DETERMINATION OF SCATTERED RADIATION IN CONTROL ROOM OF X-RAY FACILITIES IN SELECTED RADIO-DIAGNOSTIC CENTERS IN LAGOS STATE.

BY

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BEING A PROJECT SUBMITTED TO THE DEPARTMENT IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF M.SC DEGREE IN MEDICAL PHYSICS

MARCH 2016

DECLARATION

I hereby declare that this is my original research work under the supervision of **Prof. M.A. Aweda** and **Dr. Michael O. Akpochafor** to the best of my knowledge that no part of it has been presented to any institution for the award of any higher degree

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ATTESTATION

This is to certify that this thesis was undertaken by OJOMOLADE OLUWASEUN IBIKUNLE (MAT. NO: 149097012) and has been examined and approved for the award of Masters of Science Degree in Medical Physics, Department of ProjectRadiation Biology, Radiotherapy, Radio-diagnosis and Radiotherapy of Faculty of Clinical Sciences, College of Medicine, University of Lagos.

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DEDICATION

This work is dedicated to God, that has made this Master's degree a reality when I had no financial support, nothing at all to start with and to my beloved parents, Mr. and Mrs.A.I and M.B Ojomolade who taught me never to give up.

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Finally, to my Lord and Saviour Jesus Christ: Thank you for this Grace.

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ABSTRACT

It took only about 3 months for the first radiation accident to be recorded after the discovery of X-ray. This was dueto continuous and constant exposure to radiation and hence the health damage. This therefore, necessitates the need to limit radiation exposure to as low as reasonable achievable (IAEA, 2001). This study aims at determining radiation scatter to radiographers in x-ray facilities in selected centers in Lagos state. The research work carried out by making use of a survey meter (RadEye B20-ER survey meter)was carried out in fifteen most frequently X-ray diagnostic centers. Readings of the survey meter were recorded at a distance of 5cm, 10cm, 15cm and at the door within the console room where the radiographer stays for patient examination or behind the protective panel used during the operation of the machine. The readings were taken when the X-ray machine was on. IBM SPSS Statistics version 20 was used to analyze the result by conducting a T-Test and Microsoft excel was used to generate the graphs. The resultsobtained showed that in some centers, the reading gotten behind the protective panel or within the cubicle when calculated for a year, was higher than the recommended occupational limit of 20 mSv/annum averaged over 5 consecutive years. The results showed that higher reading was gotten at distances of 5cm and at the door of the X-ray room. In conclusion, it is advised that proper shielding should be put in place at these centers and in all centers in Lagos State. This is because the centers selected randomly are a representation of what is obtainable within the state. Proper quality assurance and quality control should be done regularly. Radiographers should maintain a good distance between themselves and the X-ray machine even with a proper shielding. This will drastically reduce the accumulation of dose by the healthcare personnel thereby reducing the possibility of stochastic effect of radiation.

CHAPT ER ONE

1.0 INTRODUCTION

1.1 BACKGROUND

Radiation is the propagation or emission of energy by a radioactive source through space or a material medium. This form of energy can either be in form of particle (particle radiation) or electromagnetic waves (i.e., electromagnetic radiation) (Khan, 2003). It could also be defined as the dissemination of energy from a radiative source to another medium (Murat, et al., 2010). This form of energy propagated by traveling corpuscles have a definite rest mass, definite momentum and defined position at any instant (Khan, 2003). Particle radiation are the form of energy that are propagated out which possesses mass and charge i.e. it possesses both energy and mass. This form of radiation is primarily produced by the disintegration of an unstable atom. It includes Alpha, protons, neutrons, electrons and Beta particles. (Anon., 2015)

Alpha particles are large subatomic, high energy structures of neutrons and protons. Alpha particles can travel only a short distance. It is easily stopped by a piece of paper or skin. Beta particles are fast moving electrons. The size is a fraction of the size of alpha particles. It travels farther than alpha and are more penetrating (Anon., 2015). On the other hand, electromagnetic radiation (EM) is pure energy with no mass. It is emitted as a form of vibrating or pulsating waves of magnetic and electrical energy. It is produced by a vibrating electric charge as a result, it consists of both magnetic and an electric component. Aside from acting as a wave, electromagnetic radiation acts like a stream of small "packets" of energy called photons (Anon., 2015) which has been described in terms of a stream of “photons”. All electromagnetic radiation consists of photon which carries (contain) a certain amount of energy(bundle). The photon is massless particles and travel in a wave-like pattern. Different type of electromagnetic radiation is differentiated by the amount of energy found in the photons. The energy of a photon is given by

$$E = hv = \frac{hc}{\lambda}\text{.....................................}1.1$$

where$h$ (Planck's constant) = 6.62 X 10-34 J-sec = 4.13 X 10-18 KeV-sec. When E is expressed in KeV and λ in nanometers (nm)

Electromagnetic radiation travels at the speed of light (3 x 10^8 m/s) in a straight line as shown in figure 1.1 below.

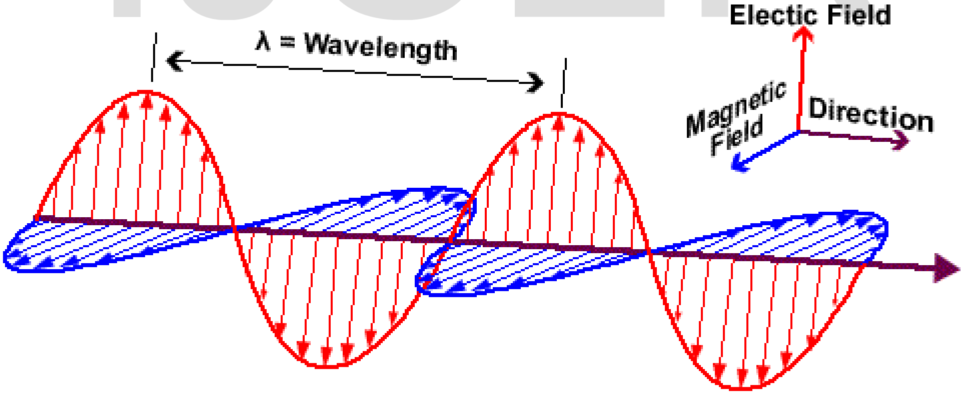

FIGURE 1.1: ELECTROMAGNETIC WAVE (ANON., 2015).

Examples of electromagnetic waves includes Radio waves, Microwaves, Infrared waves, Ultraviolet light, x-rays (x-radiation) and gamma radiation (gamma rays). These different type of electromagnetic waves differs in the wave length, frequency and energy as shown in fig 1.2. It follows that the amount of energy deposited by electromagnetic radiation increases with an increase in the frequency.

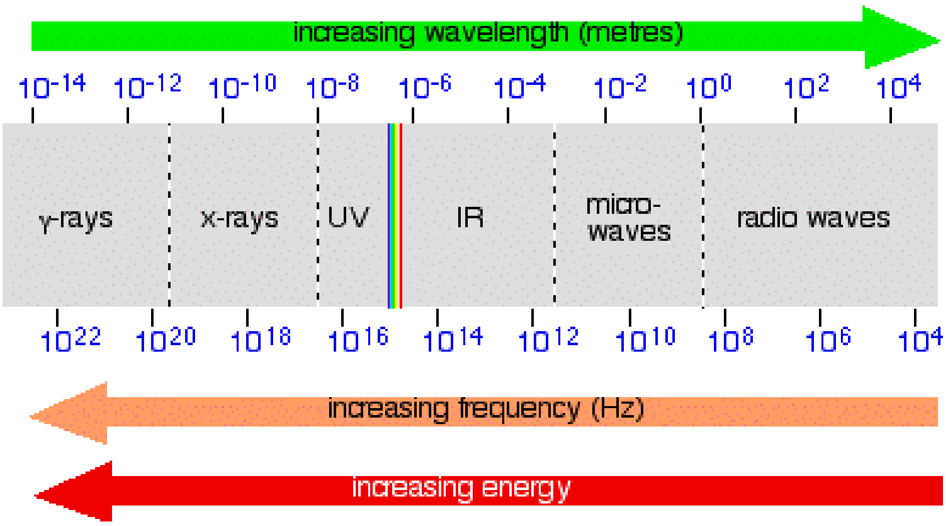

FIGURE 1.2: ELECTROMAGNETIC SPECTRUM SHOWING FREQUENCY, ENERGY AND WAVELENGTH (CLARK, 2006).

1.1.1 SOURCES OF RADIATION

There are many sources of radiation, natural sources and manmade sources. A source of natural radiation is cosmic radiation. The earth and all living things on it are constantly being bombarded by radiation from space. The sun and stars emits EM radiation of all wavelengths, when charged particles release from the sun and stars interact with the earth's magnetic field and atmosphere, a shower of radiation is produced. These radiation is typically beta and gamma radiation. Thus, the earth and everything on it are constantly being bombarded by radiation from space. The dose (energy deposited) from cosmic radiation differs across the world as a result of the elevation differences and the effects caused by the earth's magnetic field(Anon., 2015).

Radioactive material is also found on earth in nature. It's form of natural occurrence can be found in water, soil, animals and plants. The dose (energy deposited) from terrestrial sources differs in various parts of the world. Another source of natural radiation is in human

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themselves. All people have radioactive isotopes in them. Example is carbon-14and potassium-40. Figure 1.3 gives the percentage that each source of radiation contributes to the total radiation dose received by an average individual.

FIGURE 1.3: SOURCE OF RADIATION (NATURAL AND MAN-MADE).

There are different sources of manmade radiation. Some of these sources include television, combustible fuels, tobacco, smoke detectors, sets, nuclear fuel used for production of energy, nuclear weapons, nuclear medicine, dental and medical and X-rays, industrial radiography, X-ray security systems and others. The most significant source so far of man-made radiation exposure that an average person is exposed to is from medical procedures, such as radio diagnosis (diagnostic X-rays), radiation therapy, nuclear medicine and nuclear accident/bomb. All this are man-made source of radiation. The 3-D pie chart below show the source so radiation to an individual living in United States.

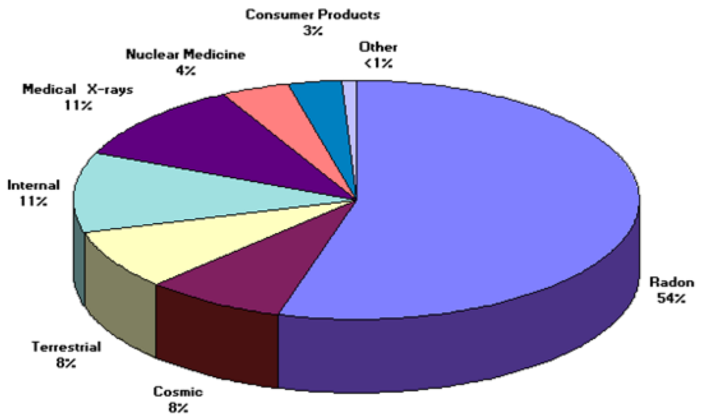

FIGURE 1.4: SOURCES OF NATURAL RADIATION IN THE US.

1.1.2 USES OF RADIATION

Most applications of X-rays are based on their ability to pass through matter. This ability varies with different substances(Anon., 2016). As a result of this property, X-ray has being employed in different industies ranging from art, engineering, medicine to mechanical industies.

ART

X-ray microscopy or microradiography: One of the uses of X-ray is in radiography in the examination and analysis of paintings. In such examinations, studies can reveal details such as the age of a painting and underlying brushstroke techniques which can be used to verify or identify the artist.

ENGINEERING

The penetrating ability of X-rays have been adopted to study and to determine the structure of crystals, concentration of elements and their atomic number. Essentially high-powered versions of the types of X-Ray machines used in medicine, industrial radiography cameras use X-rays. The pattern produced by the diffraction of X-rays through the closely spaced lattice of atoms in a crystal is recorded and then analyzed to reveal the nature of the lattice.

MECHANICAL

Castings and welded joints can be inspected for internal imperfection using x-rays. A complete machine may also be examined from radiograph without having to be dismantled. X-rays are used by manufacturers to detect product of any fault without dismantling. Custom officers also use X-rays to detect prohibited goods without opening packs.

MEDICINE

The clinical applications of X-rays fall into two primary areas:

1. Diagnostic
2. Therapeutic

Uses of X-ray for Diagnostic Purposes

Example of uses of X-rays for diagnostic purpose invovles various medical imaging modalities. These include:

RADIOGRAPHY

Medical radiography is a general term that covers several types of studies that require the visualization of the internal parts of the body using x-ray techniques. Radiography means a technique for generating and recording an x-ray pattern for the purpose of providing a static image(s) after termination of the exposure. A radiograph is an X-ray image obtained by placing a part of the patient in front of an X-ray detector and then illuminating it with a short X-ray pulse from an X-ray machine. Radiographs are useful in the detection of pathology of the skeletal system as well as for detecting some disease processes in soft tissue. Example of radigraph is X-ray. A radiographic image provides a representation of the spatial distribution of tissue components as variations in the optical density of film. The quality of the image formed can be quantified in terms of contrast, sharpness (or resolution), and noise.

