions. He is not a known Epileptic, Diabetic, Hypertensive or Asthmatic. Findings on examinations showed lowish BP 90/50 mmHg and subsequent follow up showed low blood sugar RBS 4.7mmol/L, He is presently being managed as a case of seizure disorder...Precipant of the disorder may include machinery vibrations, twinkling light flashes height and depth, hypoglycaemia and hypotension. It is apparent that locating the cell phone mast belonging to...company installed close to their house is detrimental and hazardous to his medical condition if not the cause. Kindly give necessary assistance to address the problem."

Summary of the potential health hazards associated with exposures to RF and MW radiations

- Studies have shown that even at low SAR of RF and MW radiations, there are evidences of damage to biological tissues, cells and especially DNA. RF damages have been linked to brain tumours, cancer,

suppressed immune function, depression, miscarriage, Alzheimer's disease and numerous other serious illnesses.

- Children are at the greatest risk because they are more sensitive to radiation than adults due to their thinner skulls and rapid rate of growth. Also at greater risk are the elderly, the frail, pregnant women and sickled erythrocyte persons. Doctors from the United Kingdom have issued warnings urging children under 16 not to use cell phones and to reduce their exposure to RF and MW radiations.
- Contrary to what the communications industries say, there are vast scientific research results, epidemiological and medical evidences that confirm that exposure to the RF and MW radiations emitted from cell towers, even at low SARs have profound adverse effects on biological systems and therefore on health.
- Cell phone towers expose the public to involuntary, chronic and cumulative RF and MW radiations. Low SARs of RF and MW radiations have been shown to be associated with changes in cell proliferation and DNA damages. **"Some scientific studies show adverse health effects reported in the 0.01 to 100 mW.cm⁻² range at levels hundreds, indeed, thousands of times lower than the U.S. standards"**. These harmful low levels can reach far beyond 2 km away from the cell tower location. Reported health problems include: headache, sleep disorders, memory impairment, nose bleeding, increases in seizures, blood brain barrier leakage problems, increased heart rates, lower counts, impaired nervous systems and death.
- "Human bodies are exquisitely sensitive to subtle electromagnetic harmonics and we depend on tiny electrical impulses to conduct complex life processes," says Dr. Robert Becker, the author of **The Body Electric**, and **Cross Currents, The Perils of Electropollution**.

- Dr. Gerard Hyland, a Physicist, says existing safety guidelines for cell phone towers are completely inadequate, since they focus only on the thermal effects of exposure. Hyland, twice nominated for the Nobel Prize in Medicine, says existing safety guidelines "**afford no protection**" against the non-thermal influences. *"Quite justifiably,* the public remains skeptical of attempts by governments and telecommunications industries to reassure them that all is well, particularly given the unethical way in which they often operate symbiotically so as to promote their own vested economic interests."*
- Our recent local studies have as well shown that exposures to microwave radiation even at low intensities produce DNA damages, cause anxiolytic behavioural changes, affect explorative activities, decrease in low sperm counts (reproductive systems), cancers, adverse effects on sickled erythrocyte patients and almost all blood parameters.

MY MODEST CONTRIBUTIONS

Mr. Vice Chancellor Sir, to the glory of the Almighty God, I have made notable contributions in the field of Medical Physics. My contributions are diverse, ranging from the development of radiation detectors, development of microsensors for determination and monitoring of electrical conductivity and biochemical blood parameters during extracorporeal circulations and for applications in organ conservation prior to transplantation, development of equivalent materials for mimicking different tissues for use as phantoms in Quality Control (QC) of Magnetic Resonance Imaging (MRI) facilities, development of models for thermal flow through tissues and across tissue interfaces for applications in LASER surgery, development of Mathematical models for interpreting the phenomena in functional magnetic resonance imaging fMRI, in radiotherapy, radiodiagnosis to radiation protection. Due to time and space constraints, only few of my outstanding and ground breaking contributions will be summarised in

this presentation. Ladies and gentlemen, I am glad to let you know that many of my publications, local and foreign have been widely cited in reputable international academic publications and many have stimulated further scientific studies, going by the numerous private communications between me and other researchers across the globe and online Google search. Of all these, I want to dwell mainly on those contributions that are of utmost interest to this audience that is composed of diverse background. The summary of my contributions will be broadly grouped into two: those that bring hopes to the general population as a result of the benefits and those that may cause concerns due to the possible negative impact on health. Most of these are radiation-related. Radiotherapy aims to cure or locally control cancer diseases while concurrently minimising complications in normal tissues. Radiotherapy practice involves a certain number of procedures and steps:

- (1) The radiation oncologist examines the patient and prescribes type of treatment and the amount of radiation dose for optimal management.
- (2) Patient data and imaging of the relevant anatomical parts are collected and used by the Medical Physicist in charge for the purpose of treatment planning.
- (3) Simulation of the treatment and study of radiation dose distribution are effected also by the Medical Physicist in order to ensure optimal treatment using computerised Treatment Planning System (TPS). TPS is a special computer-assisted system with a number of installed algorithms that enable patient treatment simulation, planning and dose distribution calculation in order to achieve good quality treatment. The International Commission on Radiation Units and Measurements (ICRU) has recommended that the radiation dose delivered to patients should be within $\pm 5\%$ tolerance of the prescribed dose. To achieve this precision in conventional treatment techniques, based primarily on measured and scanned data, there is the need to verify the algorithms used.

Quality assurance programme ensures that all the components of the radiation facilities used for treatment and for imaging be properly checked for accuracy and consistency, and that all the radiation generating facilities are functioning according to specifications. Due to the invasive nature of ionizing radiations used in the management of cancers, studies on radiation dose distribution in patients and quality control of the radiation generating facilities are usually carried out using phantoms. Phantoms are made of materials that mimic biological tissues, i.e. they are made of materials that are tissue equivalent vis-à-vis radiation interactions. Some of our modest contributions in this area consist in the design of phantoms of different human anatomical regions for use in radiotherapy radiation dose distribution verifications and treatment planning. Likewise, the reduction of errors and uncertainties in the dose calculation plays an important role in the success of treatment procedures. The performance and quality of any TPS is dependent on the type of algorithms used. An algorithm is defined as sequence of instructions that operate on a set of input (measured and scanned) data, transforming the information into a set of output results that are of interest. Treatment planning requires the ability to calculate the radiation dose delivers at a given point within the patient for a given beam quality and/or a number of beam orientations. We have developed a Hybrid Algorithm for applications in patient treatment planning and in quality control of radiotherapy facilities.

Design of pelvis, head and neck and trunk phantoms

We have designed phantoms of the pelvis, head and neck and trunk for use in the treatment simulation of the corresponding anatomical regions of the body, as well as for the routine quality control exercise of the treatment facility. A composition of Carbon, Hydrogen, Oxygen and Calcium was used to mimic the white matter in the brain, adipose, bone and trachea. For the trunk, pure glycerol was used for the muscle, 75% to 25% glycerol-water was used for liver,

Carboxyl-Methyl-Cellulose (CMC) was used for lungs, and 50% to 50% glycerol-water was used for adipose tissue and Sodium Laureth Sulphate for kidney. For the pelvis, the prostate, bladder, adipose, muscle and rectum had compositions of Carbon, Oxygen, Hydrogen and Magnesium while the constituent of bone for both regions were Carbon, Calcium, Oxygen, Hydrogen and Magnesium. Fig. 14 shows a typical form of the phantom with provision made for the insertion of the materials mimicking different biological tissues and the ionization chamber for measuring the radiation dose.

The phantoms were scanned with Hi-Speed CT-scanner and the images were transferred to a precise PLAN TPS. For all the phantoms, the determination of absorbed doses was done using a 6 MeV photon beam from the ELEKTA-Precise LINAC and isocentric setup. Several treatment plans were made using the full area integration algorithm in the TPS. The results were compared to those of a solid water phantom used in routine clinical measurements as control. The maximum standard deviations for the head and neck, trunk and pelvis with 12 different radiation beams were $\pm 1\% \pm 3\%$ and $\pm 4\%$ respectively. The maximum deviation between the designed phantoms and those of the solid water phantom as control was within $\pm 2\%$. All deviations were within acceptable limits prescribed $\pm 5\%$ by the ICRU; hence, the phantoms are suitable for applications in routine dose distribution verification exercises.

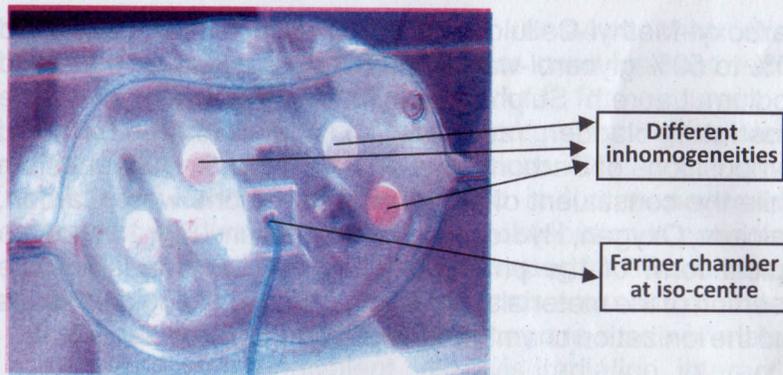


Fig. 14: Pelvis phantom showing different inserts that mimic different tissue

We observed that:

- The results follow similar trend as those of Butts et al. (2001) where anthropomorphic phantom was used.
- Larger deviations obtained with the Convolution algorithm in the presence of bone inhomogeneity could be due to unaccounted for scattered radiation contribution from the inhomogeneous materials by the algorithm.
- There is no significant deviation from the results obtained with the Pelvis and other phantoms and those with solid water phantom as control.
- This shows that the materials used in the design of the phantoms and for testing using 3 different algorithms were suitable and that the phantoms can be used successfully for radiation distribution verification exercises.
- Also, the cost of designing the phantom is minimal and it is easier to use compared to other modern verification phantoms such as the Rando Anderson phantom.
- Another advantage of these phantoms is the flexibility. Though, their shapes are of specific anatomical regions, the ability to remove and replace the inserts makes them flexible to be used to represent any other part of the body by simply changing the tissue equivalent materials.

- Current commercial pelvis and other phantoms are not readily available and are at high costs. Hence, the cost of acquiring them is a financial burden to small or low budget radiotherapy centres.

Development of Hybrid Algorithm for treatment planning

Though, there are several algorithms in the TPS that play different roles, the dose calculation algorithm plays the central role. For every algorithm, the precision of the dose distribution depends on the patient data, the parameters used and the assumptions made in the development. Examples of commercially available algorithms include: Anisotropic Analytic, Fast Fourier Transform Convolution, Superposition, Collapse Cone Convolution, Monte Carlo programs, Fast Superposition, Inhomogeneous Correction algorithm, Modified Clarkson Sector Integration, Area Integral etc. The accuracy with which algorithms are able to predict dose distribution is dependent upon the assumptions and approximations made. Also, the speed of calculation of the LINAC monitor units is highly dependent on the number of radiation fields in the plan. The verification of the accuracy and the speed of these algorithms, using heterogeneous phantom for measurement is important. An ideal algorithm is one which strikes good compromise between precision and speed in an inhomogeneous medium. Majority of the commercially available algorithms lack this quality.

Fast and precise algorithms are required especially in advanced radiotherapy techniques such as intensity modulated radiotherapy (IMRT), which involves many fields and large monitor units. We therefore developed a beam data modeling algorithm by solving the Linearised Boltzmann Transport Equation (LBTE). LBTE is a form of the Boltzmann Transport Equation (BTE) with the assumption that radiation particles only interact as they pass through matter and not with each other. This condition is only valid in the absence of external magnetic field. The

numerical method proposed by Lewis et al. was used for solving the LBTE. We used the Irregular Field Algorithm which requires the separation of the radiation dose into primary and scattered components. The concept of the dosimetry of irregular fields using Tissue to Maximum Ratio (TMR) and Scatter to Maximum Ratio (SMR) is analogous to the method using Tissue Air Ratio (TAR) and Scatter Air Ratio (SAR). The magnitude of the dose from scattered radiation at some given point can be quantified using the Scatter-Air or Scatter-Maximum Ratios. The scattering production sources are defined by:

$$q^{yy}(\vec{r}, E, \hat{\Omega}) = \int_0^\infty dE' \int_{4\pi} d\Omega' \sigma_s^{yy}(\vec{r}, E' \rightarrow E, \hat{\Omega} \cdot \hat{\Omega}') \Psi^y(\vec{r}, E', \hat{\Omega}'), \dots\dots\dots 1$$

$$q^{ye}(\vec{r}, E, \hat{\Omega}) = \int_0^\infty dE' \int_{4\pi} d\Omega' \sigma_s^{ye}(\vec{r}, E' \rightarrow E, \hat{\Omega} \cdot \hat{\Omega}') \Psi^y(\vec{r}, E', \hat{\Omega}'), \dots\dots\dots 2$$

$$q^{ee}(\vec{r}, E, \hat{\Omega}) = \int_0^\infty dE' \int_{4\pi} d\Omega' \sigma_s^{ee}(\vec{r}, E' \rightarrow E, \hat{\Omega} \cdot \hat{\Omega}') \Psi^e(\vec{r}, E', \hat{\Omega}'), \dots\dots\dots 3$$

where σ_s^{yy} Macroscopic photon-to-photon differential scattering cross section

σ_s^{ye} Macroscopic photon-to-electron differential production cross section

σ_s^{ee} Macroscopic electron-to-electron differential scattering cross section.