COMPUTED TOMOGRAPHY

Computed tomography (CT) is an imaging procedure that uses special x-ray equipment to create detailed pictures, or scans, of areas inside the body taken in different directions. These cross-sectional images can be combined into a three-dimensional image of the inside of the body and used for diagnostic purposes in various medical disciplines.

FLUOROSCOPY

Fluoroscopy is the method that provides real-time X-ray imaging that is especially useful for guiding a variety of diagnostic and interventional procedures. In its simplest form, a fluoroscope consists of an X-ray source and fluorescent screen between which a patient is placed. However, modern fluoroscopes couple the screen to an X-ray image intensifier and CCD video camera allowing the images to be recorded and played on a monitor.

X-RAYS FOR THERAPEUTIC USES.

X-rays can also as treatment. This is known as radiation therapy and is largely used for the management of cancer. X-rays are used in radiation therapy for the treatment of superficial and deeply seated tumors, depending on the energy of the X-ray beam. External beam radiation therapy (EBRT) is a method of delivering X-ray beam to patient's tumor. The X-ray beams are generated outside the patient's body by an X-ray machine or linear accelerator (linac) and are targeted at the tumor sites. These X-rays beams deposit their energy within the tumor, and with a careful treatment planning, spares healthy surrounding tissues. Some example of cancers that are treated with X-rays are: breast cancer, prostate cancer, head and neck cancer treatment etc.

1.1.3 TYPES OF RADIATION

The ability of an entity to be able to disseminate energy is determined by the ability of the material to cause ionization in matter. As a result, radiation can be classified into two broad spectrum base on the ionizing potential of atom. This potential ranges from a few electronvolts (eV) in alkali elements to a value of 24.5eV for noble gas (Helium)(Podgorsak, 2005). These classifications are:

1. Non-ionizing radiation
2. Ionizing radiation.

The figure below (figure 1.5) categorizes the different type of radiation.

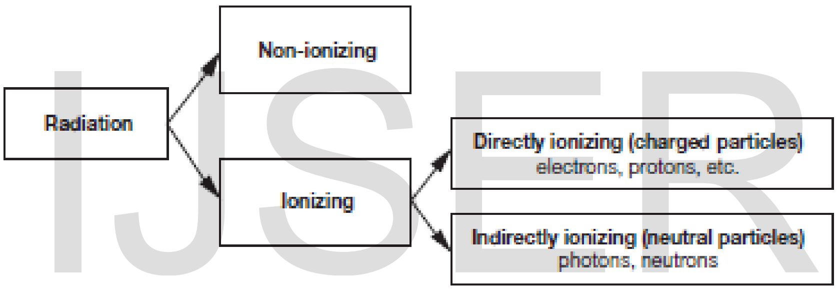

FIGURE 1.5: TYPE OF RADIATION

Non-ionizing Radiation are types of radiation that do not cause ionization when they interact with matter. While ionizing radiation on the other hand are radiation that ionize matter. Ionizing radiation can be sub-divided into two directly ionizing radiation and indirectly ionizing radiation.

Directly ionizing radiation ionization caused by charged particles. Charged particles such as protons, electrons, a particles and heavy ions. Radiation of this type deposits energy in a medium through direct coulomb interactions that occurs between the directly ionizing charged particle and orbital electrons of the atom of the interacting medium. While indirectly ionizing radiation are radiation caused by neutral particles such as photons (X-rays and

γrays), neutrons(Podgorsak, 2005). Indirectly ionizing radiation deposits energy in the medium through a two-step process:

Step 1: Photon(s) interacting with the particle causes the release of charge particle (electrons or positrons) while neutrons release protons or heavier ions.

Step 2: Charge particles that are released deposits energy to the medium through direct Coulomb interactions with the atoms(medium) orbital electrons.

1.2 BIOLOGICAL EFFECTS OF IONIZING RADIATION.

When cells are exposed to ionizing radiation the standard physical effects between radiation and the atoms or molecules of the cells occur first and the possible biological damage to cell functions follows later(Podgorsak, 2005). The biological effects of radiation within the cell result mainly from damage to the DNA, but there are other site that damaged to this part may lead to cell death. When directly ionizing radiation is absorbedin biological material, the damage to the cell may occur in one of two ways:

Direct Action or Indirect Action

1.2.1 DIRECT

Direct action invovles the interaction of the radiation directly with the critical target in the cell. During this interaction, the atoms of the target itself may become ionized or excited through Coulomb interactions. This will leading to the chain of chemocal and physical events that eventually produce the biological damage. It is predominant with radiation that possess high LET i.e high LET.

1.2.2 INDIRECT ACTION.

In this method of radiation interaction, the radiation interacts with other molecules and atoms (mostly water, since about 80% of a cell is composed of water) within the cell to produce free radicals, which are short lived yet extremely reactive free radicals such as water ion (H2O+) and hydroxyl radical (OH•)(Podgorsak, 2005). This free radicals through diffusion in the cell, damage the critical target within the cell. About two thirds of the biological damage by low LET radiations such as X-rays or electrons. Indirect action can be modified by chemical sensitizers or radiationprotectors.

1.3 TYPE OF RADIATION DAMAGE

Radiation damage on bioligical tissues can be classified base on the period of time it takes for the effect to be noticed. As thus if a bioilogical cell either receives lethal, sublethal or potentially lethal damage, the effect on biological tissue can be divided into:

1.3.1 SOMATIC EFFECTS

This effect are harm caused by radiation exposure that individuals suffers during their lifetime, Example of such effect are radiation induced cancers (carcinogenesis), opacification of the eye lens, sterility and life shortening.

1.3.2 GENETIC OR HEREDITARY EFFECTS

This are damage to biological cells which are radiation induced mutations to an individual's genes and DNA that can contribute to the birth of defective descendants.

1.3.3 STOCHASTIC (NON-DETERMINISTIC) EFFECT.

Stochastic effect is one in which the probability of occurrence increases with increasing dose but the severity in affected individuals does not depend on the dose (induction of cancer, radiation carcinogenesis and genetic effects). There is no threshold dose for effects that are truly stochastic, because these effects arise in single cells and it is assumed that there is always some small probability of the event occurring even at very small doses.

1.3.4 DETERMINISTIC (NON-STOCHASTIC) EFFECT.

A deterministic effect (tissue reaction) is one that increases in severity with increasing dose, usually above a threshold dose, in affected individuals (organ dysfunction, fibrosis, lens opacification, blood changes and decrease in sperm count). These are events caused by damage topopulations of cells, hence the presence of a threshold dose.

1.3.5 RADIATION PROTECTION IN DIAGNOSTIC MEDICINE

Radiation protection is almost as old as the invisible rays discovered by Wilhelm Röntgen on 8 November 1895. The damaging effects of X-rays were discovered shortly afterwards. Physicians and patients who had been exposed to radiation for a protracted period often developed erythema(Shannoun, et al., 2008). It is therefore important that adequate protection should be put in place to redduce the harmful effect of ionizing radiation. The rationale behind radiation protection therefore is to control (reduce) as much as possible the risk associated with the use ox-ray and working in x- ray facilitites.

The principles of radiation protection and safety upon which the radiation safety standards are based are those developed by the International Commission on Radiological Protection (ICRP). They are:

JUSTIFICATION OF PRACTICE

No practice or source within a practice should be authorized unless the practice produces sufficient benefit to the exposed individuals or to society to offset the radiation harm that it might cause; that is: unless the practice is justified, taking into account social, economic and other relevant factors(IAEA, 2006). Justification of practice implies that a practice that entails exposure to radiation should only be adopted if it yields sufficient benefit to the exposed individual or to the society that outweighs the radiation harm that it portends.

DOSE LIMITATION

The normal exposure of individuals shall be restricted so that neither the total effective dose nor the total equivalent dose to relevant organs or tissues, caused by the possible combination of exposures from authorized practices, exceeds any relevant dose limit specified(IAEA, 2006). Individual doses due to the combination of exposures from all relevant practices should not exceed specified dose limits for occupational and public exposures. The rationale for setting the dose limits are to keep doses below the threshold level for deterministic effects and also keep the risk of stochastic effects at an acceptable level. Dose limits are not applicable to medical exposures from authorized practices.

TABLE 1.1: DOSE LIMITATION

	Occupational exposure	Apprentices of 16 to 18 years of age, who are in training for employment and students of 16 to 18 years	Public exposure
Effective dose	20mSv/a average over five consecutive years; 50 mSv in a single year	6 mSv in a year	1 mSv in a year in special circumstances, an effective dose of up to 5 mSv in a single year provided that the average dose over five consecutive years does not exceed 1 mSv/a
Equivalent dose to the lens of the eye	150 mSv in a year	50 mSv in a year	15mSv in a year.
Equivalent dose to the extremities (hands and feet) or the skin	500 mSv in a year	150 mSv in a year	Equivalent dose to the skin of 50 mSv in a year.

The equivalent dose limits for the skin apply to the average dose over 1 cm^2 of the most highly irradiated area of the skin. Skin dose also contributes to the effective dose, this contribution being the average dose to the entire skin multiplied by the tissue weighing factor for the skin.

OPTIMIZATION OF PROTECTION AND SAFETY.

In relation to exposures from any particular source within a practice, except for therapeutic medical exposures, protection and safety shall be optimized in order that the magnitude of individual doses, the number of people exposed and the likelihood of incurring exposures all be kept as low as reasonably achievable, economic and social factors being taken into account. In diagnostic medical exposure, it implies keeping the exposure of patients to the minimum necessary to achieve the required diagnostic objective, taking into account norms of acceptable image quality established by appropriate professional bodies and relevant guidance levels for medical exposure, while for the medical staff it onvolves keep their overall dose below standard asstipulated in IAEA report series (20mSv average over 5 years)(IAEA, 2006). Periodic quality control tests of the X-ray equipment as well as the equipment's appropriate application also need to be fully implemented so as to ensure that optimization is achieved.

TABLE 1. 2: PRINCIPLES OF RADIATION PROTECTION AS APPLIED TO OCCUPATIONAL AND PUBLIC EXPOSURE COMPARED WITH MEDICAL EXPOSURE.

Principle of Protection	
Application in General	Specific application to medical exposure
Justification of practices: a practice that entails exposure to radiation should only be adopted if it yields sufficient benefit to the exposed individuals or to society to outweigh the radiation detriment.	Justification of practices: By weighting the diagnostic, it means, the benefit they produce against the radiation detriment they might cause taking into account the benefit and the risks of available alternative techniques that do not involve medical radiation exposure.
Dose limitation to individuals (for occupational and public exposure).	Dose limitation is not applicable to medical exposure.
Optimization of protection and safety: Providing the best available protection and safety measures under the prevailing circumstances so that the magnitude and likelihood of exposures and the numbers of individuals exposed are as low as reasonably achievable.	Optimization of protection and safety: In diagnostic and medical exposure, keeping the exposure of patients to the minimum necessary to achieve the required diagnostic objective, taking into account norms of acceptable image quality established by appropriate professional bodies and relevant guidance levels for medical exposure.

1.4 X-RAY - HISTORY

X-ray was discovered in the year 1895 by Roentgen (Murat, et al., 2010). The name X-Ray" is generally given to a photon if it is emitted by a free or bound electron and has an energy in the range from about 0.1 keV to about 100 keV. Photons emitted directly by nuclei are generally called gamma rays even if their energy is in the conventional X-ray range (Physics, 2014). Today, X-Rays are of critical importance in the fields of medical imaging; in material science (determining both composition and structure); in transportation (security); in microscopes with sub-optical resolution; in astrophysics and cosmology. (Physics, 2014). The classic way to generate X-rays is to bombard a metal target with a beam of energetic electrons. A typical commercial x-ray generator, used by a dentist or an airport baggage inspection system, employs a vacuum tube in which electrons emitted from a lament heated cathode are accelerated by an electric field supported by a high-voltage (~ 50 kV) power supply and strike a metal anode target thus generating X-Ray.