A programming code was developed for the LBTE and run on CMS XiO TPS to generate beam data. The generated data were compared with experimentally determined data. The observations and conclusions from the study are summarised as follows:

- Calculation times are longer with the Convolution and Superposition than with Hybrid algorithm for large and multiple beams.
- Calculation time scale increases linearly with the number of radiation beams.
- Hybrid algorithm accounts for presence of inhomogeneity but Convolution could not.

- Table 3 shows the results of the times used by the different algorithms for the calculation of the LINAC monitor units needed to deliver the prescribed dose for different treatment plans with energy 6 MeV.
- Our developed hybrid algorithm when applied revealed electron contamination at high energies and for large radiation beam sizes, which no other algorithm does as shown in fig. 15.

Table 3: Calculation times (in s) used by different algorithms for different patient treatment plans with 18 MeV photon beam.

CASE	Hybrid	Convolution	Superposition
Lung (single field)	5	1.2	2
Lung (Opposite fields)	6	1.8	3
Lung (12 fields)	8	12	15
Bone (12 fields)	9	13	18
Solid water (12 fields)	7	10	14
Lung (IMRT plan, 30 fields)	18	80	102
Lungs (Rapid arc plan, 57 fields)	27	135	186

- This discovery is very important with respect to patient protection because this may lead to over dosage and necrosis if not taken care of in the planning and implementation of patient treatment plans.
- This algorithm can be employed in the calculation of dose in advance techniques such as IMRT and Rapid Arc by a radiotherapy centres with CMS XiO treatment planning system as it is easy to implement.
- Hybrid algorithm can be used with the original data requirements in the CMS XiO TPS.
- Validation was performed to assure dose calculation accuracy in typical inhomogeneous phantom.
- The developed Hybrid algorithm is therefore suitable for use in beam data modeling as well as an independent quality assurance tool for checking the

accuracy of other clinical TPS algorithms during QC and facility commissioning tests.

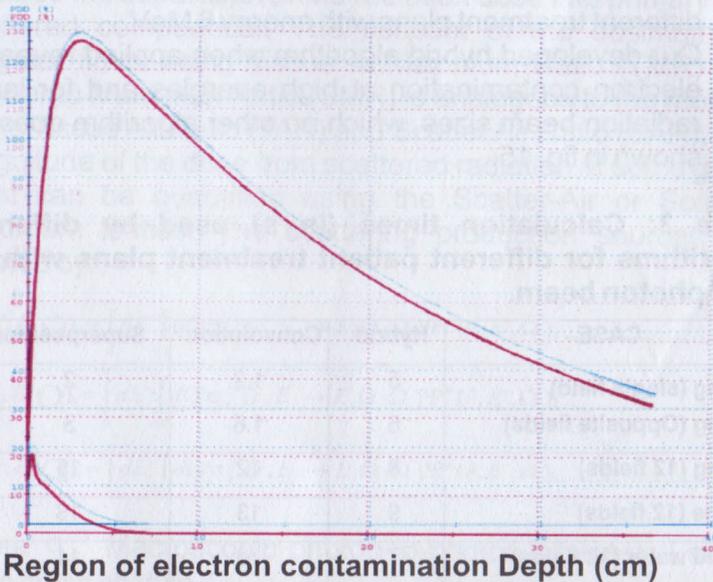


Fig. 15: 18 MeV PDD curve for 12 x 12 cm² field size showing effect of electron contamination

Finite Element Analysis of Single Slot Antenna for MW Tumour Ablation

Recently, alternative to the sophisticated radiotherapy techniques and the cumber of the treatment procedures has engaged the interest of researchers. RF tumour ablation, a form of heat coagulation process has been developed and clinically tried with success in a number of research centers. This technique is suitable only for certain types of tumours and is limited by the size of tumour that can be treated. Thermotherapy is a type of cancer treatment in which the tumour is exposed to cytotoxic temperature. Temperatures in excess of 60 °C are known to cause instantaneous death, while those from 50 °C to 60 °C will induce tissue coagulation by killing the cells and denaturing the cell protein structure. The technique is based on dielectric

heating where the dielectric material is the tissue. Heating occurs because MW field forces water molecules in the tissue to rotate and oscillate. The water molecules tend to oscillate out of phase with the applied MW fields and the absorbed MW energy is converted to heat through intermolecular friction. Tissue conductivity (σ) and relative permittivity (ϵ_r) are some of the factors that affect the MW absorption efficiency.

MW tumour ablation like RF uses suitable antennae inserted into the tumour. We have designed a Single Slot Antenna and developed MW propagation model employing numerical methods. The process involves the formulation of discrete solutions using computationally efficient approximations to Maxwell's equations. Antenna's specific absorption rate (SAR) distribution pattern and frequency-dependent reflection coefficient in tissues are essential for the optimisation of ablation. SAR represents the electromagnetic power deposited per unit mass in tissue (W/kg) and can be expressed mathematically as:

$$SAR = \frac{\sigma}{2\rho} |E|^2 \quad 4$$

where σ is tissue conductivity (S/m), ρ is the tissue density (kg/m³) and $|E|$ is the applied electric field peak amplitude (V/m).

Dipole antenna structure design for MW tumour ablation consists of the antenna slot and antenna termination tip, which is an enlarged metal structure of the coaxial central conductor. We used the finite element (FE) package (COMSOL Multiphysics™ v 4.3b) software to simulate and determine the antenna performance. The software enabled us to specify the geometry of antenna, solve the Maxwell's and the heat equations in the tumour and the surrounding tissues.

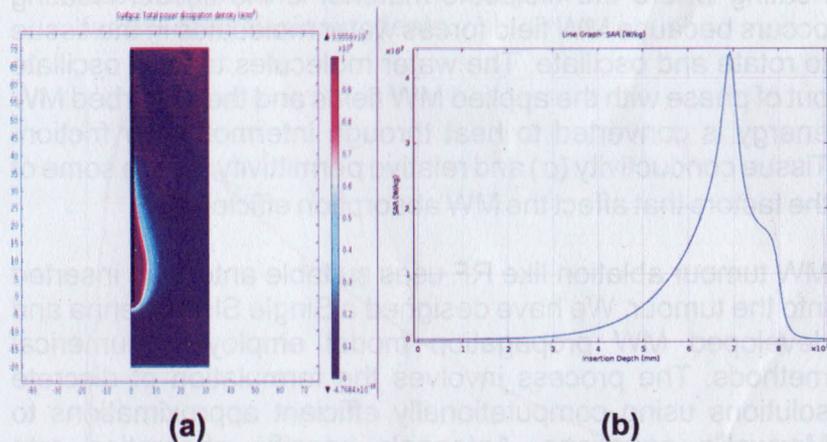


Fig. 16: (a) Absorbed power in liver and (b) SAR distribution with insertion depth using 1 mm slot size and 10mm dipole tip length

Our findings were:

- The dipole tip length has effect on the reflection coefficient, length and diameter of designed antenna.
- Ablation length increases as the dipole tip length increases while ablation diameter does not follow a particular pattern.
- Heating aspect ratios for all simulated antennas are between 0.58 and 0.76.
- The highest value for ablation length for all the simulations is 32.88 mm while that of the reflection coefficient is -29.81.
- Designs with the slot sizes greater than 9 mm (approximately half of effective radiation wavelength) produced high reflection coefficient.
- This antenna has been found to be highly efficient with good broadside radiation patterns (Fig. 16). Its major setback has been backward heating from radiating segment.

- From our findings, dipole tip length influences the power input into the tissue, ablation length and heating aspect ratio.
- The ablation diameter or length is not significantly affected by slot sizes and dipole tip length.
- The dipole tip for antenna has significant effect on power transfer to the tissue. If low reflection coefficient is required, the presence of dipole tip length might not be necessary.

Diagnosis of Sickled Erythrocyte Disease Using Thermography and Energy Exchange Processes

Mr. Vice Chancellor, Ladies and gentlemen. Our scientific explorations were not limited to the energetic ionizing but also with non-ionizing radiations. We investigated and obtained interesting results on low energy infra-red radiation (IR). IR is a form of electromagnetic radiation with a wavelength in the range of 750 nm to 1 mm, having frequencies between 0.003 - 4×10^{14} Hz and quantum energies of 0.0012–1.65 eV. Its wavelength is slightly longer than the red in the visible band of the spectrum. IR rays thus occupy that part of the electromagnetic spectrum with a frequency less than that of visible light and greater than that of microwave.

IR thermography (mapping/imaging of heat distribution) is a non-contact, non-invasive tool which maps the skin temperature. Physiological temperature distribution depends on complex relationships between the skin, inner tissues, local vasculature and metabolic and hormonal activities. Hence, the use of thermography as a diagnostic tool is based on the fact that pathologies would raise skin temperature due to increased metabolic activities. Sickle cell disease conditions are commonly associated with regional vasodilation, hyperthermia, hyperperfusion, hypermetabolism, and hypervascularisation which generate higher-temperatures. Energy exchange processes take place through conduction, convection and radiation while the physiological factors influencing the net heat storage

and change in the body heat content include metabolic heat production, radiation balance, convective transfer via sensible and latent heat, conduction and the heat loss through respiration.

The curved, crescent-shaped or sickle-shaped erythrocyte is a genetic disorder that strikes the black race far more than any other population group. It is caused by a defective gene and anaemia results from the abnormal hemoglobin, the oxygen-carrying component of red blood cells. The disease is often accompanied by intense pain and serious deficiencies of oxygen and other blood nutrients throughout the body. The disease is therefore of economic and social importance. We therefore investigated the correlation between the skin temperature and physiological energy exchange processes in the management of sickled erythrocyte (HbSS) patients. We employed the modified standard methods in the Man-ENvironment heat EXchange (MENEX 2005) models for the energy balance and transfer processes.

$$T_{sk} = 0.071t_{fh} + 0.14t_a + 0.05t_{ha} + 0.07t_f + 0.13t_l + 0.19t_{th} + 0.35t_t \quad 5$$

where t_{fh} is the skin temperature of the forehead, t_a is the skin temperature of the arm, t_{ha} is the skin temperature of the hand, t_f is the skin temperature of the foot, t_l is the skin temperature of the leg, t_{th} is the skin temperature of the thigh and t_t is the skin temperature of the trunk. These models and their applications are based on the first fundamental law of thermodynamics. The mean weighted skin temperature is used to calculate the radiative heat exchange R and the convective heat exchange C . The measured oxygen consumption rate was used to calculate the metabolic heat gain M , the evaporative E , conductive C , radiative R , respirative R_{es} and total energy balance ΔH : $\Delta H = (M - W) + E + C + R + R_{es} \quad 6$

Fig. 17 shows typical thermographs of the studied HbSS patients, indicated on each of them is the skin temperature at the abdomen, the forehead, the neck and the chest

respectively. The results obtained were analysed statistically and summarised as presented in the table 4, and compared with those of HbAA participants using the paired sample student T-test. We correlated the thermographic information with physiological parameter modifications resulting from HbSS infection in order to apply the results for the diagnosis of the disease.