1.4.1 THE X-RAY TUBE

A typical x-ray tube is made up of a highly evacuated vacuum made of glass with two electrodes at opposite end. One of the electrode is a negatively charged electrode called the Cathode and at -the other end is a positively charged electrode called Anode. Both electrodes are hermetically sealed in the tube. The Cathode is typically made of tungsten filament. This is because, when tungsten filament is heated, emits electrons. This phenomenon is known as Thermionic emission. The anode is usually made of a thick copper rod at the end with a small piece of tungsten target placed on it. On applying high voltage between the anode and the cathode, the electrons emitted from heating the filament are accelerated toward the anode. It achieves high velocities before striking the target. The x-rays are produced by the sudden deflection or acceleration of the electron caused by the attractive force of the tungsten nucleus. The x-ray beam emerges through a thin glass window in the tube envelope. Some tubes use thin beryllium windows to reduce inherent filtration of the x-ray beam. Figure 1.6 shows the systematic diagram

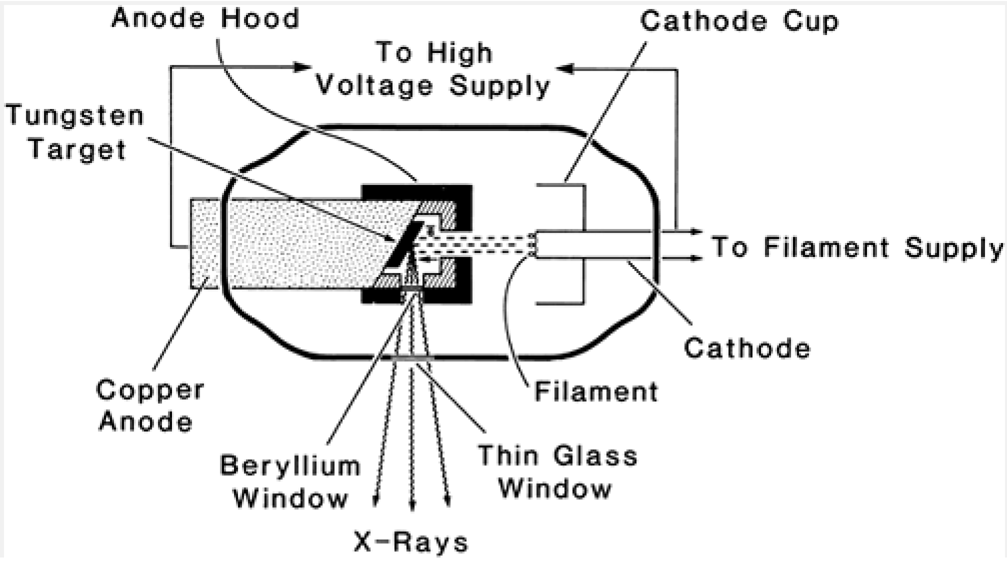

FIGURE 1.6: SCHEMATIC DIAGRAM OF A THERAPY X-RAY TUBE WITH HOODED ANODE.

X-radiation (X-Ray) is created by taking energy from electrons and converting it into photons with appropriate energies. The entire energy conversion process takes place within the x-ray tube. The quality (spectrum) and quantity (exposure)of the X-Ray produced can be controlled by adjusting the electrical quantities (KV, MA) of the machine and the exposure time, S, applied to the tube (Sprawls, 2015).

1.4.1.1 FUNCTION OF AN X-RAY TUBE.

An X-Ray tube is an energy converter. It converts energy by receiving electrical energy and converting it into two other forms: x-radiation(X-Ray) and heat. The heat produced during X-Ray production is an undesirable byproduct. As a result, X-ray tubes are constructed and designed to maximize x-ray production while dissipating heat as quick as possible. The X-ray tube consist of two principle elements:

- A Cathode and

- An Anode.

As the electrical current flows through the tube from cathode to anode, the electrons undergo an energy loss, which results in the generation of X-Rays. The cathode is the negative terminal of the X-ray tube. It is tungsten filament and when current flows through it, the filament gets heated and start emitting its surface electrons by the process of thermionic emission (Sprawls, 2015). The basic function of the cathode is to expel the electrons from the electrical circuit and focus them into a well-defined beam aimed at the anode. The cathode assembly in a modern x-ray tube (Coolidge tube) consists of a wire filament, a circuit to provide filament current, and a negatively charged focusing cup. The function of the cathode cup is to direct the electrons toward the anode so that they strike the target in a well-defined area (the focal spot). Since size of focal spot depends on filament size, the diagnostic tubes usually have two separate filaments to provide focus, namely one small and one large focal spot. The material of the filament is tungsten, which is chosen because of its high melting point (Khan, 2003). The Anode is the positive terminal of the tube. It is the component in which the X-ray is produced. It is a relatively large piece of metal that connects to the positive side of the electrical circuit (Sprawls, 2015). The anode has two primary functions:

1. To convert electronic energy into X-ray, and
2. To dissipate the heat created in the process.

The material for the anode is selected to enhance these functions. The ideal situation would be if most of the electrons created x-ray photons rather than heat. The fraction of the total electronic energy that is converted into X-ray depends on two factors: the atomic number (Z) of the anode material and the energy of the electrons. The efficiency of x-ray production depends on the atomic number (Khan, 2003). Most x-ray tubes use tungsten. The choice of tungsten as the target material in conventional x-ray tubes is based on the criteria that the target must have high atomic number and high melting point. Tungsten which has an atomic number of 74 is a good target as the anode material. In addition to a high atomic number, tungsten has several other characteristics that make it suited for this purpose. Tungsten is almost unique in its ability to maintain its strength at high temperatures, and it has a high melting point (3,370°C) and a relatively low rate of evaporation (Khan, 2003and Sprawls, 2015).

Another important requirement for the anode design is efficient removal of heat from the target. To achieve this, some tubes conducts heat through a thick copper anode to the outside of the tube where it is cooled by water, oil, or air. Another design is the use of rotating anodes to reduce the temperature of the target at any one spot. Rotating anodes have been used in diagnostic x-rays. The heat generated in the rotating anode is radiated to the oil reservoir surrounding the tube. It should be noted that the function of the oil bath surrounding an x-ray tube serves two functions:

- To insulate the tube housing from high voltage applied to the tube and
- Absorb heat from the anode.

Some stationary anodes designs are covered by a copper and tungsten shield. This is done to prevent stray electrons from striking other non-target components of the tube or striking the walls. The anode and cathode are contained in an airtight enclosure, or envelope. The envelope and its contents are often referred to as the tube insert, which is the part of the tube that has a limited lifetime and can be replaced within the housing. The majority of x-ray tubes have glass envelopes, although tubes for some applications have metal and ceramic envelopes. The primary functions of the envelope are to provide support and electrical insulation for the anode and cathode assemblies and to maintain a vacuum in the tube. A vacuum in the tube is needed because the presence of gases in the x-ray tube would allow electricity to flow through the tube freely, rather than only in the electron beam. This would interfere with x-ray production and possibly damage the circuit. The x-ray tube housing provides several functions in addition to enclosing and supporting the other components. It functions as a shield and absorbs radiation, except for the radiation that passes through the window as the useful x-ray beam. Its relatively large exterior surface dissipates most of the heat created within the tube. The space between the housing and insert is filled with oil, which provides electrical insulation and transfers heat from the insert to the housing surface (Sprawls, 2015).

The energy used by the x-ray tube to produce x-radiation is supplied by an electrical circuit. The circuit connects the tube to the source of electrical energy, that in the x-ray room is often referred to as the generator. The generator receives the electrical energy from the electrical power system and converts it into the appropriate form direct current (DC) to apply to the x-ray tube. The generator also provides the ability to adjust certain electrical quantities that control the x-ray production process. The three principle electrical quantities that can be adjusted are the:

- KV (the voltage or electrical potential applied to the tube). For each kV of voltage, each electron has 1 keV of energy.
- MA (the electrical current that flows through the tube)
- S (duration of the exposure or exposure time, generally a fraction of a second)

The circuit is actually a circulatory system for electrons. They pickup energy as they pass through the generator and transfer their energy to the x-ray tube anode as shown in figure 1.7 below.

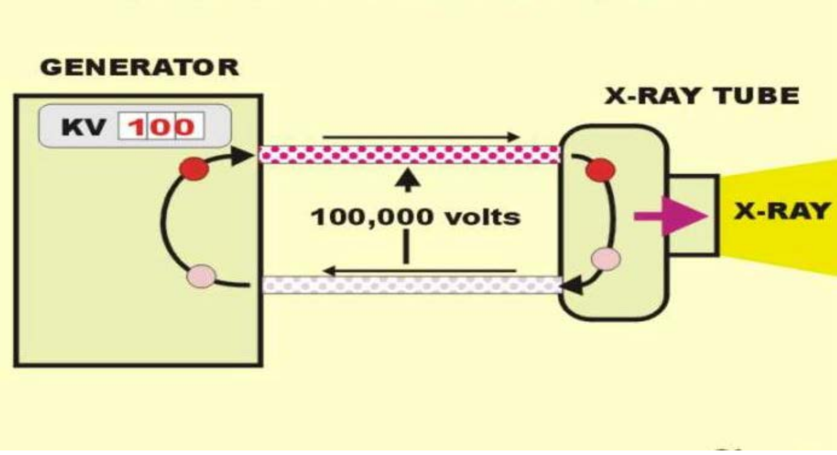

FIGURE 1.7: AN ELECTRON CIRCULATORY SYSTEM OF AN X-RAY SYSTEM.

1.4.3 INTERACTION OF X-RAYS WITH MATTER.

X-ray interacts with matters when it transverse through it with the outcome that energy is transferred to the medium. The step that are invovled in the interaction involves the ejection of electrons from the atoms of the matter as a result of energy being transferred to it. Thus producing ionization and excitation of the atoms along their paths. In an event whereby the absorbing matter (medium) consists of body tissues, it may deposit sufficient energy within the cells, which will cause ionization of the atoms in the cell, with an end result of destroying their reproductive capacity, death or damage. In other instance, most of the absorbed energy will produce no biological effect as it is converted into heat (Khan, 2003). The interaction depends on the energy of the photon and the atomic number Z of the attenuator. For biological tissue and energy within the diagnostic x-ray range not exceeding Kilo-voltage range (below Megavoltage), basic interaction that take place are: coherent scattering, photoelectric effect, Compton effect,

1.4.3.1 COHERENT SCATTERING:

The coherent scatteringis also known as Rayleigh scattering or classical scattering. This interaction occurs electromagnetic wave(x-ray) passing near the electron within the atom of the biological tissue and setting it into oscillation. This oscillating electron will reradiates the energy at the same frequency as the incident x-ray. These reradiated energy (scattered x-rays) possess the same wavelength as the incident beam as shown in figure 1.9 below. . Therefore, there is no loss of energy or ionization in the tissue. The only effect is the scattering of the photon at small angles. This interaction is only of importance for only of academic interest in radiation therapy (Khan, 2003).

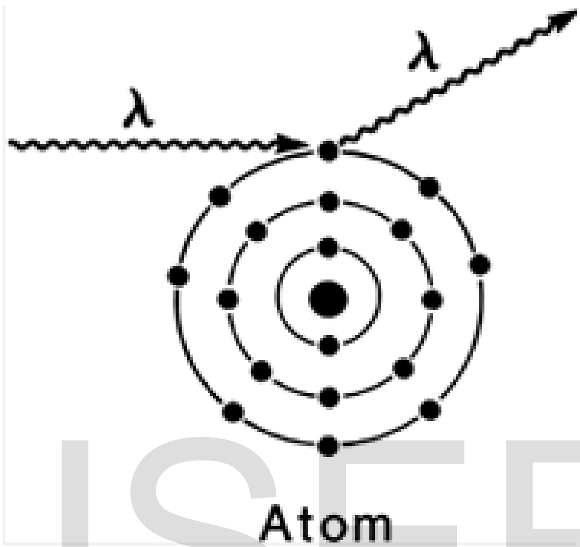

FIGURE 1.8: DIAGRAM ILLUSTRATING THE PROCESS OF COHERENT SCATTERING.

1.4.3.2 PHOTOELECTRIC EFFECT

In this form of interaction the incident photon(x-ray) interacts with an atom, transfering energy to it, thus ejecting one of the orbital electrons from the atom. In this interaction, the entire energy of the photon is first absorbed by the atom after which it is transferred to the atomic electron. Kinetic energy of the ejected electron which is called the photoelectron is equal to binding energy of the electron subtracted from the energy of the incident photon. As a result of the ejected electron, a vacancy is created in the shell leaving the atom in an excited state. This vacancy can be filled by an electron from an outer orbital shell with the emission of characteristic x-rays. Figure 1.10 shows the emmission of characteristics X-Ray and Auger electron that are released in Photoelectric effect.There is also the possibility of emission of Auger electrons but which possiblity is low due to the fact that the K shell binding energy of soft tissues is only about 0.5 keV. Such energy of the characteristic photons can be considered to be locally absorbed in biologic absorbers, and are very low. Interactions of this type can take place with electrons in the K, L, M, or N shells.