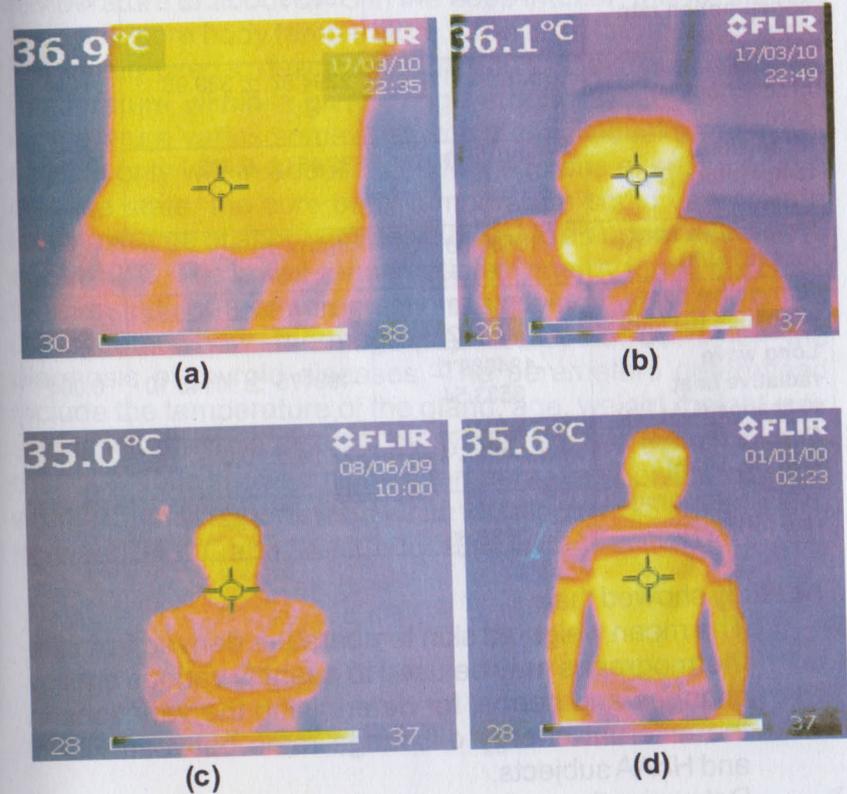


Fig. 17: Typical thermographs of the studied HbSS patients are presented in the figure, indicated on them are the skin temperatures at (a) abdomen, (b) forehead, (c) neck and (d) chest

Table 4: Summary of the heat exchange parameters of homozygous sickle (HbSS) compared with non-sickle (HbAA) cell subjects

Physiological parameters	Non-sickle cell (HbAA) (Mean \pm SEM)	Homozygous sickle cell (HbSS) Mean \pm SEM	p-value
Oxygen consumption rate (VO_2) (ml/s)	50.88 \pm 4.69	130.99 \pm 21.17	0.005
Metabolic heat production (M) (J/h)	916.88 \pm 111.31	2294.87 \pm 330.95	0.007
Mean skin temperature (T_{sk}) ($^{\circ}C$)	35.06 \pm 0.128	35.45 \pm 0.402	0.455
Evaporative heat loss (E) (J/h)	-10566.90 \pm 36.45	-10414.70 \pm 116.105	0.300
Convective heat exchange (C) (J/h)	-10646.20 \pm 134.92	-11044.60 \pm 425.52	0.455
Long wave radiative heat exchange (L_r) (J/h)	-134689 \pm 3533.54	-199175 \pm 11145.10	0.001
Respiratory heat loss (R_{es}) (J/h)	-22.54 \pm 0.0	-22.54 \pm 0.0	N/A
Total energy prod. rate (ΔH) (J/h)	155003 \pm 3638.68	225491 \pm 12729.78	0.001

The study showed that:

- The mean weighted skin temperature derived from the thermographs may be used to quantify various energy changes and hence, for determining the variations in the different energy exchange rates between HbSS and HbAA subjects.
- Determination of the skin temperature thermographically provides the required parameter for calculating the various energy exchange rates.
- Significant differences in the VO_2 , M, L_r , and ΔH values are useful in delineating patients with sickled erythrocyte (HbSS) from the normal (HbAA).
- Age, sex and body mass index (BMI) seem not to play significant role in this SS assessment method.

- Our method provides a quick and non-invasive method of assessing the status of HbSS individuals based on the differences in the energy exchange rates.

Diagnosis of thyroid diseases using thermography

The human body maintains itself at a nearly constant temperature of about $37^{\circ}C$ in the deep interior; this is referred to as the "core body temperature." The term thermoregulation is normally used to describe the maintenance of this core body temperature within a given range around $37^{\circ}C$. The actual temperature varies somewhat with the individual and time of day but only within about $1^{\circ}C$. With vigorous exercise or in a disease state, the core body temperature could vary from a lower extreme of approximately $35.5^{\circ}C$ to an upper extreme of about $40^{\circ}C$. The law of conservation of energy forms the basis for the study of thermoregulation. Applying this principle, we investigated how thermography could be used for the diagnosis of thyroid diseases. The parameters determined include the temperature of the gland, age, weight, height, sex and type of thyroid disease by cytological analysis. Patients' thermographs showed highest temperatures between $37.1^{\circ}C$ and $37.5^{\circ}C$ for hyperthyroid while for hypothyroid cases it was between $34.4^{\circ}C$ and $34.9^{\circ}C$ Fig. 18(a and b)

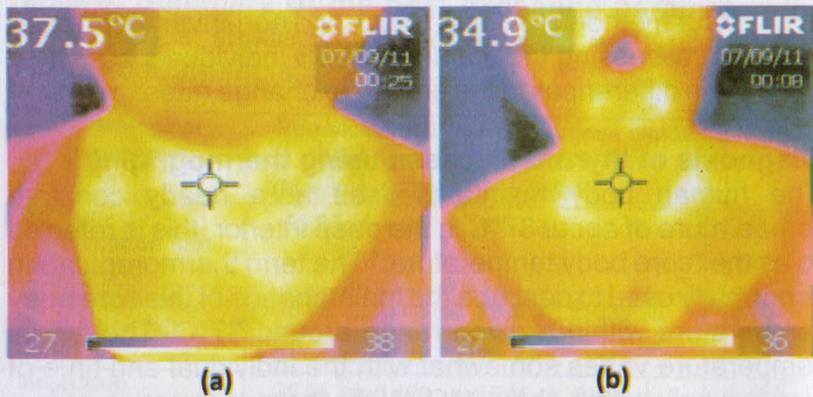


Fig 18: Typical thermographs of (a) hyperthyroidic and (b) hypothyroidic patients

The study revealed that:

- The results of fine needle cytological classification of thyroid diseases and the frequency distribution according to sex showed that 4 (11%) patients are malignant and 33 (91%) are benign, out of 37 patients, only 6 cases showed hypothyroid while the remaining 31 cases were hyperthyroid (Fig 19)
- Ultrasonographic findings revealed cystic echo texture in 10 cases (27%), a solid echo texture in 12 (32%), mixed echo texture in 14 cases (39%) and coarse echo texture in only 1 case (2.7%).
- Results showed that thyroid swellings prevail among middle-aged and the mean age of the patients was 40.97 ± 08.72 years.

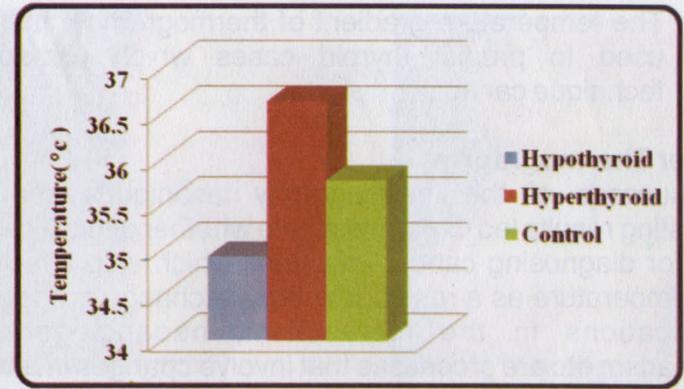


Fig. 19: Variation of mean skin temperature with disease type

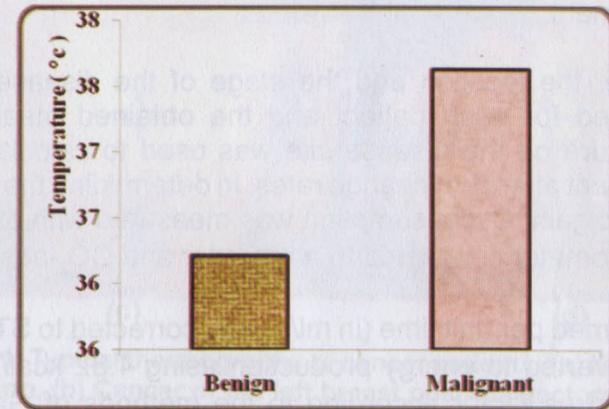


Fig. 20: Dependence of disease type on temperature

- The mean temperature around the thyroid gland is approximately the same for both males and females among the control.
- Thermographic technique showed slightly higher temperature in thyroid malignant than that of benign (Fig. 20).
- Hyperthyroid have higher temperature than control and hypothyroid patients.
- Females are more likely prone to thyroid diseases than males.

- The temperature gradient of thermogramme may be used to predict thyroid cases which ultrasound technique cannot.

Cancer Thermography

The success of the thermography techniques and the interesting results led us to investigate whether or not it can be used for diagnosing cancer infections which also affect the skin temperature as a result of energy exchange processes. Modifications in the metabolism, neoangiogenesis, vascularism etc are processes that involve changes in energy and temperature distribution. We therefore investigated the correlation between the skin temperature and energy exchange processes in view of applications in cancer management.

The type, the location and the stage of the disease were determined for each patient and the obtained mean skin temperature on the disease site was used to calculate the various heat energy exchange rates. In determining the rate of metabolic gain, O₂ consumption was measured with oxygen-filled spirometer connected to a recorder and CO₂-absorbing system.

O₂ consumed per unit time (in ml/s) was corrected to STP and then converted to energy production using 4.82 kcal/l of O₂ consumed as factor according to the methods of Ganong. Oxygen consumption rate is given by:

$$VO_{2max} = 15H_{max}/H_{rest} \quad 7$$

where $H_{max} = 205.8 - (0.685 \times \text{age})$ is the maximum heart rate (in beats per minute) and H_{rest} is the resting heart rate. Typical thermographs of some studied cancer patients are presented in fig. 21 for (a) keloid on the left arm, (b) cancer on the left breast after mastectomy, (c) cancer of the cervix and (d) cancer of the thyroid.

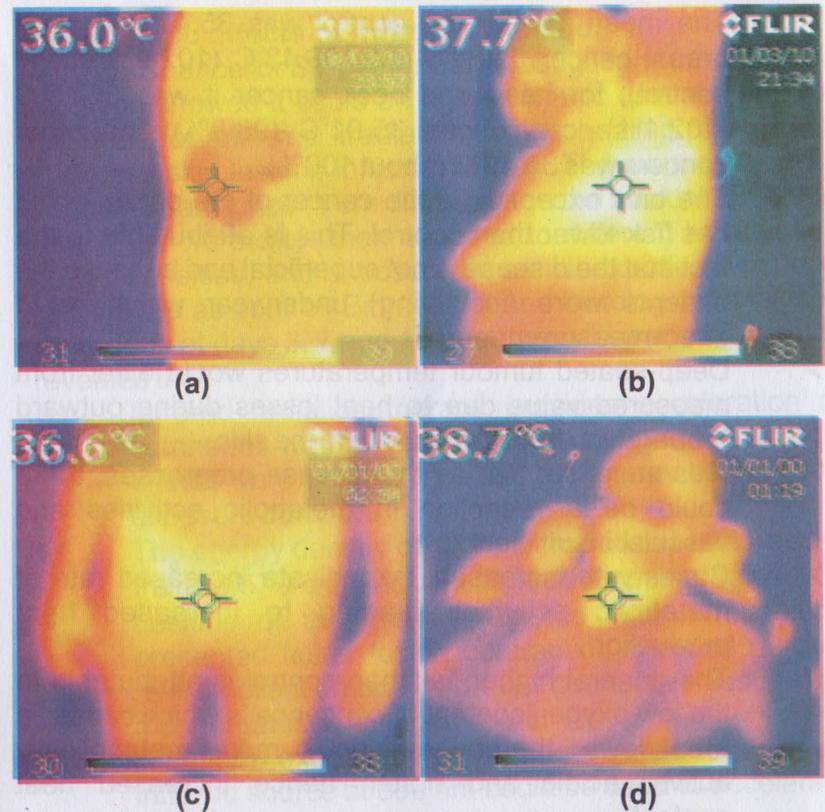


Fig 21: Typical thermographs of cancer patients: (a) Keloid on the left arm, (b) Cancer of the left breast post-mastectomy, (c) is the Cancer of the cervix and (d) is the Cancer of the thyroid

- The distribution of the 107 cancers by type is such that the cancer of the breast was the most seen in our radiotherapy clinic during the study period, followed by the Head and Neck and cancer of the cervix.
- More women are affected by the disease than men; the ratio of female to male is about 2.34:1. This is obviously due to the fact that carcinomas of the breast and cervix which account for over 50% of all malignancies are peculiar to women.
- The results show that in general, cancer patients have higher Tsk values than control.

- The mean Tsk for the control was 35.44°C, that of breast cancer patients was 36.43°C (102.9% of the control), for head and neck cancer it was 36.19°C (102.1%), cervix was 35.01°C (98.8%) and other cancers was 35.43°C (about 100%).
- The only exception is the cancer of the cervix which has Tsk lower than control. This is attributable to the fact that the disease is not superficial and because the patients wore (insulating) underwear which could affect measurements.
- Deep-seated tumour temperatures would differ from measured value due to heat losses during outward propagation from tumour site to the skin.
- This suggests that as the disease progresses, there could be a reduction in metabolic activities and vascular insufficiency.
- Cases with increased Tsk indicate increased rate of metabolic activities leading to increased heat production.
- The general higher Tsk than control is attributable to the low oxygen content of cancer cells which causes a breakdown, thereby making it more metabolically active, acidic and hotter, hence increased heat content.
- Cancerous cells survive better in low oxygen concentrations because the energy needed for respiration is produced by fermentation of sugar instead of using oxygen, whereas normal cells require alkaline and high oxygen environments for oxidative phosphorylation.
- Determination of the skin temperature thermographically provides the required parameters for calculating the various energy exchange rates, a method that provides a quick and non-invasive method of assessing individuals at risk of developing cancer based on the values of the various energy exchange rates.