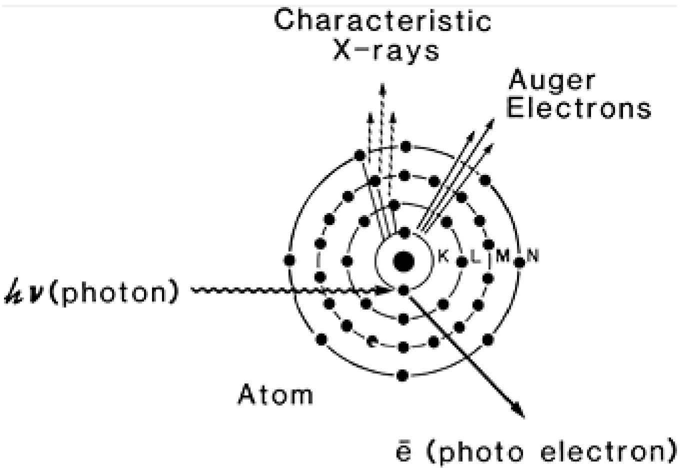

FIGURE 1.9: ILLUSTRATION OF THE PHOTOELECTRIC EFFECT.

1.4.3.3 COMPTON EFFECT.

The Compton effect (incoherent scattering) represents a photon(x-ray) interaction with an essentially 'free and stationary' orbital electron. The energy of the incident photon *hν* is greater than the orbital electron binding energy. Part of the photon's energy is lost to the recoil (Compton) electron and is scattered as photon *hν*' through a scattering angle θ. The term free here means that the binding energy of the electron is much less than the energy of the bombarding photon(Podgorsak, 2005). The figure below show the incident photon before interaction and the scattered photon after interaction scattered at an angle of θ

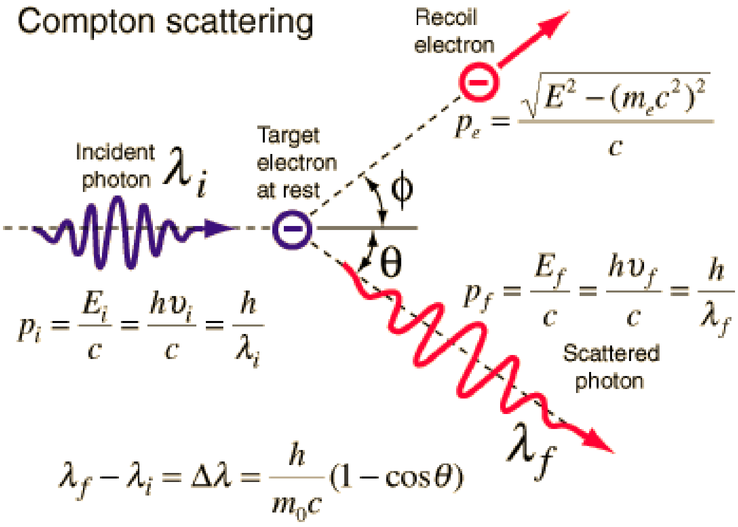

FIGURE 1. 10: SCHEMATIC DIAGRAM OF COMPTON SCATTERING.

Using the Planck relationship and the relativistic energy expression, conservation of energy takes the form

$$h\upsilon_i + m_e c^2 = h\upsilon_f + \sqrt{p_e^2 c^2 + m_e^2 c^4} \qquad \textit{Conservation of energy}$$

Conservation of momentum requires

$$\vec{p}_i = \vec{p}_f + \vec{p}_e \qquad \textit{Conservation of momentum}$$

where p=E/c is used for the photon momentum. Squaring this equation using the scalar product gives

$$p_e^2 = (\vec{p}_i - \vec{p}_f)\cdot(\vec{p}_i - \vec{p}_f) = p_i^2 + p_f^2 - 2p_i p_f \cos\theta$$

Again using the Planck relationship and the relativistic energy expression:

$$\textit{Multiply by } c^2 \quad \textit{Substitute } pc=h\upsilon \qquad (p_e c)^2 = (h\upsilon_i)^2 + (h\upsilon_f)^2 - 2h^2\upsilon_i\upsilon_f\cos\theta$$

The energy conservation expression above can be squared to give

$$(p_e c)^2 = (h\upsilon_i)^2 + (h\upsilon_f)^2 - 2h^2\upsilon_i\upsilon_f + 2m_e c^2(h\upsilon_i - h\upsilon_f)$$

These two forms can be equated to give

$$-2h^2\upsilon_i\upsilon_f\cos\theta = -2h^2\upsilon_i\upsilon_f + 2m_e c^2(h\upsilon_i - h\upsilon_f)$$

which can be rearranged to

$$\frac{1}{h\upsilon_f} - \frac{1}{h\upsilon_i} = \frac{1}{m_e c^2}(1 - \cos\theta)$$

and finally to the standard Compton formula:

$$\lambda_f - \lambda_i = \Delta\lambda = \frac{h}{m_e c}(1 - \cos\theta)$$

1.4 LAYOUT OF AN X-RAY CENTER

There are different guidelines to constructing an X-ray centers. The basic principle behind all this guidliness is to provide adequate protectin, minimize scattered radiation and exposure to the gneral public.

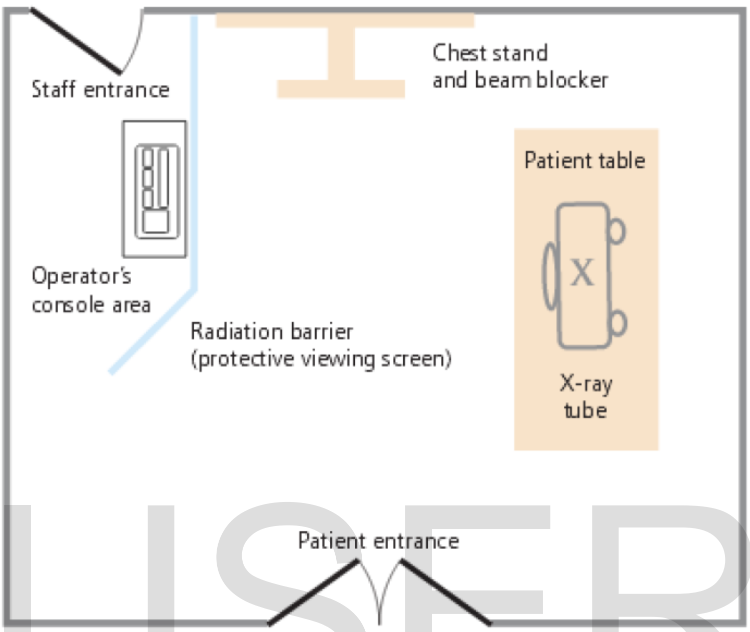

FIGURE 1. 11: MODEL LAYOUT - X-RAY INSTALLATION.

A good layout for a radiographic room based on the two-corridor design is shown in Figure 1.8. The room is designed for general X‑ray radiography with the facility to use either the patient table or the chest stand/vertical. An area of 33 m^2 has been suggested for general X‑ray systems (Ireland, 2009). Table 1.3 below gives the shielding properties of common building materials. This information is needed by new facilities in setting up the facility to be used for the diagnostic center that will house an X-ray machine. Existing facilities can also use this figure to better access the present structure and make adequate protection as is required.

TABLE 1.3: SHIELDING PROPERTIES OF COMMON BUILDING MATERIALS.

Material	Thickness (mm)	Pb equivalence (mm)	Transmission (%)
Concrete (solid)	100	1.5	0.20
Concrete (aerated)	150	0.05	3.0
Brick (solid)	110	1.5	0.02
Brick (cored)	90	0.41	5.3
Lead sheet (15 kg m-2)	1.3	1.3	0.30
Lead sheet (10 kg m-2)	0.88	0.88	1.1
Plasterboard (2 sheets of 13 mm gyprock)	26	0.15	20
Plasterboard (2 sheets of R40 barium board)	32	1.1	0.50

Data required for radiation shielding design of an X-ray room include consideration of:

- Type of X-ray equipment
- Usage (workload)
- Positioning
- Whether multiple tubes/receptors are being used
- Primary beam access (vs. scatter only)
- Operator location
- Occupancy of Surrounding areas

The General recommendations for the design of a radiology room as specified by Radiological Protection Institute of Ireland in the report of june 2009 is given as;

- The equipment should be positioned so that the primary radiation beam is not directed at the operator's console, windows or doors. Particular attention must be paid to the shielding of areas where the primary beam will be directed, for example the wall behind the vertical cassette holder.

- The floor of the X-ray room must be shielded for the primary radiation beam if there is occupancy in the room below and the beam is not otherwise attenuated.
- The operator’s console area should be located so that: it is adjacent to the staff entrance door; the operator has a clear panoramic view of the patient and the access doors to the room; and radiation is scattered at least twice before entering the protective area.
- The protective screen should be at least 2 m in height and of sufficient width to allow at least two people stand behind the screen during an exposure.
- Personal protective equipment (lead aprons, thyroid shields, gonad shields) should be available and reinforced hangers should be used for the storage of lead aprons.
- Multilingual pregnancy signs should be displayed in the waiting room and patient cubicles, advising female patients to declare their known or suspected pregnancy prior to undergoing a radiological examination.
- Radiation warning lights should be positioned at all access doors to the room and preferably at eye level. The light should illuminate during the preparation period (if applicable) and continue for the duration of the exposure.
- Radiation warning lights may not be required if the operator can prevent inadvertent access to the room during exposures (for example if there is only one appropriately positioned door).
- Appropriately worded radiation warning signs must be posted on access doors to the room.

- An X‑ray room should not be used for more than one radiological procedure at a time, unless specifically designed for this purpose.
- The X‑ray room should not be a throughway to another room.
- A pragmatic approach to radiation shielding should be considered; it may be more prudent and possibly more cost effective to specify a consistent level of shielding in all boundaries in the room rather than specifying different levels of shielding in each boundary.

1.4.1 SOURCES OF EXPOSURE THAT MUST BE SHIELDED IN X-ray CENTERS

The sources of exposure that must be shielded in a diagnostic x-ray room are primary radiation, scattered radiation and leakage radiation. Primary radiation can be defined as the useful beam that passes through the open area defined by the collimator of the x-ray tube. The amount of primary radiation depends on the output of the x-ray tube (determined by the kVp, mAs and distance) per examination, the number of examinations performed during an average week and the fraction of time the x-ray beam is directed toward any particular location.Scatter and leakage radiation are together called secondary or stray radiation.Scattered radiation arises from the interaction of the primary beam with the patient, causing a portion of the primary x-rays to be redirected. For radiation protection purposes scatter is considered as a separate radiation source with essentially the same photon energy spectrum (penetrability) as the primary beam while Leakage is the radiation that emanates from the x-ray tube housing other than the useful beam. Because leakage radiation passes through the shielding of the housing, its effective energy is very high (only the highest energy photons are transmitted). For the purpose of this research radiation beam and leakage radiation are used interchangeably to mean radiation other than the primary that is not being stopped by the shielding materials and contributes to the cumulative dose received by the radiographer or health worker with an X-ray facility.

1.5 QUALITY ASSURANCE

The International Organization for Standardization (ISO) defines QA "Quality Assurance" as all those planned and systematic actions necessary to provide adequate confidence that a product or service will satisfy the given requirements for quality. A quality assurance program in diagnostic radiology as defined by the WHO is an organized effort by the staff operating a facility to ensure that the diagnostic images produced are of sufficiently high quality so that they consistently provide adequate diagnostic information at the lowest possible cost and with the least possible exposure of the patient to radiation. Quality control test that are carried out for a radiographic X-ray unit with screen film are: linearity and reproducibility of mA/mAs, reproducibility and accuracy of timer, accuracy of source-to-film distance indicators, light/X-ray field congruence, half-value layer, focal spot size consistency, representative entrance skin air kerma , X-ray tube housing leakage and reproducibility and accuracy of peak kilovoltage (kVp). Radaition tolerance for patient, medical staff and the general public as stipulated by BSS.

1.5.1 RADIATION MONITORING DETECTORS

The detrimental health effect of radiation is enormous if exposure to radiation is not monitored or known. Depending on the dose received, there could either be an immediate effect (deterministic effect) or a long term effect which might manifest in terms of carcinogenic effect or hereditary effect(Khan, 2003). As a result, it is important for radiation monitoring especially at places where radiation is being used. Radiation exposure to humans can be broadly classified as internal and external exposure. X-ray is a source of external exposures.

Monitoring external exposure within an X-ray facility refers to measuring:

- Radiation levels in and around work areas;

- Radiation levels around radiotherapy equipment (X-ray machine);
- Knowing the equivalent doses received by individuals working with radiation.

In order to carry out the steps above, there is need to carry out radiation monitoring. Radiation monitoring is carried out:

- To assess individual exposures;
- To assess workplace conditions for conducive environment;
- To ensure acceptably safe and satisfactory radiological conditions in the workplace;
- To keep records of monitoring, over a long period of time, for the purposes of regulation or good practice.

In order to carry out this monitoring, specialized instruments are need. This instruments are called "Radiation monitoring instruments". They are used both for area monitoring and for individual monitoring. Instruments which are used for area monitoring are Survey meters while instruments which are used for recording the equivalent doses that is received by individuals working within radiation environment are referred to as individual dosimeter (personal dosimeters). All instruments must be calibrated in terms of the appropriate quantities used in radiation protection.

1.5.2 AREA SURVEY METERS

Radiation instruments which are used as survey meters are either solid state detector or gas filled detectors. A gas filled detector is usually cylindrical in shape, having an outer wall and a central electrode which is well insulated from each other. The wall material is usually of tissue equivalent material for ionization chamber detectors and while the material is of brass or copper for other types of detector. Depending upon the design of the gas filled detector and the voltage applied between the two electrodes, the detector can operate in one of three regions, the ionization region B, proportional region C or Geiger–Müller (GM) region E).

FIGURE 2.1: AREA SURVEY METERS

1.5.3 GEIGER–MÜLLER COUNTERS

The discharge spreads in the GM region throughout the volume of the detector and the pulse height becomes independent of the primary ionization or the energy of the interacting particles. In a GM counter detector, the gas multiplication spreads along the entire length of the anode. Gas filled detectors cannot be operated at voltages beyond the GM region because they continuously discharge. Owing to the large charge amplification (nine to ten orders of magnitude), GM survey meters are widely used at very low radiation levels (e.g. in areas of public occupancy around radiotherapy treatment rooms). They are particularly applicable for leak testing and detection of radioactive contamination. GM counters exhibit strong energy dependence at low photon energiesand are not suitable for use in pulsed radiation fields. They are considered indicators of radiation, whereas ionization chambers are used for more precise measurements.

The commonly available features of area survey meters are:

- A ‘low battery’ visual indication;
- Automatic zeroing, automatic ranging and automatic back-illumination facilities;
- A variable response time and memory to store the data;

- The option of both ‘rate’ and ‘integrate’ modes of operation;
- An analog or digital display, marked in conventional (exposure/air kerma) or ‘ambient dose equivalent’ or ‘personal dose equivalent’ units;
- An audio indication of radiation levels (through the ‘chirp’ rate);
- A resettable/non-resettable alarm facility with adjustable alarm levels;
- A visual indication of radiation with flashing LEDs;
- Remote operation and display of readings.

1.6 STATEMENT OF PROBLEM

In the use of radiation, the basic principles of radiological protection to the staff and likewise the general public as recommended by the International Commission of Radiological Protection (ICRP) are Limitation of dose and optimization of protection, including. Limitation of dose is one of the key principle to in other to reduce the probability of stochastic effect/genetic effect with particular reference to the health workers (radiographers). In the design of some X-ray centers, the guidelines as stipulated by international bodies such as IAEA, ICTP are not strictly followed. In most centers, the design of a appropriate protective panel around the X-ray room is deficient in terms of the shielding calculations and this affects the dose limit to the staff averaged at 20 mSv/annual over five consecutive years and1 mSv per year for the general public. However this is not the case as most centers do not have a purposely built X-ray room(facility). As a result, there is bond to be scatteres radiation to the members of health staff in such facilities and even to the generral public.

Most radiographer are ingnorant of the fact that scattered radiation exist in Nigeria and especially in lagos, which is the economic and industrial nerve centre of the country. It has a number of private hospitals and diagnostic centres of varying standards. Some are located within hospital and some in rented offices/ struture. Most of these struture are not purpose built to house a radiation emiiting equipment (X-ray) and therefore poor shielding. Therefore there is high probability of radiation scatter in some of the centers in the console to some of the radiation workers. As a result of this, there is need for periodic check of radiation scatter by conducting routine measurement in x-ray center to ensure that there is proper shielding

1.7 AIM AND OBJECTIVE

The aim of this study are:

- To determine the radiation scatter from within selected x-ray centers in lagos state.

SPECIFIC OBJECTIVE

- To determine x-ray scatter during patient examination.
- To compare the measured data to standard (International Radiation monitoring standards).

1.8 SIGNIFICANCE OF THE STUDY

Most radiographers are ignorant of the fact that scatter radiation exists and those that know about it have wrong attitude towards it. The so-call proprietor do not care about this but are concerned about making more money.In Nigeria, X-ray is the most frequently used ionizing radiation in medicine despite advances in magnetic resonance imaging and ultrasound techniques (Oluwafisoye et al., 2010). As the number of X-ray examinations performed increased, more attention has been focused on keeping the doses received to minimum due to the emergence of data on the long term risks of cancer arising from ionizing radiation exposure (Martin et al, 2006). In Nigeria today, new cases of cancer are recorded more frequently especially going by the register of cancer patient in LUTH. The significance of this study is of particular important to the radiograhers operating the X-ray machine. This is because a lot of X-ray centers are designed below specification and thus providing scatterradiation to the radiographers. Likewise, shielding appartus are not provided, not properly used or inadequate to minimize scattered radiation from getting to the X-ray machine operators. This study aims to confirm radiographers are not unduely exposed to scatter radiation and that the average dose received when calculated or checked is not above their annual limit as stipulated by international standards.

1.9 OPERATIONAL DEFINITION OF TERMS

ALARA: As Low as Reasonably Achievable

BSS Basic Safety Standard.

IAEA International Atomic Energy Agency.

ICRPInternational Commission on Radiological Protection

ICTPInternational Centre for Theoretical Physics (Trieste, Italy)

kV – Kilovolt. It is the voltage applied across the X-ray tube.

kVp – Kilovolt peak. It is the maximum voltage applied across the X-ray tube and it governs the maximum energy of the X-rays produced.

kVp Accuracy – percentage deviation of the measured kVp from the selected kVp.

mAs – Milliamperes seconds. It is the product of the current that flows through the X-ray tube and the exposure time.

Milliamperes (mA) is the current that flows through the X-ray tube.

Optimization – This implies keeping exposures of patients to the minimum necessary to achieve the required diagnostic objective.

Patient dose is used as a general term for radiation load to the patient. It is the amount of energy deposited by an ionizing radiation in the patient during exposure. It can be quantified as skin dose, mean absorbed dose, or effective dose.

Quality control (QC) Quality Assurance" is all those planned and systematic actions necessary to provide adequate confidence that a product or service will satisfy the given requirements for quality.

Quality control (QC) is a periodic evaluation designed to ensure continued reliable performance an equipment.

RPO: Radiation Protection Officer

Skin dose measures the absorbed dose in Gray **(Gy)** to the skin of the patient including all scatter effects.

TLD: Thermoluminescent Detector

IBMInternational Business Machine

SPSSStatistical Package for the Social Science

Sievert (Sv)A unit of equivalent absorbed dose equal to 100 rem.

Absorbed dose Thisis the concentration of energy deposited in tissue as a result of an exposure to ionizing radiation.

Exposure The exposure is the absolute value of the total charge of the ions of one sign produced in air when all the electrons liberated by photons per unit mass of air are completely stopped in air.

CHAPTER TWO

2.0 LITERATURE REVIEW

The normal exposure of individuals shall be restricted so that neither the total effective dose nor the total equivalent dose to relevant organs or tissues, caused by the possible combination of exposures from authorized practices, exceeds any relevant dose limit specified(IAEA, 2006). This implies that the total dose collected or at which radiation health work is exposed to should not exceed the limit specified which is 20mSv average over five (5) years. When some of this facilities are visited, it is mostly observed that proper radiation protection program, Quality assurance and quality control program were not in place and the application of dose limitation as adviced by IAEA (IAEA, 2006) is not being followed. As a result, there is an increase in the record of leakage exposure record by researchers(Oluwafisoye, et al.,2009, Nzotta and Chiaghanam, 2010 Eze et al., 2011, Ekpo et al., 2013, Briggs-Kamara, et al., and others) that visit such facilities on research purpose. This signified the need to carry out this research in lagos state. Below are some of the review on the initial work done by researchers on radiation protection within and around X-ray facilities in Nigeria.

Mcvey, et al., 2004, worked on calculating the amount of scatter inside and outside the planned locations of the protective paneling barriers as part of the radiation protection design process for an X-ray room. In doing this, scatter and leakage radiation was taking into consideration. In the study, the use of a Monte Carlo code which was developed to calculate the percentage scatter in order to consolidate the current data (single phase generators) and provide for new data (modern X-ray units with medium frequency generators) as required. The methodology employed was in using a Monte Carlo code XYZSCAT, which was developed based on the EGS4 code system for this purpose. The result showed that the variation of scatter at the X-ray roomas either the heigh of the protective screen is increased from an height of 200cm to an height of where it touches the suspended ceiling which is at an height of 288cm. The scatter at this point is 74% at eye heigh and 61% lower at gonad height than the scatter values for a screen height of 200 cm. The eye and gonad level is used because all radio sensitive organs in the body lies between this level. Also when the heigh of the X-ray room is varied keeping the height of the protective screen constant, there is also a considerable decrease in the scatter at the eye and gonad level when the suspended ceiling heigh is the same as the protective screen (touching the top of the protective screen). Monte Carlo calculations of dose at the X-ray room entrance show that if a door was placed in this position then it would not need to be lead lined.

Oluwafisoye, et al.,2009, carried out an environmental survey and quality control test of X-ray facilities of a large Nigerian hospital. The methodology used in this study was to carry out environmental monitoring using calibrated radiation monitor device model minirad 1000+ and X-ray test device model 4000 m+ which is factory calibrated and non-invasive, was used for the quality control tests. Along-side the monitoring, questionnaires were also shared among the most senior personnel of the hospital. This study was carried out at the X-ray unit of the Jon-Ken hospital, Lagos (private hospital). The result obtained showed dose rate greater than the background exposure in and around the X-ray room, patient waiting room and the reception. This factors possess a higher risk to the patient and the public. This is because stochastic effect of radiation increases with the increase in dose. The test for kVp consistency, kVp accuracy and timer accuracy that were carried out on the X-ray machine were outside the acceptable limit. Also, linearity of mAs and optical radiation field congruency test conducted on the machine were found not acceptable. The inconsistent nature of the kVp would have adverse effect on the image contrast and this will cause the radiographer to take repeated exposure of the patient. Though the study did not quantify the radiation level to the staff it was able to established the fact of the non-compliance to dose limitation and lack of proper radiation protection program (QA/QC) within the facility.

Nzotta and Chiaghanam, 2010, evaluated the occupational Radiation Dose to X-ray workers in Radiological units in South Eastern Nigeria in three hospitals which are university of Benin teaching Hospital, Federal Medical Centre Umuahia and Federal Medical Centre Owerri. The total number of staff monitored in each hospital being; Thirty-nine (39), Eleven (11) and Nine (9) respectively were measured every quarter, from 1st January 2005 to 30th December 2007 for the various category of staff working in the centers. The study took note of the type of X-ray machine that are of used most of which are refurbished machine that have output that are now either higher or below the standards of European community reference value. Thus, there is a discrepancy between the actual output and set factors. Also within Nigeria, only about 25% of radiation worker are being monitored. This is based on 1999 data(Nzotta & Chiaghanam, 2010). One of the major cause of radiation exposure to staff is the scatter in the X-rayroom, irregular quality control. The monitoring of the staffs within this center totaling 58 was done using TLD's badges. The results therefore, suggested the approximate radiation exposure to the personnel (radiation staff) to be below the recommended ½ of the permissible dose of 20mSv per annum as set by international commission on radiological protection (ICRP). The Research concluded that low awareness of the radiation regulations among radiology staff in Nigeria is greatly responsible for the low corporation received from the staff. It was also observed that higher the departmental work load, the higher the annual dose value for all category of staff.