Therapeutic effects of infra-red radiation

Mr. Vice Chancellor Sir, our further investigations into infra-red radiation showed it could be of therapeutic use. We studied the effect of infra-red irradiation on the healing rate of full-thickness skin lesions inflicted on rats. The wounds were of about the same size (1 cm diameter) on the back of 20 Wistar rats. They were after then exposed to different i-r radiation power densities, and exposure times. Unexposed wounded rats served as control. Biometrical and histological analyses were done at days 3, 7 and 14 post-wounding and our results revealed that:

- Infrared radiation therapy provides acceleration of cutaneous wound healing in rats and the therapeutic effects were dependent upon the energy density and exposure duration.
- The energy density of 11.78 J/cm² led to better results than 23.57 J/cm² and constitutes the optimal value.
- Lesions of the group irradiated with 11.78 J/cm² presented faster lesion contraction showing quicker re-epithelisation and reformed connective tissue with more organised collagen fibers.
- A uniform exposure from a single irradiation with an infrared source at 650 nm could be used to accelerate the biological response in healing processes.
- Histopathological findings revealed reduction in inflammatory cells, increase in activity of collagen synthesis and high vascularisation.
- Collagen fibers were mostly mature and well organised in the exposed animals, which indicate better regeneration and faster healing with restoration of structural and functional integrity of the wound area when compared with the unexposed rats.

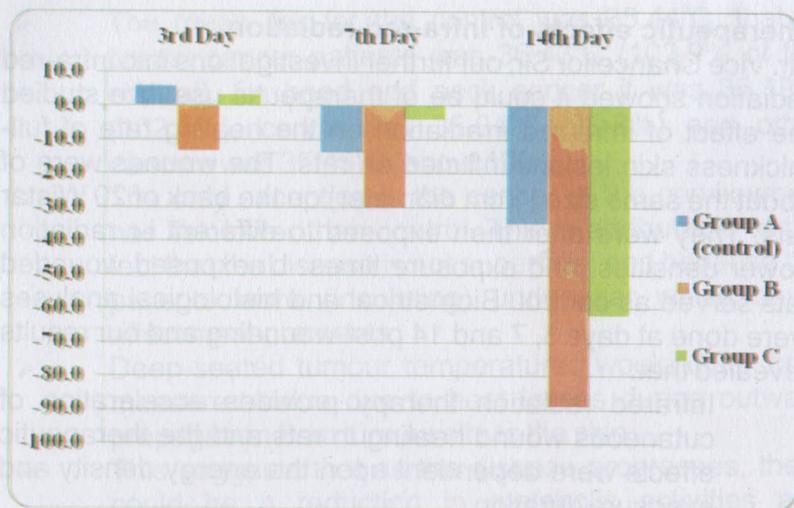


Fig. 22: Percentage changes in the wound sizes on the different animal groups. Group B received 11.78 J/cm^2 while C received 23.57 J/cm^2

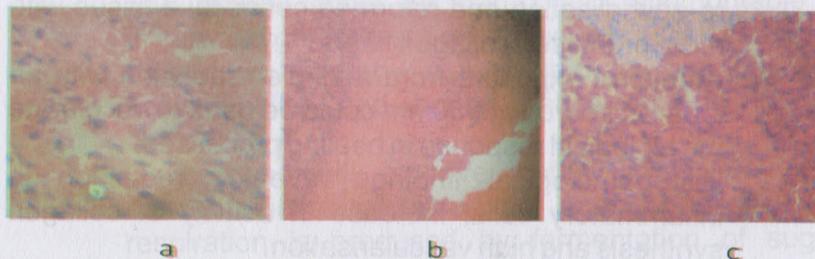


Fig. 23: Slides of samples irradiated with 11.78 J/cm^2 for 30 seconds on the (a) 3rd day, showing granulation tissue with congested thin walled vascular channels and observable collagen, (b) 7th day, showing moderate inflammatory cells, and (c) 14th day, moderate suppuration with neutrophils predominating (H & E 40 X)

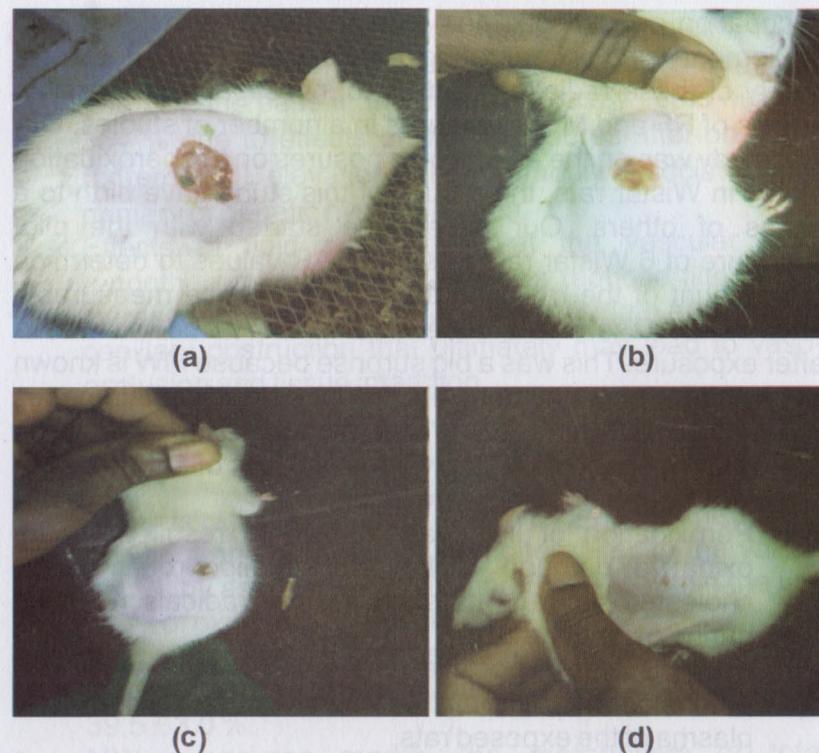


Fig 24: Typical wound healing progress in infra-red irradiated rat on (a) day 1, (b) day 3, (c) day 7 and (d) day 14 post-wounding respectively

Effects of Microwave exposures on the peroxidation status in Wistar rats

Mr. Vice Chancellor Sir, distinguished colleagues, ladies and gentlemen. Some bands of the electromagnetic radiation spectrum are beneficial and raise the hopes of mankind to improve quality of life and provide socio-economic advantages, some of the bands carry along some undesirable effects when living objects are exposed to them, thereby constituting a source of fears. The accelerated increase and numerous industrial, medical and research applications of non-ionizing radiations are accompanied by significant increases in human and environmental RF and MW exposures. Exposures could result from the practice of profession, type of

occupation or domestic and industrial uses of devices and equipment using or generating the radiations. The question of safety of these radiations led us to investigate the possible effects of RF and MW exposures in a number of studies. Our first study was on the effects of exposures on the peroxidation status in Wistar rats, the results of this study gave birth to a series of others. Our experience started with the pilot exposure of 6 Wistar rats to some SAR values to determine the amount of the radiation that could produce measurable effects. All these 6 rats developed tumours about 3 weeks after exposure. This was a big surprise because MW is known to be non-ionizing and does not produce significant damages like ionizing radiations. 200 Wistar rats were used to study the peroxidative effect of varying values of SARs of MW radiation on lipids and the following were noted:

- Peroxidation of lipids are known to result from the oxidative damage to low density lipoprotein (LDL) cholesterol by agents such as free radicals released during oxidative stress.
- There is also a positive correlation between the lipid peroxidation status and the level of LDL in the blood plasma of the exposed rats.
- The results of study indicate that the applied MW field affects the lipid peroxidation status of the exposed rats significantly ($p < 0.005$).
- The peroxidation indicator, MDA value decreased from the normal 4.13 ± 0.15 to $2.10 \times 10 \text{gl}^{-1}$.
- Whole body exposures produce and promote the production of free radicals in biological systems.
- Athermal interaction processes lead to the production of free radicals, aqueous electrons, O° , $\text{H}_2\text{O}_2^\circ$, H_3O° etc due to reactions of phagocytic cells.
- Thermal interactions enhance these processes.
- Administration of vitamins C and E cushions this effect.

The interesting results led to extending the study to include exposure effects on the low density lipoprotein (LDL), high

density lipoprotein (HDL), total cholesterol lipoprotein (TCL), and triglyceride (TRG) and the following were observed:

- The LDL increase in the irradiated rats was as high as 354 % due to effects of MW exposures after one day. Extreme LDL elevations are commonly associated with primary or genetic hyperlipidemia.
- Effects of lipid peroxidation at the vascular level (endothelium) includes K^+ leakage reduced filterability, increased red cell rigidity which can initiate episodes of capillary obstruction that ultimately may lead to vaso-occlusion and tissue infarction.
- The significant increase in LDL status due to MW radiation exposures is an indication of potential health risks.
- Administration of vitamins C and E, the well known and powerful antioxidants, caused decreases in the values of LDL by as much as 273.8 and 253.0 % within the first week of exposures respectively.
- It was observed that plasma lipid peroxidation status (PLPS) decreased from its pre-supplementation level by 39.5 ± 3.0 %.
- MW exposures modify the metabolism of total cholesterol (TCL) in the blood plasma quite significantly as shown by the p-value ($p < 0.005$).
- This is to be expected, since both the LDL and HDL levels were significantly affected by the exposure and as well by the administration of the antioxidants.
- MW exposures affected the triglyceride (TRG) status significantly. Also, the vitamins C and E supplementation produced further enhancement of this effect.
- The corresponding p-values lends credence to this fact which again is consistent with the report by Lee et al. (2002), that antioxidants provide a protective effect on oxidative stress as may be induced by exercise and as in the case of our study, MW exposures.

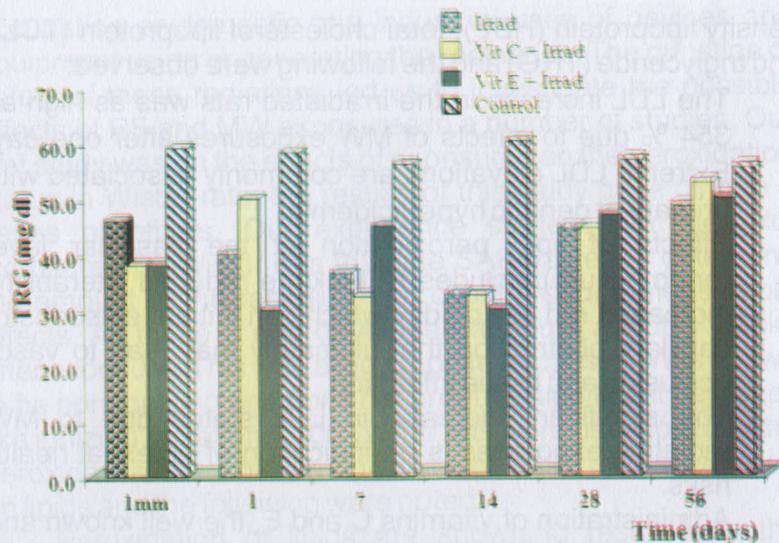


Fig. 25: Variation of triglyceride status after MW exposure and administration of vitamins C and E

Conclusions from the study

- MW interactions in biological tissues lead to the production of ROS, which cause oxidative reactions that eventually affect the status of the physiological parameters LDL, HDL, TCL and TRG. Fig. 24.
- Consequences of the changes in the LDL, HDL, TCL and TGR status on health include atherosclerosis by LDL, induced cytotoxicity and its inhibition by HDL in human vascular smooth muscle and endothelial cells in culture etc.
- The possible health impacts of MW exposures are no more news as a lot of works using experimental animals, human experiences and epidemiological studies have been published. With the ever increasing applications of MW radiations, public exposures will continue to increase proportionately, hence, the need to be vigilant and make concerted efforts to minimise the potential negative health impacts.
- Workers in MW industries, Medicine, telecommunications and allied industries, Physiotherapeutic,

Physiotherapeutic, Radiotherapeutic users and other Medical equipment operators and researchers need to be cautious and possibly, should be monitored for MW exposures to ensure they do not exceed the recommended annual SAR limits, a practice similar to personal dosimetry of workers and users of ionizing radiations.

- The modifying role of ascorbic acid and α -tocopherol on the effects of LDL, HDL, TCL and TRG as obtained from this study suggests that their administration could cushion the health detriments of MW exposures.
- Dietary habits rich in these anti-oxidants will be of much assistance to regular and professional MW workers and users in addition to the adoption of exposure optimisation principles of distance, time and SAR limitation.