Eze et al., 2011 assessed the state of occupational radiation protection and monitoring in public and private X-ray facilities in Edo state, Nigeria. Taking note that radiation monitoring of staff in X-ray facilities ensures adequate protection and improves awareness of radiation protection of the staff and the public from medical exposure to radiation. The research was conducted on eighteen (18) functional X-ray facilities within Edo state Nigeria alongside with questionnaires. In this study, it was study revealed that there is low radiation monitoring by hospitals in Edo State as only two (20%) of the 10 government hospitals and five (62.5%) of the eight private hospitals are monitored. None of this centers have dedicated medical physicist, or radiation safety officer or a dedicated TLD reader. Only one (12.5%) private X-ray center has a purpose built structure with adequate safety measures while other private X-ray centers operated in rental buildings that are not designed to be used as a radiation facility center. All this centers are located in a residential area. In addition, these buildings are also used for offices. The lead lining of doors and walls in three (37.5%) private units where limited while no lead lining or barium plasters are used in five (62.5%) private units. Out of the public centers, only one (10%) has a purpose-built adequately designed X-ray unit with lead lining of doors, barium coating of walls and the offices are located away from X-ray rooms. No X-ray unit in Edo State uses digital radiography information system. The study, however, gave a general overview of the radiation safety measures that are taking in for the construction, location and usage of the radiation facilities monitored. It did not take readings to determine the amount of scattered radiation or exposure to ionizing radiation gotten by staffs, patient and even the general public.

Esien et al., 2012 estimated the workload per patient, the average number of patient per week, the total workload, workload distribution as well as the use factors for the different barriers in the general radiography room of Ahmadu Bello University teaching hospital, Zaria, as a way of estimating of the sufficiency of shielding for the room and determining the radiation exposure to its environment, while comparing it with NCRP 147 standard. kVpandmAs for every exposure in the room was recorded manually for 3 months (12 weeks) with a total of

2281 patients. By making use of NCRP 147 theoretical model of workload distribution, a workload spectrum was achieved base on the number of patients seen in the room per week. In this stored, average number of patient per week was 190 patients/week, this value is also high when compared with NCRP 147 recommendation (112 patients/week). The total workload for the room was 288.8mA min week^{-1} which is higher than the recommend240mA min week^{-1} by NCRP 147. It was observed that following the recommendation by NCRP 147, by using the calculated workload would result in adequate protection for the installation. The study however was limited to just a hospital which cannot be overall conclusive. It also only worked on calculating what protection would be needed for future installation taking into consideration the overall workload. However, it did not consider the state of the present barrier or amount of scattered radiation within the radiographer's console.

Ekpo et al., 2013, carried out an assessment of the implementation of radiation dose limiting strategies in radiography practice, in Lagos, Nigeria. This is because ionizing radiation have far reaching consequences to biological tissues even at low doses which will gradually accumulate within the body. In this study, observation of radiological procedures was carried out in selected hospitals in Lagos state alongside with the use of questionnaires. The research which spanned a period of three months (May-July 2012) monitored a total of 9000 procedures. Each Hospital recorded an average of 30 Conventional X-ray cases, this cases includes special investigations done daily during the time of the research. The radiation dose limiting methods, rules and parameters assessed were the implementation of radiation beam collimation, use of radiation intensification accessories (type of film/screen combination), application of 10-day/28-day rule, X-ray machine servicing, implementation of quality assurance program and proper combination of exposure factors. It was observed that there was no proper quality assurance program carried out in all the x-ray unit observed thiscontributed to higher radiation dose to the patients. In 80% of all the diagnostic rooms investigated, there was poor routine servicing. However, this study did not carry out readings to determine the amount of radiation dose to health workers within this facility over the period of their work. It dealt more on patient dose and little information on supporting staff and risk involved in working is such environment as stated above. The study recommended that there should be effective implementation of Quality Assurance programs in the radio-diagnostic facilities, radiation scatter/leakage survey which are practical steps that can aid reduced radiation dose to patient staff and the environment.

Briggs-Kamara, et al., 2013, carried out a Radiation safety study of X-ray Irradiation facilities at three hospitals in Port Harcourt Rivers State The study employed the use of Radalert-100 which is a specialized Geiger Muller counter to take measurements of radiation emissions levels and the extent of scatter radiation to the environment. Also in this study, a pocket dosimeter was also used to measure absorbed doses. The background radiation in this centers was determined as within normal range of between 0.09 and 1.70μSv (ICRP, 1992). It was observed that with exposure timeranging from between 0.06ms to 4s depending on body part under investigation, for older X-ray machines, higher amount of radiation was required to achieve a particular result. As a result, there is an increase in radiation dose; which equate to a corresponding increase in biological effect to the body cells (tissue). There was also scattered radiation from the X-ray machine especially older machines which ultimate contributes to radiation dose recorded in the patient waiting area. Also, patient and the health workers get increasing radiation exposure due to repeated radiological procedures which mostly was as a result of technical fault and handling/packaging of the X-Ray results. The study reached a conclusion on the urgent need for radiation workers to be given introductory seminars on radiation safety before they start working with radiation, ensure that all accessories for X-ray machines are working properly and within safety limits, calibration of their machines, overhaul all existing Health and Safety Inspection Agencies charged with regulation or accreditation of radiation workers, periodic and regular inspection and monitoring of machines, sensitization of patients/general public about radiation and radiation protection, appointment of a qualified persons that would have the responsibility for assuring proper maintenance of the x-ray machines in line with Preventive and Corrective Maintenance programs for X-ray machines as detailed by the International Atomic Energy Agency, IAEA, adequate lead-lining of radiation rooms and lead-lined gloves and aprons to be worn by staff and patients likewise.

Oluwafisoye, et al.,2013, in the research paper environmental assessment, instrumentation-qualitytests of radiological equipment and human health implications assessed health implication of human exposure to ionizing radiation with emphases on exposure to sub-lethal doses over a period of time. The methodology used in this research was to investigate the efficiency/output of X-ray machine in a private radiology center in Nigeria using a multi-purpose measuring non-invasive X-ray test device, Victoreen model 4000M+ to collect data that bothered on the Timer (Accuracy and Reproducibility), Peak Tube Voltage kVp, Linearity of X-ray output and Consistency of output and minirad model 1000+ GM Survey Meter for environmental monitoring. The result obtained in this research showed dosage at the entrance of the lead lined door measuring between 3.0 to 3.6 μSv/h, while dose is at a factor of 60 higher than the background dose rate of the adjacent room and the waiting lobby. It was observed that for the center under study, the measured values fell short of IAEA (1996) standard, for time accuracy, reading were not within ±5% of the settings, X-ray equipment was found not to measure accurately and does not reproduce set values, measured kVp values are not linear when compared with that of the settings and not reproducible. Also, QC test carried out on the consistency of the machine showed non-compliance with records showing that Radiation Safety Officers and Medical Physicists were not engaged in the activities of the center and a completely overhauled of the center was recommended. Follow-up on this research showed compliance of the center to recommendations, i.e. an improved facility and safety measured now put in place.

2.2 THE RADEYE B20-ER

The RadEye B20-ER is a modern compact multi-purpose contamination meter for alpha, beta, gamma and X-ray radiation. It is a survey meter which is a simple, robust, reliable contamination and dose rate measurement tools for characterizing alpha, beta, gamma and X-ray radiation. By virtue of optional gamma energy filters, deep or shallow dose rate measurement from 17 - 1300 keV can be performed. It can be used for first responders need to quickly identify mixed radioactive surface contamination in facility and field environments. The RadEye B20-ER Multi-Purpose Survey Meters provide a handheld, on-site solution for homeland security personnel, fire brigades, emergency response personnel, agencies involved in decontamination and decommissioning projects and hospital and pharmaceutical industry employees. The detectors type used is the pancake GM-tube, window dia. 44 mm (1.7 in.) 1.8 to 2.0mg/cm2 Efficiency 2p Efficiency (ref. to 50mm diameter without rubber sleeve): Am-241; Co-60: 25%; Sr/Y-90: 36%; C-14: 19%. Energy Range 17 keV - 3 MeV; according to IEC 60846-1). It has a battery life of more than 500 hours on two AAA batteries, and alarm types of LED, sound and vibrator. The gamma dose rate: 0-100mSv/h (0-10rem/h); Contamination measuring range: 0-500kcps.

The unit of measurement of the survey meter is in dose rate (µSv/h)

Where µSv = 0.001mSv

1mSv = 0.001Sv

Therefore

$$1\mu Sv = 10^{-6}Sv.$$

For diagnostic radiation: The equivalent dose in milliSievert (mSv) = the absorbed dose in mGy.

CHAPTER THREE

3.0 MATERIALS AND METHOD

In this study, radiation scatter from various hospitals and diagnostic centers in Lagos state were determined and theexposure (dose rate)where measured at different distances from the radiographers operating console. The centers visited cut across Five local government araea in Lagos. They are Surulere LGA, AmuwoOdofin LGA, Ojo LGA, Ajeromi LGA and Ikeja LGA. The centers are fifteen in numbers and were diagnostic center owned by individuals, diagnostic centers owned by a group/company and private and government owned hospitals. The centers have requested for animosity in this research as a result their names will not be disclosed for this research. The Centers are represented by “C”. Therefore, we have C1, C2, C3, …... and C15.The exposure was measured using calibrated survey meter: RadEye B20-ER Multi-Purpose Survey Meter. data were collected at distances of 5cm, 10ccm and 15cm away from the console and also at the door of the X-ray machine.The detector was placed at different locations behind the protective panel or within the console room to take readings. Measurement gotten were compared with international guidelines to ascertain that the exposure of health personnel within the facilities does not exceed the recommended rate of 20mSv per year average over 5 years (BSS).As a result, it is able to give the reading of the background radiation instantaneously. The figure below is the RadEye B20-ER Multi-Purpose Survey Meters used in this study.

FIGURE 3.1: RADEYE B20-ER MULTI-PURPOSE SURVEY METERS

3.2 DATA COLLECTION PROCEDURES.

The readings were taking at different distance (5cm, 10cm and 15cm from the X-ray door or protective panel) and also at the door of the console room or directly behind the protective panel. This distance where used because it is assumed that all necessary protective measures (lead lined wall, lead lined windows) have being put in place. As a result, measurements are taking with reference to the protective screen or wall and to where the radiographer usually stays behind this protective shields to catty out esposures. In taking the reading the survey meter was held in place before any X-ray examination begins.

Experimental Setup

The detector was either placed on the console table, or hand held in at the location where the radiographers stays (in front of the machine’s control panel or behind the protective panel) as shown in figure 3,2. The highest instantaneous reading was taken on the detector display.

FIGURE 3.2: A CONSOLE ROOM (SUPERVISED AREA).

All measurements were taken when examinations were going on. Before taking any reading within a center, the background radiation of that center was first recorded when no examination was going on. The X-ray machines on these centers are: Mx-4, Summit, Agrostarppp, Allenger, Clean, Siemen elena AB, Watsan MX-4, picker International Roetgen 301, Allenger, XCMC - R1, Portable X-ray Unit Model DIG 1100, Philip Medi-zin system 22315 Ambury, Toshiba Rotande and Mobilet (B) Siemen.

The frequency "F" is the amount of patient treated multiply by the number of exposure carried out for examination on the patient. This value is gotten by oral confirmation from the radiographers about the average amount of patient the center treats in a day and the number of exposure carried out before a test can be confirmed to have being concluded. The total amount of working hours in this facilities are 6 days in a week aside from the two government owned hospital which took part in this study. Therefore, for 6 working days in a week for a year, it totals to 261days.

After the collection of data for various distance (5cm, 10cm and 15cm; door of console), the data collected where tabulated. The percentage deviation of the dose rate measured in the console was calculated using the formula:

$$\%D = \frac{\text{observed} - \text{expected}}{\text{Expected}} \times 100$$

Where Observed = Measured survey meter reading

Expected = Occupational exposure (20 mSv for Health workers and 1mSv for Public).

The age and the working condition of the machines was confirmed. Centers with x-ray machine but without any personnel to operate it and centers with machines not working are not considered in this study.

CHAPTER FOUR

4.0 RESULTS AND ANALYSIS.

Fifteen X-ray centers at various diagnostic centers within Lagos state were investigated in this study. Table 4.1 gives an overview of monitoring, protection and shielding equipment that are present on this facility. Measurement were taking at distances of 5cm, 10cm, 15cm and at the door of the X-ray room. Table 4.2 gives the recorded value for each location where the survey meter was placed for readings. The amount of radiation getting behind the protective panel, walls or windows for each of the centers were measured. These value were then multiplied by the total no of exposure done in a day. The total number of exposure in a day is gotten by multiplying the number of exposure gotten by each patient multiplied by the number of patient attended to in a day. This no is called the frequency of exposure “F”as explained in previous chapter. This is shown in Table 4.2 and 4.3.

TABLE 4.1: PROTECTING EQUIPMENT

		C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15
1	Main door to x-ray room (Lead Lined)	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
2	Main door to x-ray room (Lead efficient)	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N
3	Cubicle Type Lead Wood	N	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
4	Cubicle Type Lead wall	Y	N	N	Y	N	N	N	N	N	N	N	N	N	N	N
5	Cubicle Efficient	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N
6	Door Interlock provided	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
7	Provision of lead apron	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	N
8	Hazard warning light Provided	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
9	Hazard warning sign (Displayed)	Y	Y	Y	Y	Y	N	Y	Y	Y	N	Y	Y	Y	N	Y
10	Functional Air-Conditional Provided	Y	Y	N	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	N	Y
16.	Personal Monitoring Device (TLD'S)	Y	Y	N	N	Y	N	N	Y	N	N	N	N	N	N	Y

Table 4.1 represents the centers in the horizontal axis and the parameters that are considered such as Main door to x-ray room (Lead Lined), Main door to x-ray room (Lead efficient), Cubicle Type Lead Wood, Cubicle Type Lead wall, Cubicle Efficient, Door Interlock provided, Provision of lead apron, Hazard warning light Provided, Hazard warning sign (Displayed), Functional Air-Conditional Provided and Personal Monitoring Device (TLD'S) on the vertical axis. The Y represent Yes which indicate the

availability or functionality of the parameter considered. While the N represent the number which indicate the unavailability of the parameter considered on the table.

TABLE 4.2: MEASURED RADIATION SCATTER

INVESTIGATIONS	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15
Background within Facility premises(µSv)	0.07	0.10	0.11	0.10	0.07	0.12	0.10	0.11	0.11	0.13	0.10	0.09	0.11	0.12	0.11
Background within the X-ray room(µSv)	0.08	0.11	0.11	0.09	0.11	0.12	0.10	0.09	0.10	0.12	0.10	0.09	0.10	0.12	0.09
Radiation detected during exposure.(µSv)	0.10	22.64	151.00	3.84	66.40	130.00	5.69	0.91	57.90	22.04	35.00	70.80	58.50	3.51	11.50

TABLE 4.3: SHOWS THE MEASUREMENT OF EXPOSURE AT DIFFERENT CENTER AT 5CM, 10CM, 15CM AND AT THE CONSOLE DOOR

Center Name	Machine Name	mAs	kVA	5cm (μSv)	10cm (μSv)	15cm (μSv)	Door (μSv)	Frequency
C1	Mx-4	8.00	7.00	0.12	0.11	0.11	0.10	20
C2	Summit,	40.00	109.00	8.94	3.69	0.89	22.64	100
C3	Agrostarppp	30.00	130.00	70.20	104.70	56.40	151.00	20
C4	Allenger	21.00	83.00	3.15	2.79	0.94	3.84	35
C5	Clean	70.00	100.00	16.89	2.84	0.18	66.40	25
C6	Siemen elena AB	32.00	100.00	71.60	78.80	30.70	130.00	40
C7	Watsan MX-4	40.00	60.00	0.98	3.29	0.45	5.69	10
C8	picker International Roetgen 301	40.00	83.00	0.89	0.18	0.15	0.91	10
C9	Mx-4	200.00	100.00	18.30	14.40	8.10	57.90	10
C10	Allenger	40.00	78.00	15.24	8.94	3.63	22.04	35
C11	XCMC - R1	40.00	95.00	5.12	3.06	6.72	35.00	20
C12	Portable X-ray Unit Model DIG 1100	20.00	101.00	50.20	28.50	9.17	70.80	40
C13	Philip Medi-zin system 22315 Ambury	20.00	110.00	30.10	10.20	4.12	58.50	20
C14	Toshiba Rotande SN: 13A486	25.00	115.00	0.75	0.17	0.52	3.51	90
C15	Mobilet (B) Siemen	20.00	70.00	8.74	13.50	8.70	11.50	20

TABLE 4.4: SHOWS THE CALCULATED DOSE RATE FOR A YEAR WITH 216 WORKING DAYS MULTIPLY BY THE NUMBER OF TIMES THE MACHINE IS IN OPERATION (FREQUENCY) IN A DAY.

Center Name	5cm (μSv)	10cm (μSv)	15cm (μSv)	Door (μSv)	Days in a year	Frequency	At 5cm in a year (μSv)	At 10cm in a year (μSv)	At 15cm in a year (μSv)	At the door in a year (μSv)
C1	0.12	0.11	0.11	0.10	261	20	626.40	574.20	574.20	522.00
C2	8.94	3.69	0.89	22.64	261	100	233334.00	96309.00	23229.00	590904.00
C3	70.20	104.70	56.40	151.00	261	20	366444.00	546534.00	294408.00	788220.00
C4	3.15	2.79	0.94	3.84	261	35	28775.25	25486.65	8586.90	35078.40
C5	16.89	2.84	0.18	66.40	261	25	110207.30	18531.00	1174.50	433260.00
C6	71.60	78.80	30.70	130.00	261	40	747504.00	822672.00	320508.00	1357200.00
C7	0.98	3.29	0.45	5.69	261	10	2557.80	8586.90	1174.50	14850.90
C8	0.89	0.18	0.15	0.91	261	10	2322.90	469.80	391.50	2375.10
C9	18.30	14.40	8.10	57.90	261	10	47763.00	37584.00	21141.00	151119.00
C10	15.24	8.94	3.63	22.04	261	35	139217.40	81666.90	33160.05	201335.40
C11	5.12	3.06	6.72	35.00	261	30	40089.60	23959.80	52617.60	274050.00
C12	50.20	28.50	9.17	70.80	261	40	524088.00	297540.00	95734.80	739152.00
C13	30.10	10.20	4.12	58.50	261	20	157122.00	53244.00	21506.40	305370.00
C14	0.75	0.17	0.52	3.51	261	90	17617.50	3993.30	12214.80	82449.90
C15	8.74	13.50	8.70	11.50	261	20	45622.80	70470.00	45414.00	60030.00

TABLE 4.5: SHOWS THE CALCULATED DOSE RATE FOR A YEAR FOR EACH CENTER AT VARIOUS DISTANCE WERE READINGS WERE TAKEN.

Center Name	At 5cm in a year (μSv)	At 10cm in a year (μSv)	At 15cm in a year (μSv)	At the door in a year (μSv)
C1	626.40	574.20	574.20	522.00
C2	233334.00	96309.00	23229.00	590904.00
C3	584640.00	366444.00	182700.00	788220.00
C4	28775.25	25486.65	8586.90	35078.40
C5	110207.30	18531.00	1174.50	433260.00
C6	822672.00	747504.00	320508.00	1357200.00
C7	8586.90	2557.80	1174.50	14850.90
C8	2322.90	469.80	391.50	2375.10
C9	47763.00	37584.00	21141.00	151119.00
C10	139217.40	81666.90	33160.05	201335.40
C11	39150.00	23490.00	52617.60	274050.00
C12	524088.00	297540.00	95734.80	739152.00
C13	157122.00	53244.00	21506.40	305370.00
C14	17617.50	3993.30	12214.80	82449.90
C15	45622.80	70470.00	45414.00	60030.00

TABLE 4.6: T-TEST

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Standard - At 5cm in a year	-164116.3600000	253905.4172113	65558.0968247	-304724.4933549	-23508.2266451	-2.503	14	.025
Pair 2	Standard - At 10cm in a year	-101724.3100000	204598.4859249	52827.1019098	-215027.1749373	11578.5549373	-1.926	14	.075
Pair 3	Standard - At 15cm in a year	-34675.1500000	87845.2793089	22681.5535871	-83322.2441949	13971.9441949	-1.529	14	.149
Pair 4	Standard - At the door in a year	-315727.7800000	387242.8729483	99985.6798578	-530175.7351413	-101279.8248587	-3.158	14	.007

Table 4.6 is a paired T-Test of the cumulative dose gotten at the different centers and at locations of 5cm, 10cm, 15cm and at the door. The readings at the 5cm and at the door are significant in this finding. This means that considerable measure of scattered radiation was recorded at the different locations.

TABLE 4.7: SHOWS THE PERCENTAGE DEVIATION OF READING TAKING AT DIFFERENT CENTER TO THE RECOMMENDED DOSE RATE OF 20MSV (20000SV)

Center Name	At 5cm in a year (µSv)	At 10cm in a year (µSv)	At 15cm in a year (µSv)	At the door in a year (µSv)	Expected (µSv)	Percentage Deviation			
						5cm	10cm	15cm	Door
C1	626.40	574.20	574.20	522.00	20000	-0.97	-0.97	-0.97	-0.97
C2	233334.00	96309.00	23229.00	590904.00	20000	10.67	3.82	0.16	28.55
C3	366444.00	546534.00	294408.00	788220.00	20000	17.32	26.33	13.72	38.41
C4	28775.25	25486.65	8586.90	35078.40	20000	0.44	0.27	-0.57	0.75
C5	110207.30	18531.00	1174.50	433260.00	20000	4.51	-0.07	-0.94	20.66
C6	747504.00	822672.00	320508.00	1357200.00	20000	36.38	40.13	15.03	66.86
C7	2557.80	8586.90	1174.50	14850.90	20000	-0.87	-0.57	-0.94	-0.26
C8	2322.90	469.80	391.50	2375.10	20000	-0.88	-0.98	-0.98	-0.88
C9	47763.00	37584.00	21141.00	151119.00	20000	1.39	0.88	0.06	6.56
C10	139217.40	81666.90	33160.05	201335.40	20000	5.96	3.08	0.66	9.07
C11	40089.60	23959.80	52617.60	274050.00	20000	1.00	0.20	1.63	12.70
C12	524088.00	297540.00	95734.80	739152.00	20000	25.2	13.88	3.79	35.96
C13	157122.00	53244.00	21506.40	305370.00	20000	6.86	1.66	0.08	14.27
C14	17617.50	3993.30	12214.80	82449.90	20000	-0.12	-0.80	-0.39	3.12
C15	45622.80	70470.00	45414.00	60030.00	20000	1.28	2.52	1.27	2.00

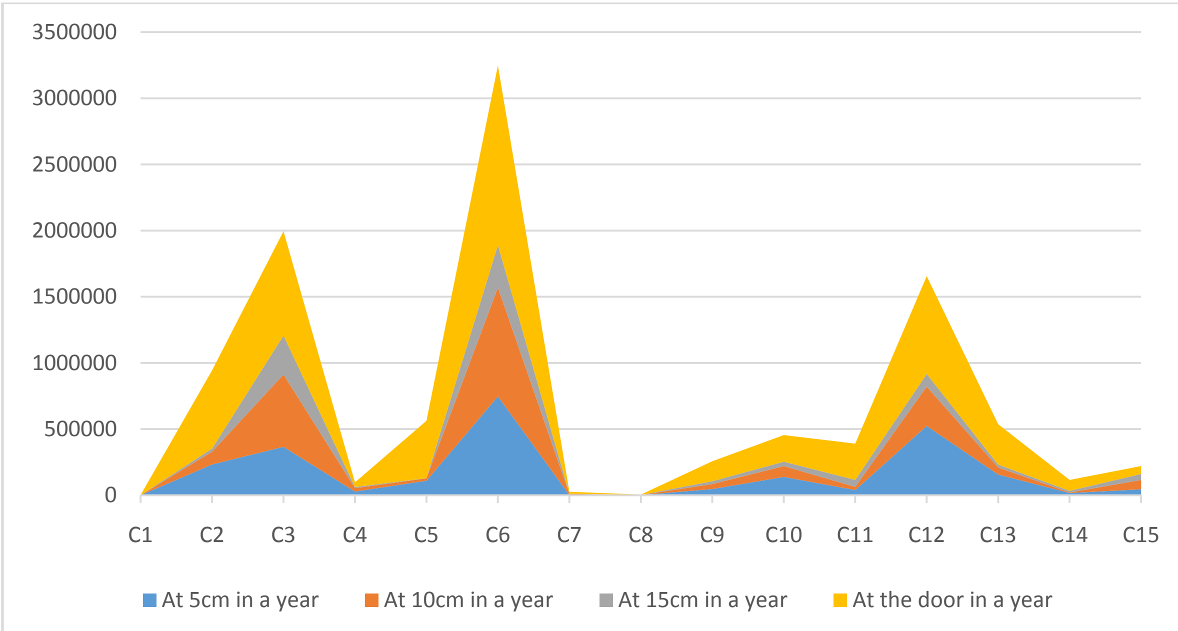

FIGURE 4. 1: STACKED AREA CHART SHOWING CUMULATIVE EXPOSURE IN A YEAR FOR 216 WORKING DAYS

FIGURE 4.2: CONSOLE ROOM OF CENTER 2

In all the centers, the reading from the center 6 is the highest. Figure 4.3 show a comparison between the total dose from all the centers in a tree Map chart while Figure 4.4 show the increment in the dose rate measured in this centers.