Anxiolytic and explorative behavioural effects of low SAR microwave radiation exposures on *Sprague Dawley* rats

We embarked on a study to determine the effects of low Specific Absorption Ratio (SAR) MW exposures on the anxiolytic behaviour and explorative activities using Sprague Dawley rats as model. Anxiolytic behaviours were studied using EPM and Y-maze models. Exploratory activity studies were carried out using white-painted wooden board with 4 elevated plus maze (EPM) holes 1 cm diameter and 2 cm deep. These are the standard setups used in studying anxiolytic and explorative activities due to effects of certain drugs. The mean number of dips in the explorative study varied with time after exposure from a minimum of 1.1 in females exposed to 2.39 W.kg^{-1} 6 days post-exposure to 15.4, 1 h post-exposure to SAR of 0.48 W kg^{-1} . The number reduced from 15.6 ± 4.88 to 8.5 ± 0.58 in males and from 14.8 ± 1.51 to 8.3 ± 0.44 in females. In the anxiolytic activity studies, the variation in the percentage time spent at open end of maze models was from a minimum of 3.92% with SAR of 2.39 W kg^{-1} in males, 1 h post exposure to 75.11 % in females after 15 days. 1 h after exposure, it reduced from

79.13 to 28.45 with females and increased gradually with time to attain the control value after 15 days. The variations in the percentage cumulative time spent in the open or closed arm of the EPM show both time- and SAR-dependence. These observations demonstrated that MW exposures may have caused fear and anxiety at open and elevated areas. These results correlate with those reported by Yamaguichi et al. Also, MW exposures altered the exploratory behaviour in male and female rats compared with control. There was no significant difference between both sexes in the measured values, indicating that the effects of exposures are not sex-dependent.

Absorption of MW energy may cause an increase in tissue temperature and the initial rate of temperature increase is directly proportional to the SAR. A well-established athermal mechanism of interaction at frequencies below a few tens of MHz is through electrical stimulation of excitable membranes of nerve and muscle cells. From the results we developed the hypothesis that the various interaction mechanisms observed and the previous ones producing behavioural changes are probably due to one or more of the following:

- ↓ Effects of MW interactions on nerve cells that may increase or decrease the amount of neurotransmitters released at the synaptic cleft which may also increase or decrease the rate of generation of action potentials, increase the conduction implies greater excitability which may be revealed in form of fear, ecstasy or increase in secretion from gland etc.
- ↓ Effects on the normal synthetic and metabolic activities of cells. Production of reactive oxygen species and hence athermal effects having consequences on the nucleus; damage to organelles, DNA and chromosomes, which can lead to genetic effects and inadequate production of neurotransmitters by the Golgi apparatus.
- ↓ Deletion of receptors for the neurotransmitters on the post synaptic membrane. This event reduces rate of

generation of impulses (action potential).

- ↓ If the glial cells serving as a myelin sheath, as seen in oligodendocytes-CNS and Schwann cells-PNS get affected, it may produce a degenerative effect on those lipid coatings or even lead to production of free radicals.
- ↓ If the ependima cells and meningeal cells are affected, there may be problem of cerebrospinal fluid production or excretion or inadequate carrying out of produce meningitis.
- ↓ If some tissues in the hippocampus are damaged by the MW exposures, similar conditions seen in Alzheimer's disease may show up.
- ↓ The heating effect of the radiation can raise or readjust the biological thermostat in the hypothalamus, thus giving the brain a higher than normal temperature. Local warming of the interior hypothalamus triggers physiological and behavioural heat loss mechanism. The animal tries to lose more heat and cool its temperature beyond the normal body temperature because the body thermostat has been readjusted. This results in hypothermia. Persistent hypothermia reduces brain metabolism.

Microwave radiation exposures affect cardiovascular system and antioxidants modify the effects

A study on the possible effects of MW exposures on the blood pressure (BP) and heart pulse rate (PR) was conducted. The BP and PR were monitored in Wistar rats for a period of 8 weeks post-irradiation. MW exposures caused an increase in the values of BP and PR from the normal mean of 123.0 ± 1.2 mmHg and 430 ± 2.0 beats per minute (BPM) to a maximum of 145.0 ± 5.0 mmHg and 480.0 ± 6.8 BPM within the first 2 h, and then gradually reduced to normal values after about a week. 4 mg kg⁻¹ body weight of ascorbic acid (vitamin C) and alpha-tocopherol (vitamin E) administered 4 days pre-irradiation caused a decrease in the values of these parameters to a

minimum of 128.0 ± 0.4 mmHg and 440.0 ± 1.8 BPM within the first day.

- ↓ The results showed that MW exposures cause significant increase in the BP and PR.
- ↓ The changes observed in the BP and PR are attributed to N_2O_3 inhibition by free radicals produced by the MW interactions.
- ↓ N_2O_3 is a well known vascular smooth muscle relaxant, a by-product of lipid peroxidation and oxidative stress due to increased free radicals production from the MW exposure.
- ↓ These results agree with the findings of Kalns et al. in whose work oxidative stress preceded circulation failure (CF) induced by 35 GHz MW heating. They hypothesized that oxidative stress might have played a role in the pathophysiology of MW induced CF.
- ↓ This oxidative stress has been identified to result from depletion of antioxidants which includes vitamin C, and excessive production of free radicals and other reactive oxygen species like OH° , O° and $H_2O_2^\circ$ etc resulting from MW-tissue interactions.
- ↓ Lipoprotein cholesterol is responsible for the nitric oxide inhibition, hence, the elevation of the BP and PR.
- ↓ The lower values in these parameters with the vitamins C and E treated groups, showed the strong scavenging action by the antioxidant on the MW induced excess free radicals.
- ↓ The results of this study show that MW exposure has influence on the cardiovascular system; both the blood pressure and pulse rate were initially raised from 125 mmHg to 145 mmHg and from 430 BPM to 480 BPM respectively immediately after MW exposure, indicating 15% and 12% rise over the control values respectively.
- ↓ This could be attributed to both the heating effect and more importantly, the increased free radical production from MW interactions.
- ↓ Administration of vitamins C and E cushioned the

harmful effects of MW exposures on the cardiovascular system, showing protective effect on the harmful action of the MW radiation exposures.

- ↓ Implication of this observation is that persons habitually found or working in MW fields may fortify their diet with antioxidants to reduce the potential health detriments.

Microwave radiation exposures affect hematological parameters and antioxidants modify the effects in rats

In order to find an answer to the question whether or not exposure to MW affects blood parameters, we conducted an investigation using 140 adult Wistar rats to study 7 parameters; Hb, RBC, WBC, PCV, Platelet, Neutrophil and Lymphocyte. We found that:

- ↓ Hb value reduced from the control mean value of about 16.2 g/dl to 10.0 g/dl immediately after irradiation and maintained this value till after 2 days when the value slightly increased to 10.0 g/dl. It then increased to 13.0 g/dl after 4 days and the control value was attained only at the 8th week.
- ↓ RBC value reduced from the control mean value of about 50.0 to 41.0×10^4 cells/mm³ immediately after irradiation. The value then increased to 45.0×10^4 cells/mm³ after 1 day and then gently increased to 49.0, 51.0, 52.0 and 53.0×10^4 cells/mm³ after 1, 2, 4 and 8 weeks respectively.
- ↓ WBC value reduced from the control mean value of about 6880.0 to 4000.0×10^6 cells/mm³ immediately after irradiation. The value then increased to 6000.0×10^6 cells/mm³ after 1 day and then gently varied between 7000.0 and 7300.0×10^6 cells/mm³ between the first and the 8th week
- ↓ The PCV decreased significantly from the control value of 49.0% to 30.0% immediately after exposure. There was no significant increase in the value until after 4 weeks when it became 38.6% and it finally attained the value of 51.1% only after the 8th week.
- ↓ Platelet count reduced from the control value of 300.0

to $210.0 \times 10^9/l$ immediately after exposure. It then increased to $215.0 \times 10^9/l$ after a day and to 246.0, 274.0, 280.0 and $281.0 \times 10^9/l$ after 1, 2, 4 and 8 weeks respectively.

- ↓ Neutrophill value did not vary significantly as the effect of MW exposure merely reduced the value from the control of 21.0% to 20.0% immediately after (Figure 6).
- ↓ The value varied between 21% and 23% from 1 day through all the 8 week study period.
- ↓ Observations with lymphocyte counts are similar to those of neutrophill, MW radiation exposure apparently did not produce significant effects on the status
- ↓ Effects on Hb, RBC, WBC, PCV etc observed showed that MW exposures may have harmful effects on the peripheral blood cells due the fall in their values.
- ↓ It was noted that the role of vitamin E was more significant than that of vitamin C. This can be understood from the fact that vitamin E is the most powerful antioxidant.

Effects of 2.45 GHz Radiofrequency Radiation Exposures on Normal and Sickle Erythrocytes

Having established that exposures to MW radiation affect blood parameters in rats, we proceeded to investigate what the situation could be in man. 20 subjects were used for this study, 10 adult sickle cell and 10 adult non-sickle cell patients. Blood samples were collected for analysis before and after being irradiated with an RF source. Osmotic fragility of the red blood cells (RBC), the packed cell volume (PCV) and the percentage haemolysis for irreversibly sickle cells and non-sickle cells were determined and the results compared:

- ↓ The possible effects were studied through determination of osmotic fragility and measurement of irreversibly sickled cells.
- ↓ It was discovered that osmotic fragility of the sickle cell subjects was much higher than that of non-sickle cell subjects.

- ↓ The mean corpuscular fragility of sickle cells observed was much less than that of non-sickle cells.
- ↓ The value at complete lysis for non-sickle cells before irradiation ($HbAA_b$) was $0.22 \pm 0.01\%$ and after ($HbAA_a$) it increased to $0.23 \pm 0.02\%$ with a p-value < 0.05 .
- ↓ In the sickle cell samples before ($HbSS_b$) and after ($HbSS_a$), the values were $0.12 \pm 0.01\%$ and $0.42 \pm 0.01\%$ respectively with p-value < 0.01 .
- ↓ The PCV values for the $HbAA_b$ sample ranged from 37.50 to 55.49% with a mean (\pm SEM) of $44.93 \pm 0.90\%$.
- ↓ The range for the $HbAA_a$ was from 26.02 to 34.12 % giving a mean of $30.12 \pm 0.20\%$ ($p < 0.01$).
- ↓ The values for $HbSS_b$ samples ranged between 20.00 and 34.00% giving a mean of $26.53 \pm 1.20\%$ while for the $HbAA_a$ the range was 1.00 to 6.06%, giving a mean value of $5.06 \pm 1.00\%$ ($p < 0.01$).
- ↓ The percentage haemolysis remains persistently high after exposure of sickle cells while that of non-sickle cells showed little variations compared with control.
- ↓ The results obtained demonstrate that exposures to RF radiation have much harmful effects on sickle cell and have no significant effect on non-sickle cell carriers.
- ↓ It is advisable for sickle cell patients not to routinely work under RF fields or be engaged in professional or occupational practices involving frequent RF exposures.

9(m) Effects of exposure to 2.45 GHz microwave radiation on vital organs

Does MW radiation exposure have any effects on the reproductive functions? To answer this question, 36 rats were used for investigation, exposing them to different SAR values of 0.00 (control), 0.48, 0.95, 1.43, 1.91 and 2.39 W kg^{-1} in the irradiation chamber. Variations in the bodyweights, organ weights, and sperm gross motility, sperm morphology and sperm

counts were determined for the different values of applied SAR.

MW exposures reduced the growth rate and organ weights in a proportion that depends on the applied SAR-value.

The greatest increases in body weight and the lowest sperm gross motility were observed in the youngest age group exposed to 0.48 W kg^{-1} .

This same trend was observed in sperm counts and changes in sperm morphology.

The live to dead ratio from the semen analysis of smears showed that low SAR MW exposure caused death of sperm cells as demonstrated by cell membrane taking up the eosin-nigrosin vital stain.

The major types of sperm cell abnormality observed were coiled tail, which is an indication of alteration of cell membrane integrity, detached head and pyriform head.

The highest number of coiled tail and detached head 18.4 ± 5.03 and 28.80 ± 12.83 were obtained in group exposed to SAR 1.91 W kg^{-1} , but the highest number of pyriform head was found in the group exposed to SAR 2.39 W kg^{-1} .

MW exposures led to significant decrease in the sperm motility in all the exposed groups compared to the control. The highest motility of 76.4 ± 0.17 was obtained in the control while the lowest motility of 8.30 ± 0.11 was obtained in the exposed to SAR 1.91 W kg^{-1} .

The live to death ratio in the smear showed that MW affects the sperm with highest ratio obtained in the control group while the lowest ratio was obtained in the group exposed to SAR 0.48 W kg^{-1} .

The epididymal sperm count was significantly reduced in all the exposed groups. The highest count $55.75 \pm 0.53 \times 10^6 \text{ ml}$ was obtained in the control while the lowest $4.50 \pm 0.13 \times 10^6 \text{ ml}$ was obtained in group exposed to 1.91 W kg^{-1} followed by the group exposed to 0.48 W kg^{-1} with $5.45 \pm 0.10 \times 10^6 \text{ ml}$.

Our findings have shown some of the adverse effects of MW radiation on the reproductive organs such as higher growth rate, organ weight, sperm count, sperm motility and sperm morphology.

Throughout the period of 4 weeks post-exposure to different SARs, the body weight and some reproductive functions in the male rats, the effects were found to be SAR-dependent. The results also showed that exposure to SAR of 0.48 W kg^{-1} and above produced adverse effects on testicular metabolism with significant reduction in sperm counts, sperm motility and morphology.

Although, rats are known to be more metabolically active than humans, these results provide an indication of possible effects that may be expected on male reproductive system in humans.

Mild reduction in the number of spermatozoa was observed in the seminal vesicle as compared to control group and the liver shows mild oedema with cloudiness.

The testis, seminal vesicle and epididymis show reduction in the number of germ cells as compared to control group, cellular swelling and cloudiness occasional isolated cell necrosis was observed in the liver.

According to the results of histology, it was evident that the kidney and ovary were most affected in the entire female exposed to 2.45 GHz MW radiation.

Hyperchromasia was observed in the ovary of the animals exposed to MW radiation and this is a descriptive term referring to the hyperchromatic state of nucleus (elevated chromatin) and this state suggests malignancy.

Vascular/glomerular congestion, interstitial spaces hemorrhage and tubular cells cloudiness was observed in the kidney and the chief function of the kidney is to process blood plasma and excrete urine.

- ⚡ These functions are important because they play a vital role in the clearance and excretion of xenobiotics including drugs and drug-product from the body.
- ⚡ This situation also suggests renal failure if the radiation SAR is higher than the values used and if exposed for longer time. In the male, the testis and liver were affected the organs when exposed to various levels of MW radiation.
- ⚡ The degree of reduction in the number of the germ cells varies with SAR, highest reduction was observed in the group exposed to 2.39 W/kg, which suggests that MW radiation has the potential to affects male fertility adversely.
- ⚡ Edema, cloudiness, glomeruli congestion and occasional cell necrosis was observed in the liver the severity of the pathology was SAR-dependent.
- ⚡ From this study, it can be deduced that the liver, kidney and reproductive organs are more sensitive to microwave radiation.

Genotoxic effects of low 2.45 GHz microwave radiation exposures on Sprague Dawley rats

For about a decade now, there has been divided opinion as to whether MW and RF radiations can cause cancer. As reported earlier, we observed development of cancer in 6 Wistar rats while conducting a study on the peroxidation of lipids. Those who do not believe MW and RF can cause cancer base their arguments on the fact that they are non-ionizing radiations. They can only cause excitation in atoms and molecules and produce heat. In fact, the exposure safe limits recommended by the relevant international and national regulatory bodies were fixed based on the heating effects. Our studies and those published by others recently have proven that these radiations produce non-thermal effects. We have demonstrated that they interact with polar molecules to produce the chemically active products described as reactive oxygen species (ROS). These chemicals are known to be toxic to living cells and can interact with the nuclear DNA to produce genetic mutation.

Only ionizing radiations are known to possess sufficient energy to produce radicals, a process described as indirect effect of ionizing radiation in radiotherapy. The action of ROS on DNA to cause damages explains the reason why the MW and RF are able to cause cancer. Indeed, many of the effects observed in the series of our studies on MW and RF are attributed to the non-thermal effects. The question naturally comes up as to what amount of the radiation is sufficient to produce DNA strand breaks and genetic mutation? This question led us into further studies, using 200 experimental animals exposed to low SAR-values and investigating the effects of the exposures on a number of tissues. The international recommended MW safe limit is 6 W/kg. We decided to vary SAR between 0.48 and 4.30 W/kg, varying the SAR values at very small intervals for a fine search. The DNA of different tissues was extracted, precipitated and quantified. Induced deoxyribonucleic acid (DNA) damages were assessed using the methods of DNA Direct Amplification of Length Polymorphisms (DALP) and the Single Cell Gel Electrophoresis (SCGE). Densitometric gel analysis demonstrated distinctly altered band patterns within the range of 40 and 120 bp in exposed samples and in the tail DNA of the same animals before exposure compared with control. Results were re-affirmed with SCGE (comet assay) for the same cells. We deduced from the results that:

- ⚡ Different tissues had different sensitivities to exposures with the brains having the highest. DNA damages were sex-independent.
- ⚡ There was statistically significant difference in the Olive moment and % DNA in the tail of the exposed tissues compared with control ($p < 0.05$).
- ⚡ Observed effects were attributed to magnetic field interactions and production of reactive oxygen species.
- ⚡ Results showed that MW radiation exposures produced DNA single strand breaks and the direct genome analysis of DNA of various tissues demonstrated potential for genotoxicity.

- ✚ A multilocus monomorphic band profile was demonstrated with direct amplification of length polymorphic (DALP) of rat DNA in the tissues studied.
- ✚ Single strand break detected from comet assay, showing that low SAR exposure to MW radiation could result in single strand breaks of DNA in blood leucocytes, brain, lung, and spleen cells of rats.
- ✚ The results obtained from the electrophoresis direct genome analysis of DNA of different tissues demonstrated that MW is capable of inducing genotoxic effects in living tissues.
- ✚ From the results, the brain has the highest DNA damage as observed from comet assay; this suggests that brain cells are highly radiosensitive.
- ✚ Particularly, DNA damage in brain cells could affect neurological functions and also possibly lead to neurodegenerative diseases.
- ✚ Unrepaired or inaccurately repaired DNA damage can lead to cell death as well as genomic instability, mutations, and ultimately to cancer, aging and other diseases.
- ✚ It is obvious that MW is not able to induce genotoxic effects by direct interaction with DNA, because their intrinsic quantum energy ($E = hv$) is too low to dislodge an electron from a molecule (being non-ionizing).
- ✚ Among the putative mechanisms by which MW affects DNA, it is primarily by increasing free radical life span and the concentration of free radicals in cells.
- ✚ Oxidative damage to DNA caused by free radicals, especially by the highly reactive hydroxyl radical, generates a multiplicity of modifications, which include modified bases and sugars, DNA-protein cross links, base-free sites and strand breaks.
- ✚ These findings showed that exposure to MW radiation at SAR even as low as 0.48 W kg^{-1} is potentially genotoxic as it produced DNA strand breaks.

Peroxidation in food samples treated with MW radiation

Production of peroxides in food samples treated with microwave radiation was investigated. Beans, Egusi-soup, Jollof-rice, Fish and Meat pie from popular eateries. Melondialdehyde, an index of lipid peroxidation was determined in both the exposed and control samples.

- ✚ The results indicated production of peroxides in the microwave-treated food samples with statistically significant higher level of melondialdehyde (MDA).
- ✚ The degree of peroxidation and therefore the extent of the negative impacts on endogenous antioxidant varied with duration of radiation exposure.
- ✚ Peroxidation was most pronounced in egusi (205.10 MDA mg/100g) exposed for 15 min while it was least in fish (6.10 MDA mg/100g) exposed for 5 min.
- ✚ MDA being by-product of polyunsaturated fatty acid peroxidation and being genotoxic, reacts with DNA to form highly mutagenic adducts in cells.
- ✚ Regular and heavy consumption of microwave treated foods may expose the consumers to increased health risks, especially cardiovascular diseases, diabetes, atherosclerosis and cancers.
- ✚ After the exposure of the various food samples to MW as described above, both the samples and the control were analysed and the level of (μmole) MDA produced determined by TBA, using the method of Buege and Aust, 1978.
- ✚ The results obtained show that the level of peroxidation produced in Beans, increased by 14.8% after 5 min, by 39.0% after 10 min and by 46.2% after 15 min of MW exposure respectively (Fig 26).
- ✚ In Egusi-soup, the peroxidation level produced increased by 14.3% after 5 min, 20.3% after 10 min and 65.4% after 15 min exposure time respectively.
- ✚ In fish, the peroxidation increased by 4.4% after 5 min, 21.9% after 10 min and 73.7% after 15 min exposure respectively.

- ✚ For Jollof rice, the peroxidation increased by 14.7% after 5 min, 28.7% after 10 min and 56.5% after 15 min exposure respectively.
- ✚ In Meat pie, peroxidation increased by 10.2% after 5 min, 21.7% after 10 min and 68.1% after 15 min exposure time respectively.
- ✚ In all cases, the results show that the MDA level increases progressively as the exposure time increases and that there is statistically significant increase in MDA produced in MW treated food samples compared with control.
- ✚ The increase observed is highest in Egusi soup, which is principally made up of melon that is rich in polyunsaturated fatty acid.
- ✚ In addition, it has the highest fluid content compared to the other studied samples.
- ✚ During MW exposures, free radicals (OH*) and reactive oxygen species (ROS) are being generated through MW interactions. These products are highly reactive and polyunsaturated fatty acids are susceptible to their attacks which induce lipid peroxidation.
- ✚ This reaction leads to formation of MDA (Del Rio et al., 2005), a well known toxic compound which also causes oxidative stress in biological systems.
- ✚ Microwave radiation treated foods contain free radicals produced as a result of the radiation interactions with the food materials. Lipid peroxidation is a free-radical-mediated chain of reactions that once initiated, results in an oxidative deterioration of polyunsaturated lipids. The most common targets are components of biological membranes.
- ✚ When propagated in biological membranes, these reactions can be initiated or enhanced by a number of toxic products, including endoperoxides and aldehydes.
- ✚ Since peroxidation of lipid is associated with MDA accumulation, it is important to ascertain the MDA contents of the varieties of food products sold in

- eateries and likewise prepared at homes with microwave oven.
- ✚ The results provide indication as to the safety of the MW treated foods, a question that has aroused some public concerns.
- ✚ The results provide strong indication that the longer the time of irradiation and the higher the fluid content of the food, the higher the amount of peroxidation produced.
- ✚ In view of the toxic effects of MDA and its implications on the health of the consumers, this study underscores the need for public enlightenment on the domestic and industrial uses of microwave oven to cook and thaw foods.
- ✚ Campaigns through media to let the public know about the potential health hazard associated with consumption of MW treated foods both in eateries and at their individual homes will go a long way to reduce the health risks associated with significant and/or regular consumption.

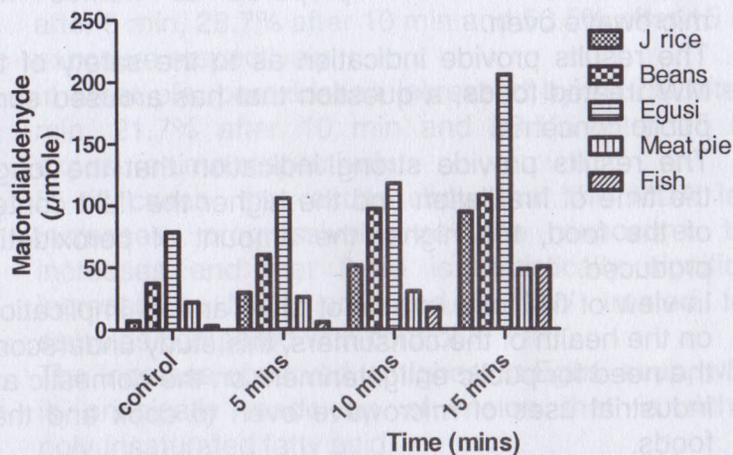


Fig. 26: Bar Charts showing the statistical analysis of MDA (μmole) level variation with exposure time in the studied food samples. Degree of peroxidation varies with exposure time to MW. Egusi (melon) shows the highest concentration of MDA with a mean of $126.70 \mu\text{mole}$ and standard deviation (SD) of 54.83 . Bean is next with concentration $75.53 \mu\text{mole}$ and SD of 32.87 . Jollof rice follows with concentration of $45.73 \mu\text{mole}$ and SD 37.06 , while meat pile has a concentration of $31.73 \mu\text{mole}$ and SD of 11.51 and fish have the least concentration of $19.12 \mu\text{mole}$ with SD 21.37

Antidotes to the Quandary (Principles of Radiation Protection)

Mr. Vice Chancellor Sir, distinguished audience, you will agree with me that the results of our exploration into radiations indeed produce quandary. Radiations are like a cutlass one can use to clear the bush for farming and obtain bountiful harvest at the end of the season. The same cutlass may be used to commit criminal and murderous acts. What is achieved with the cutlass depends on mental stability and integrity of the user. Radiations present numerous and diverse socio-economic, security, industrial and health benefits which apparently are not quantifiable. We have also seen that radiations may produce undesirable damages to our physical body and mental health. As at

today, man has reached a stage of socio-technological development such that he cannot live without the use of these radiations. The issue of withdrawal from the society of radiation sources and radiation facilities is completely ruled out. The solution to the quandary will therefore be development of methods of prudent avoidance of exposures that may negatively affect human health in the multifarious applications. We therefore have to adopt the principles of radiation protection which are justification, optimisation and limitation.

Justification

All radiation exposures must be justified. This means, all unnecessary exposures must be avoided. Traffic within radiation environments must be for the well trained staff alone and must be restricted to the public. Procedures involving the use of radiation must be weighed, the benefits against the detriments associated with the use. It has to be assured that the benefits outweigh the detriments before the application could be justified. In case another methods not involving exposure to radiation are available to achieve the same end result, such methods should be use in place of the one involving radiation exposure.