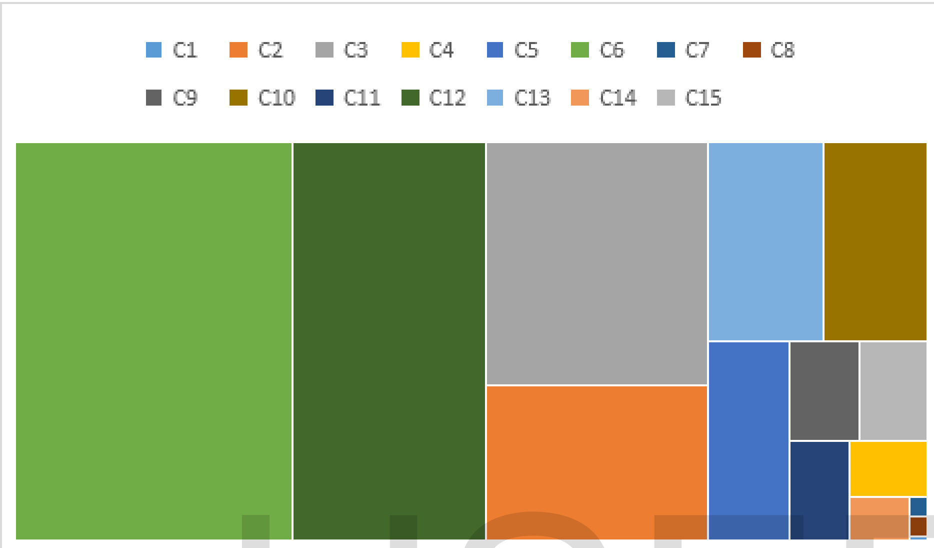

FIGURE 4.3: TREE MAP CHART COMPARING THE DIFFERENT CENTERS.

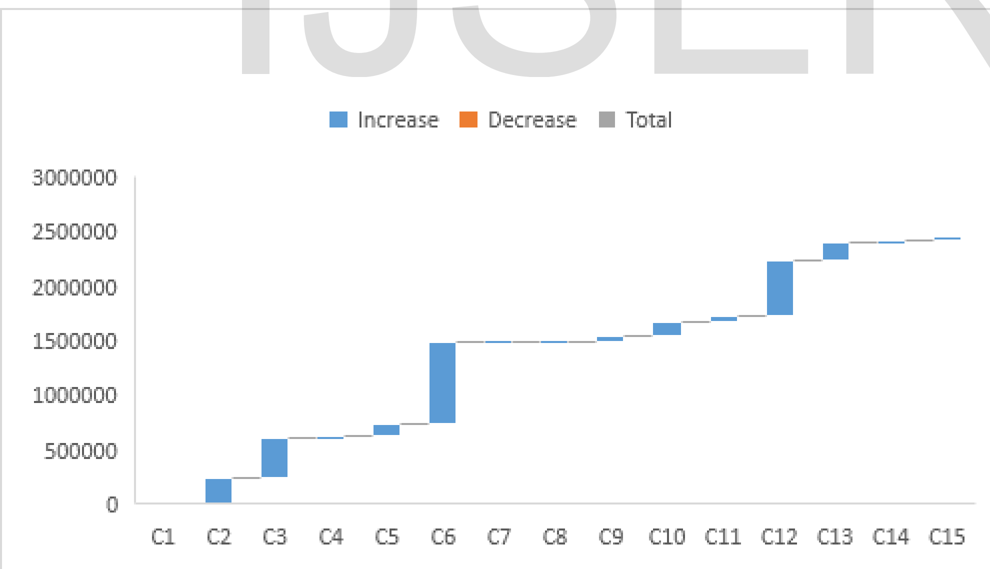

FIGURE 4.4: WATERFALL CHART OF THE DOSE IN A YEAR.

Figure 4.3 shows that in center 6 (C6), the value for the highest scattered radiation was measure here when compared to other centers. This means that, radiographers at this center are exposed to more radiation due to scattered radiation from the X-ray machine during operation of the machine. Fig 4.4 show the difference in this value recorded with different centers that participated in the study.

ANALYSIS OF THE RESULTS OF THE DOSE MEASURED AT C1 TO C15.

The result of the exposure measured at center 1 to center 15 is shown in table 4.1 to Table 4.5. It showsthe background radiation of the centers and readings taking at distance 5cm, 10cm and 15cm away from the X-ray door within the console/protective paneland reading taking at the X ray door. Table 4.7 and Table 4.8 shows the T-Test carried out on the reading gotten for the fifteen centers. The T-test shows that the reading at the door and at 5cm is significant in this study. Dose rate measured at center 1, 7,8 and 9 shows conformity with standard but dose rate measure at other centers are higher that the advised occupational limit of 20mSv in a year. This calculation was done for a radiographer working in this facility for 6 days in a week for an entire year without holidays.

CHAPTER FIVE

DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1 DISCUSSION

The results showed that for allthe centersstudied, there is a degree of radiation scatter in the console or behind the protective panel that is in use as shown in Figure 3.

The background radiation in this centers was determined using the survey meter to acquire the readings as shown in table 4.3. It was discovered that the values were within normal range of between 0.09 and 1.70µSv (ICRP, 1992) The readings were tabulated and a chart to compare the values gotten at the different distance was plotted (Figure 4.1).

In Figure 4.1is a stacked area chart showing the relationship between the measured scattered radiation at 5cm, 10cm, 15cm and at the door. From the graph above it shows that as the detector is gradually moved away from the viewing glass, the scattered radiation measured in the console room gradually drops. However, there are exceptions to this: This is seen in center 3, 5, 6, 7 and 15 as shown in Table 4.3. In these centers a protective panel is used only. In this setup, the radiographer is protected when he/she stands directly in front of the protective panel. When the survey meter was placed at a distance away from the protective panel in either direction, more scattered radiation is picked by the survey meter. This result is better explained by the research of Mcvey, et al., 2004, which showed that the closer the protective protective panel is to the ceiling or vise versa, there is a considerable decrease in scattered radiation that gets to the X-ray machine operator.

A unique observation was also seen in center two (C2). This center makes use of a control room rather than a protective panel. However, the top of the room is not covered as shown in figure

4.3. As a result of this, the amount of scattered radiation that is being picked by the detector is higher than the backgroud. It is more when the detector is placed up (point A) and lesser when the detector s placed close to the floor (point B).

Center 1 and 4 arethe only purposely built X-ray room in all centers visited as shown in figure 4.1. Other centers where remodified to fit in the X-ray machine. As a result, they have lead wood as the cubicle type within the X-ray room aside from center 5 which though it is purposely built has a protective panel. This protective panel is being used in this center while the lead concreate has being abandone by the radiographer. There is hazard warning light present in most of the centers which is meant to indicate when the X-ray machine is in use. During the course of this research, it was observed that none of the light were funtional except for center 1 and 2 as shown in figure 4.1. hazard warning signs where also present in centers 6, 10 and 14. Personal monitoring device (TLD) were not in use by the radiographers except for centers 1, 2, 8 and 15. All other centers do not have any form of personal monitoring device on them while some claim they are in the process of acquiring TLD for use in the center.

Table 4.2 gives the result of the background radiation in all centers visited in relation to the dose measured at the door of the X-ray room. The background radiation in this centers shows compliance with normal range of between 0.09 and 1.70μSv (ICRP, 1992). Aside from center 1, there is a significant increase in the measured scattered radiation at the door of the X-ray room of this centers. Table 4.3gives the cumulative dose rate measured at distances of 5, 10, and 15cm and at the door of the X-ray room. Multiplying the values gotten at different locations (5, 10, 15cm and at the door of the X-ray room) by 261 days (which is the total number of 6 working days in a week for a year (2016) without holidays) and by the frquency of use. The frequency of use in this case in the number of exposure the machine carries out in a day. The result when compared with the advised limit for occupational exposure showed alarming rate in some centers Table 4.4. Centers 10 especially has a high value for total accumulated dose for a radiographer working in the center for 6 days a week for a year without holidays. Other center such as center**C**2,C3,C4,C5,C6,C9,C11,C12,C13 and C14also have high reading calculated for year. With the excemption of center C1which has a low value whilecenterC7,C8 and C15 falls within the range of 20mSv per year. This figure are shown in table 4.4.Table 4.7 gives the mean, standard error of the mean and standard deviation of the cummulative reading of the centers at different distances (5, 10, 15cm and at the door of the X-ray room). Table 4.6 is a T-Test carried out on the table 4.5 The T-Test helps summarize the data to get the level of significance for each distance. The table shows that the values for distance at 5cm and at the door are significant as $P > 0.05$ when compared with the occupational limit of 20mSv per year average over five consecutive year.

5.2 CONCLUSION

In conclusion, the research was able to confirm that approximately 73% of the centers that took part in this research all have scattered/leakage radiation getting to the radiographer. As a result of this exposures, there is an overall accumulation of radiation dose over days of work which invariantly exceeds the occupational limit of 20mSv per year over five consecutive years as stipulated by IAEA(IAEA, 2011). Even when the highest limit of 50 mSv is applied, the accumulated dose over 5 consecutive years exceeds the total of 100 mSv for occupational exposure. (ICRP, 2007).This condition of work is not appropriate as it increases the probability of this worker to either develop genetic effect, stochastic effect or increase probability of developing cancer.

5.3 RECOMMENDATION

There is a need for radiation workers to be given introductory seminars on radiation safety before they start working with radiation. This is because, during the research a lot of the radiographers within the centers do not know much about the effect of ionizing radiation to biological cells. The general idea about it being harmful is known, but an understanding about the stochastic effect of radiation and the accumulation of dose from several exposure is lacking. As a result, proper orientation and subsequent update program should be designed both internally within the facility or externally by governing bodies. It is also important to ensure that all accessories for X-ray machines are working properly and within safety limits.

The provision of personal monitoring equipment such as TLD badge and appropriate means of readingthis badges after specified period is important. This is because it provides a means of monitoring the amount of radiation that the radiographer or health worker within these facilities are exposed to in a year or over a period of time. In this way proper monitoring in ensuring that the occupational limit (20mSv/year average over 5 consecutive year) for the radiographer is not exceeded. Unlike center 6 where the cumulative dose average over a year is calculate and it exceeds the occupational limit, such circumstance needs to be quickly detected and appropriate action taken. Alongside the TLD, the provision of lead-lined gloves and aprons to be worn by staff and patients is also important towards radiation safety

Urgent overhaul of all existing Health and Safety Inspection Agencies charged with regulation or accreditation of radiation workers is needed. This is because in the state, the centers show that there is no form of regulatory body that enforces the regulation of the NNRA within the state. The future registrant is responsible for ensuring appropriate plans (for structural shielding approval) and other relevant details are provided to the Radiological Council so that the application for registration can be properly assessed. Registration must be approved prior to any use of the equipment. Registrants modifying premises (e.g. new equipment, relocation of existing equipment, structural shielding changes) must provide PRIOR NOTICE in writing to the Radiological Council of their plans and obtain the necessary approval. As a result, all center operates independent without setting proper radiation safety procedures. The best that is obtainable are in centers with head radiographer such as center 1,2,15 that have constant update of radiation protection procedure and effect of ionizing radiation. The recommended centers are partly so maybe due to the fact that the head radiographers also work within the facilities. Other centers showed poor protection standard and as thus high level of leakage radiation/scatter.

Periodic and regular inspection and monitoring of machines, sensitization of patients/general public about radiation and radiation protection should also be a procedure that should be adopted. The appointment of a qualified persons that would have the responsibility for assuring proper maintenance of the x-ray machines in line with Preventive and Corrective Maintenance programs for X-ray machines as detailed by the International Atomic Energy Agency, IAEA should be encouragedand enforced in all the centers. Future construction of X-ray rooms or in general radiation facilities should be enforced to comply with standard. Rooms should be designed according to standard specifications with adequate lead-lining of radiation rooms and console room. This will reduce scatter radiation from getting into the radiographer's console or the waiting room for patient. In a case were protective panel is to be used proper construction of the protective panel in order to properly protect the operator is important.

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The appointment of a qualified personnel as radiation protection officer(RPO) is important towards ensuring the safety of the workers. It was noticed that in all the centers, it was only one center (center C15) that acknowledge the presence of a radiation protection officer within the facility. Even at this the RPO was a radiographer. Under the Basic Safety standard, it is advised that the radiation protection officer should be a qualified person with a good knowledge of ionizing radiation and the biological effect of ionizing radiation. In this report it was stipulated that such officer should preferably be a medical physicist.

This study was able to assess the scatter radiation to radiographers which can be used as a model for what is obtainable within the state. The application of the suggestion above would improve the safety of health workers working in X-ray centers. During the course of this research, some centers refused to be used for the research. In overall twenty-eight centers were visited but only fifteen took part in the investigation.

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