Optimisation

In the event the use and exposure to radiation is justified, this should not be a reason for superfluous exposures. Only the minimum amount of the radiation and the exposure to achieve the best results should be given. For the unavoidable exposures, the three factors to consider are (i) distance, (ii) time and (iii) shielding. In air, the intensity of radiation reduces according to the inverse square law. The farther one is away from the radiation source, the lower the intensity and hence the lower the radiation dose or the SAR. The longer the time spent in a radiation field, the more the exposure and therefore the greater the health risks. For some types of radiation, there are protective kits, garments and devices that the exposed person must put on to limit the

exposure. Protective barriers and panels in some cases are used to shield against exposures.

Limitation

In order to reduce the probability of developing radiation-induced sicknesses and other undesirable effects of exposures, International and National regulatory bodies have recommended exposure limits of individuals for the different types of radiation. Compliance with the set exposure limits will serve as a guide and minimise the probability of developing the negative health impacts of radiation exposures. Recommended exposure limits are given per annum. The management of exposures with the goal of limiting the amount to the recommended value involves the use of a suitable radiation detector that records the amount of cumulative exposure over a month, the monthly recording of this amount and the summation of the values over a year are compared with recommendation.

Recommendations

✚ Medical Physics is a relatively new and a developing field, even in the developed countries. The training of Medical Physicists in the Department commenced shortly after I joined the University. The training of clinical Medical Physicists is best done in the hospital setting because it involves more of practical applications of Physics theories and concepts in Medicine. I wish to appreciate the Management of the University for allowing this programme to run in the Department of Radiation Biology, Radiotherapy, Radiodiagnosis and Radiography since 1994/1995 academic session. There is paucity of qualified Medical Physicists in Nigeria, as in most other countries of the world. Most of the established Radiotherapy Services in Nigeria do not have technically competent Physicists to man the facilities. I am glad to inform you Mr. Vice-Chancellor Sir, that University of Lagos is the only Institution in the country running Hospital-based Medical Physics Programmes up to Ph.D. level, to supply the nation's required manpower in the hospital setting. I am also glad to

inform you Sir, that the Federal Government and the Federal Ministry of Health have realised the indispensable need of Medical Physics services, therefore the Residency (Clinical) Training Programme commenced about 2 years ago. I am also glad to inform you Sir, that most of the candidates are products of this great University. As the awareness about the field is fast increasing, the pressure of demands for admission into our programme is proportionately increasing, being the most professionally relevant programme to hospital services. Due to some limitations and constraints as a unit in the already large and four-in-one Department, we have not been able to optimally fulfill our mission to the nation. I therefore recommend Sir, that the current programme be upgraded to the status of a Department. This is what operates in Institutions abroad running similar programmes. Thank you in advance Sir, for your anticipated favourable consideration of this request.

✚ Medical Physics services in the hospital cut across most other Departments in the hospital and indeed, across all the Faculties of the College of Medicine. We serve Radiodiagnosis, Physiotherapy, Physiology, Surgery, Internal Medicine, Pediatrics, Anatomy etc. As the Unit aspires to become a full flesh Department so as to be able to play the relevant role across all Faculties of the College, I wish to recommend stronger collaboration among all the Faculties and Departments in the College in the areas of collaborative research and development. Great discoveries and inventions evolve more easily with collaborative work. With collaboration, research works could be more industry oriented and hence, it will become easier to attract funding. My vision in the immediate future is to have most of our research works industry-based and sponsored. The dream is achievable only through collaborative efforts. This is a clarion call as quality and relevant research to our social needs and publications only can make our great University even greater, God being on our side.

⚡ It is evident today that the rate of death due to cancer infections is fast increasing in Nigeria. Unfortunately, most victims are ignorant of the causes. Many other illnesses unknown a few years ago are today plaguing our society. The advent and acquisition of modern telecommunications technologies has largely contributed to health problems. The consequences of exposures to RF and MW radiations are serious issues. Again, both Government and the telecommunications industries continue to deceive the public that the radiations are safe. This is not a problem peculiar to Nigeria, it is worldwide. The deceit is in order to protect the economic interests of the industry. Despite the scientific proofs and epidemiological findings, many still do not believe the radiations are hazardous to health while others do not care, probably because the effects do not manifest immediately. We have so many cases of victims of cell phone masts erected within residential premises all over the country. The situation is worse in Lagos, being the city with the highest population density. I hereby recommend to individuals here present and indeed to all across the country, to be prudent in the use of cell phones, prevent children under 16 years from using cell phones, to keep distance from cell phone masts, drastically reduce the domestic use of microwave ovens and minimise the consumption of fast foods and drinks prepared with microwave radiation.

⚡ One major problem confronting the radiation safety and protection regulatory bodies in Nigeria is that they use the obsolete safety standards set many years ago by other foreign bodies. One of the major breakthroughs in our research is the discovery that RF and MW interact with biological media and polar molecules to generate toxic radicals (ROS), which cause lots of damage to tissues, including genetic mutations. The standards set many years ago by the relevant National and International Organisations were based only on the heating effects of the radiations, being ignorant of the athermal effects which are responsible for most of the health deleterious effects. We do not have

National Standards, we hereby recommend to Government to establish a National Body and develop policies, regulations and guidelines that meet our national peculiar requirements. Since the global proliferation of GSM and the accompanying health problems, many countries have been reviewing their policies and standards in response to public agitations. Nigeria, like other civilised nations of the world should embark on this all important project in order to minimise the current environmental radiation poisoning of the public.

⚡ I wish to recommend to my clinical colleagues in the College of Medicine to have a revisit to the techniques of thermography and clinical applications of infra-red radiation. The radiation has been known for many decades but not much of its exploration and exploitation has been made. Our research experience has demonstrated the immense potentials in the clinical applications of the radiation and thermographic method of medical imaging.

⚡ As both ionizing and non-ionizing radiations have been identified as environmental pollutants, harmful over a short and long duration of time, and as the number of exposed victims being brought to clinics is increasing, I want to recommend both special and periodic trainings for our clinical colleagues on radiation safety and radiation protection. All Clinicians need to be able to identify radiation exposure symptoms and render appropriate assistance to victims as they are brought to the clinics. Just as some symptoms of Ebola viral infection are similar to malaria, and the emergence of the infection led to the training on the handling and delineating the infection from malaria, so it is necessary to familiarise doctors with the symptoms of radiation exposure. For example, profuse nose bleeding without accident or violent shock of the victim living close to a GSM mast, among other symptoms, may not easily be linked to radiation exposures when the victim sees a doctor at the GOPD.

Acknowledgements

“Unless the Lord builds the house, they labour in vain who build it; unless the Lord keeps watch over a city, the watchmen wake but in vain” (Psa. 127¹).

I started this lecture by appreciating the Awesome, Almighty God, the King of all kings, and the Lord of all lords and the Origin of all knowledge because He is All-knowing (Omniscient), who is the secret behind my achievements. I must end the lecture as well by appreciating Him because He is the beginning and the end, the Alpha and the Omega, the One Who was, who is and who is soon coming back. I acknowledge and adore your Excellency and Supremacy Daddy. You made me what I am today, lifting me from grass to grace. I am a product of your love, mercy, grace and favour. Be thou magnified.

By divine arrangements, I have been favoured to receive the supports of some individuals and corporate bodies who have contributed immensely to my academic career and achievements being celebrated today. I want to start by appreciating our amiable and virile Vice-Chancellor, Prof. Rahamon Bello. I like your management style Sir. I also appreciate all the principal officers of this great citadel of learning, for the provision of conducive environment to work and conduct research. I want to appreciate the Provosts of the College of Medicine, past and especially the present. You have been great Ma, by demonstrating that what a man can do, a woman may do even better, being the first and historical female College Provost. My appreciation goes to the Faculty of Clinical Sciences Deans past and current, in particular the current, Prof. Eburn Lesi and the entire Faculty staff. I appreciate all my colleagues, academic and non-academic staff in the Department of RBRRR. The Department is one family and this creates a friendly working environment.

Most of my teachers have always been more than teachers to me; some have become personal friends and even family

friends. I quickly remember late Mr. S. B. Togun of blessed memory, who was my closest teacher and mentor, whose model lifestyle has greatly influenced me during my secondary education. I want to remember my wonderful lecturers: Prof. J. B. Aladekomo, Prof. Dele Olaniyi, Prof. S. B. Kolawole etc., all of the Obafemi Awolowo University, Ile-Ife. I pay homage to Messieurs les Profs. Daniel Blanc, Jean-Pierre Morucci, Andre Dutriex, Jean Dutreix, Jean Chaveudra etc, all of the Centre de Physiques Atomique de Toulouse and Institut Goustave Roussy, Villejuif, Paris, France, who collectively and individually formed me as Medical Physicist. May the good Lord reward you all.

I want to appreciate my in-laws, the Olawuyi family members, the Olaniyan family members and the Akinpelu family members. Time and space will not allow me mention you all by names. I want to as well appreciate my beloved brothers and sisters in Christ, members of the Gideons International in Nigeria, South-West State Association and Lagos-Ikorodu Camp in particular. I remember all the members of the Scripture Union International (Nigeria), especially Ikeja Area and Ikorodu zone. I experience the effects of your spiritual supports in fellowship, love, prayers etc. I most especially express my profound appreciation to the good shepherds of the Super Abundant Life Temple, Haruna District 1 Headquarters Church of the Foursquare Gospel Church, the persons of Rev. (Dr.) and Rev. (Mrs.) Isaac Idowu Obakin, who load me weekly with rich spiritual diet of the Word of God. Your anointing will not run dry and you will not lose your reward on the last day. I appreciated all the other Pastors, Deacons, Deaconesses and all members of the Church for your steadfast brotherly love towards me and my family. May God reward you all.

I again want to confess and publicly, that God has been so good to me. I find it difficult to appropriately express appreciation to God for His unmerited favour in my life. He has blessed me with so many things and so many people, and has also multiplied me on all sides. **Emmanuel**,

Oluwakemi, Esther, Daniel, Ruth and my lovely grandson Enoch, anytime I see you I praise God for your lives. You are wonderful children and a source of joy to me and to God. I am proud of you all. Remain in God's service and you will soon discover that in your lives even the sky cannot limit the place to which God will lift you.

Huuuuuun!!! There is somebody here so distinct, a gift from on high, a sweet lady, a rare gem, my mother, my friend, my lover, my helpmeet, my support, partner with inner beauty, a virtuous woman indeed. As you were wonderful to my late father and mother, even more are you to me. Honestly, I cannot imagine what my life would have been like without you by my side darling, Mrs. Monisola Oyerike Anike AWEDA. God bless you with long life, good health and peace. You will enjoy your old age and eat the fruit of your labour.

I want to end with my favourite hymn:

*The King of love my Shepherd is;
Whose goodness faileth never;
I nothing lack if I am His,
And He is mine forever.*

*And so through all the length of days,
Thy goodness faileth never;
Good Shepherd may I sing Thy praise,
Within Thy house for ever.*

Mr. Vice-Chancellor Sir, Ladies and Gentlemen, Thank you for listening.

Que Dieu vous bennis tous.

The Lord says, "Wise people should not boast that they are wise. Powerful people should not boast that they are powerful. Rich people should not boast that they are rich. If people want to boast, they should boast about this: They should boast that they understand and know me. They should boast that they know and understand that I, the Lord, act out of faithfulness, fairness and justice in the earth and that I desire people who do these things," says the Lord. Jer. 9²³⁻²⁴ (NET).

References

- Aladekomo, J. B. and Aweda, M. A. (1987). A Single Photon Counting Method for Photofluorescence Lifetime Measurements. *Nig. J. Sci.* 2(1), 99-104.
- Aweda, M. A. (1997). Dosimetry Considerations in HDR Intracavitary Brachytherapy. *West Afric. J. Radiol.* 4(1), 19-23.
- Aweda, M. A. (1997). Automation of Biochemical Blood Parameter Monitoring During Extracorporeal Circulation. *J. Nig. Med. Rehab. Therapists.* 2(3), 22-26.
- Aweda, M. A. (1997). A Thick-Film Electrical Conductivity Sensor for Clinical and Diagnostic Applications. *J. Nig. Med. Rehab. Therapists.* 2(4), 31-35.
- Aweda, M. A. (1998). Optimisation of Quality in Teletherapy Procedures with Megavoltage Photon and Electron Beams. *J. Nig. Med. Rehab. Therapists.* 3(5), 28 - 36.
- Aweda, M. A. (1998). Craniospinal Irradiation with Complex Fields using Multileaf Collimation System. *J. Nig. Med. Rehab. Therapists.* 3(6), 28-36.
- Aweda, M. A. (1999). A New Radiation Dose Calculation Method for Interstitial Brachytherapy Radionuclides. *J. Nig. Med. Rehab. Therapists.* 4(7), 31-34.
- Aweda, M. A. (2000). Photophysical Processes in the Clinical Applications of Non-Ionizing Radiation. *J. Nig. Med. Rehab. Therapists* 5(2) 15-19.
- Aweda, M. A. (2004). Assessment of Glycerol, gelatin and Agar gels as equivalent materials for mammalian organs in proton nuclear magnetic resonance imaging. *West Africa J Radiol.* 11(1), 24-30.
- Aweda, M. A. (2001). Radiation Exposure Levels at the National Iron-Ore Mining Project, Itakpe, Kogi State, Nigeria. *J. Sci., Tech and Environ.* 1, 83-92.
- Aweda, M. A. (2002). Natural Background Radiation Distribution in Kogi State, Nigeria. *The J. Sci., Tech and Environ.* 2(1), 25-32.
- Aweda, M. A. (2002). Biological Effects of Power Frequency Field Exposures. *J. Nig. Med. Rehab. Therapists* 7(1), 14-22.

- Aweda, M. A.** (2002). Dose Distribution Perturbation by Prosthetic Materials in Radiation Therapy. *J. Nig. Med. Rehab. Therapists.* 7(1), 11-15.
- Aweda, M. A.** (2003). Assessment of Power Frequency Field Exposure Levels in Lagos State, Nigeria. *J. Nig. Med. Rehab. Therap.* 8(1), 20-25.
- Aweda, M. A.** Gbenebitse, S. O. and Meindinyo R. O. (2003). Effects of 2.45 GHz Microwave exposures on the peroxidation status in Wistar rats. *Nig. Postgrad. Med. Journ.* 10(4), 243-246.
- Aweda, M. A.** Gbenebitse, S. O. and Kehinde M. O. (2004). Effects of 2.45 GHz Radiofrequency Radiation Exposures on Normal and Sick Erythrocytes. *Nig. J. Health and Biomed. Scies.* 3(1), 56-59.
- Aweda, M. A.** (2005). Evaluation of Patient Skin Effective Dose due to Diagnostic Procedures with X-Rays in Lagos State, Nigeria. *Nig. J. Health and Biomed. Sci.* 4(1), 46-52.
- Aweda, M. A.** Ajekigbe, A. T. and Olorunnisomo I. O. (2006). Scintigraphic analysis of thyroid diseases at the Lagos University Teaching Hospital, Lagos, Nigeria. *West Africa J. Radiol.* 13(1), 33-40.
- Aweda, M. A.** and Awosanya, G. O. G. (2007). Safety Awareness in Selected x-ray Diagnostic Centers in Surulere and Ikeja Local Government Areas of Lagos State, Nigeria. *Nig. Journal of Health and Biomed Sci.* 6(1), 67-72.
- Aweda, M. A.** (2008). Assessment of pre-operational radiological conditions at the LINAC centre of the Lagos University Teaching Hospital, Nigeria. *Nig. Quart. Journ. Hosp. Med.* 18(1), 5-11.
- Aweda, M. A.** (2006). Optimisation of Quality in Paediatric x-ray Diagnostic Procedures: A Review. *Arch. of Nig Med. and Med. Sci.* 2(3), 6-12.
- Aweda, M. A.** (2008). Recent Technological Developments in the Clinical Applications of Ionizing Radiations. *Nig. Quart. Journal Hosp. Med.* 18(4), 216-226.

- Aweda, M. A.** Ajekigbe, A. T., Ibitoye, A. Z. Ewwhierhurma, B. O. and Eletu O. B. (2009). Potential health risks due to telecommunications radiofrequency radiation exposures in Lagos State Nigeria. *Nig. Quart. Journal Hosp. Med.* 19(1), 6-14.
- Ibitoye, A. Z. and **Aweda, M. A.** (2011) Assessment of Radiofrequency Power Density Distribution around GSM and Broadcast Antenna Masts in Lagos City, Nigeria. *Nig. Quart. Journal Hosp. Med.* 21(1), 35-40.
- Oyekunle, E. and **Aweda, M.** Effects of Radiotherapy on Cancer Patients Infected with HIV/AIDS in Nigeria. *Proceedings of the International Conference on Cancer organised by the IAEA, Vienna 24-27 May, 2009.*
- Aweda, M. A.** and Arogundade, R. A. (2007). Patient Dose Reduction Methods in Computerized Tomography Procedures: A Review. *Int'l. J. Phys. Sci.* 2(1), 1 - 9.
- Usikalu, M. R., **Aweda, M. A.** Babatunde, E. B., and Awobajo, F. O. (2010). Low level microwave exposure decreases the number of male germ cells and affect vital organs of Sprague Dawley rats. *Am. J. Sci. Ind. Res.*, 1(3), 410-420.
- Aweda, M. A.**, Gbenebitse, S. and Meindinyo, R. O. (2010). Microwave radiation exposures affect the LDL, HDL, TCL and TRG status in rats. *Int'l. J. Phys Sci.* 5(7), 1015-1022.
- Aweda, M. A.**, Usikalu, R. M., Wan J. H., Ding N., and Zhu J. Y. (2010). Genotoxic effects of low 2.45 GHz microwave radiation exposures on Sprague Dawley rats. *Int'l Journ. Genetics and Mol. Biol.* 2(8), 176-181.
- Aweda, M. A.**, Usikalu, M. R., Adeyemi, O. O. and Yemitan, O. K. (2010). Anxiolytic and explorative behavioral effects of low SAR microwave radiation exposures on *Sprague Dawley* rats. *Archives of Applied Science Research.* 2(6), 37-46.
- Aweda, M. A.**, Ketiku, K. K., Ajekigbe, A. T., and Edi A. A. (2010). Potential role of thermography in cancer management. *Archives of Applied Science Research.* 2(6), 300-312.

- Aweda, M. A.**, Usikalu, R. M., and Awobajo, F. O. (2011). Effects of exposure to 2.45 GHz microwave radiation on male rat reproductive system. *Int'l. Journ. Current Research*. 2(1), 120-128.
- Aweda, M. A.**, Edi, A. A. and Kehinde, M. O. (2011). Assessment of sickled erythrocyte disease using thermography and energy exchange processes techniques. *Int'l Journal Current Research*, 3(3), 77-83.
- Aweda, M. A.**, Meindinyo, R. O. K., Gbeneditise, S. O. and Ibitoye, A. Z. (2011). Microwave radiation exposures affect cardiovascular system and antioxidants modify the effects. *Advances in Applied Science Research*. 2(2), 246 - 251.
- Aweda, M. A.**, Meindinyo, R. O. K., and Ibitoye, A. Z. (2011). Microwave radiation exposures affect hematological parameters and antioxidants modify the effects in rats. *Int'l. J. Current Research*. 3(4), 140-145.
- Awojoyogbe, O. B., Boubakker Karemt, **Aweda, M. A.** and Dada M. (2010). BPES-Related Mathematical Development for the Phase Shift Due to RF Magnetic Field in Heart Inferior Coronary Artery NMR Imaging. *J. Clinic Experiment Cardiol*. 1(2), 1-3.
- Ibitoye, Z., **Aweda, M.** and Irurhe, N. (2011). Annual effective dose status among the radiation staff of the Lagos University Teaching Hospita, Lagos, Nigeria. *Afri. Journ. Basic and Applied Sci.*, 3(4), 126 – 130.
- Dada, M., Faromika, O. P., Awojoyogbe, O. B., **Aweda, M. A.** and Fuwape, I. A. (2010). Mathematical formulation of NMR experimental parameters for diffusion magnetic resonance imaging – part I (Cylindrical geometry). *Mathematics, Games Theory and Algebra Compendium (vol. 3), Chap. 1*. Nova Publishers, New York. Edit. Jacob A. Mathias. pp. 1-20, 2013.
- Aweda, M. A.**, Awojoyogbe, O. B. and Dada M. (2011). Potentials of proton magnetic resonance techniques in

- radiotherapy procedures: A review. *Am. J. Sci. Ind. Res.* 2(3), 352-362.
- Awojoyogbe, O. B., Dada, M., Faromika, O. P., **Aweda, M. A.** and Fuwape, I. A. (2010). Mathematical formulation of NMR experimental parameters for diffusion magnetic resonance imaging – part II (Spherical geometry). *Mathematics, Games Theory and Algebra Compendium (vol. 3), Chap. 2*. Nova Publishers, New York. Edit. Jacob A. Mathias. pp. 21- 40, 2013.
- Dada, O. M., Faromika, O. P., Awojoyogbe, O. B., Dada, O. E. and **Aweda, M. A.** (2011). The Impact of Geometry Factors on NMR Diffusion Measurements by the Stejskal and Tanner Pulsed Gradients Method. *Int'l. Journal Theoretical Physics, Group Theory and Nonlinear Optics*. 15(1-2).
- Aweda, M. A.**, Agida, M., Dada, M., Awojoyogbe, O. B., Isah, K., Faromika, O. P., Boubaker, K., De K. and Ojambati O. S. (2011). A solution to Laser-induced heat equation inside a two-layer tissue model using Boubaker Polynomials Expansion Scheme. *J. Laser Micro/Nanoengineering*, 6(2), 105 – 109.
- Dada, M., **Aweda, M. A.**, Awojoyogbe, O. B. and Boubaker, K. (2012). Boubaker Polynomials Expression to the Magnetic Phase-Shift Induced in Leon-Vigmond 3-D Model of the Human Heart. *Journal of Mech in Medicine and Biol*. 12(1), 1-7.
- Aweda, M. A.**, Akpochafor, M. O., Moalosi, T. G. C., Mohlapholi, M. S. and Louv M. (2012). Precision comparison of different monitor unit algorithms using an in-house designed phantom. *Archives of Applied Science Research* 4(2), 914-922.
- Aweda, M. A.**, Agida M., Dada, M., Awojoyogbe, O. B., Isah, K., Faromika, O. P., Boubaker, K. B., De K. and Ojambati O. S. (2012). Boubaker Polynomials Expansion Scheme Solution to the Heat Transfer Equation Inside Laser Heated Biological Tissues. *J. Heat Transfer* (2012) vol. 134, Issue 6, pg 1-4.
- Aweda, M. A.**, Adeyomoye, A. A. and Abe, G. A. (2012). Thermographic analysis of thyroid diseases at the

Lagos University Teaching Hospital, Nigeria. *Advances in Applied Science Research*, 3 (4), 2027-2032.

Dada, O. M., Awojoyogbe, O. B., Baroni, S. and **Aweda, M. A.** (2013). Application of Bloch NMR equation and Pennes bioheat equation to theranostics. *Proceedings of the World Molecular Imaging Society, Annual Congress 2013, Georgia, USA.*

Aweda, M. Adebayo, Ibitoye, A. Zaccheaus, Akpochafor, M. Onoriode, and Madu B. Chibuzo (2013). Entrance radiation dose determination for selected cancer patients at the Lagos University Teaching Hospital, Nigeria. *Radiography* 19(2), 113-116.

Akpochafor, M. O., **Aweda, M. A.**, Omojola, A. D. and Adeneye, S. O. (2013). Verification of a treatment planning system using an in-house designed trunk phantom. *J. Applied Phys.* 5(2), 41 - 46.

Akpochafor, M.O., **Aweda, M.A.**, Ibitoye, Z.A. and Adeneye, S.O. (2013). Thermoluminescent dosimetry in clinical kilovoltage beams. *Radiography*, 19, 326-330.

Akpochafor, M. O., **Aweda, M. A.**, Durosinmi-Etti, F. A. and Adeneye, S. O. (2013). Hybrid algorithm for dose calculation in CMS Xio treatment planning system. *J. Applied Phys.* 5(1), 59-75.

Akpochafor, M. O., Adeosun A. S., Eze C. U., Adeneye, S. K., and **Aweda, M. A.** (2014). Assessment of Ultrasound Equipment as a Possible Source of Nosocomial Infection in Lagos State Hospitals and Radio- Diagnostic Centres. *J. Dental and Med. Sci.* 13(1), 79-86.

Akpochafor, M. O., Ibitoye A. Z., Adeneye S. O. and **Aweda M. A.** (2013). Verification of Treatment Planning System using as in-house designed Head and Neck phantom. *Arch. Appl. Sci. Research.* 4(6), 1-8.

Akpochafor, M. O., **Aweda M. A.**, Durosinmi-Etti F. A., Adeneye S. O., and Omojola A. D. (2014). Simulation of the Linear Boltzmann Transport Equation in modeling of photon beam data. *J. Appl. Phys.* 5(6), 72-86.

Aweda, M. A. and Osuntoki B. O. (2013) Peroxidation status in microwave irradiated food samples. *Int'l Journal of Medical Sci. and Biotechnol.* 1(3), 42-51.

Ibitoye, A. Z, Adeneye S. O, Akpochafor M. O., Nwoye E. O, and **Aweda M. A.** (2014). Finite Element Analysis of Single Slot Antenna for Microwave Tumour Ablation. *J. Appl. Phys.* 5(6), 55-62.



University of Lagos Press and Bookshop Ltd