# QUALITY EVALUATION OF DIAGNOSTIC RADIOLOGY DEPARTMENTS IN ZARIA AND SABON GARI LOCAL GOVERNMENT AREAS OF KADUNA STATE

**BY**

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**ZARIA.**

**SEPTEMBER, 2000**

## DECLARATION

I hereby declare that this thesis is record of my research work carried out by me. It has not been submitted by any one in A.B.U. Zaria or any where else for the award of any degree. References made to the work of others have been duly acknowledged.

ALIYU SA'ID

Date: 20/11/02

## CERTIFICATION

This thesis entitled **"QUALITY EVALUATION OF DIAGNOSTIC RADIOLOGY DEPARTMENTS IN ZARIA AND SABON GARI LOCAL GOVERNMENTS"** by ALIYU SA'ID meets the regulations governing the award of the degree, master of science of Ahmadu Bello University, and is approved for its contributions to knowledge and literary presentation.

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## DEDICATION

This is dedicated to my parents, Alhaji Saidu Maccido and Hajiya Bilkisu Saidu.

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# ABSTRACT

The evaluation of the quality of radiographic practices in diagnostic radiology Departments is very important for reduction of radiation doses to patient, personnel and members of the public. To this end, a number of quality control test were performed in eight hospitals in Zaria and Sabon Gari Local Government Areas of Kaduna State. The test is test on structural shielding, Reject analysis, test for exposure timer setting, test for light beam misalignment, x-ray beam misalignment and darkroom safe light test.

The result of the tests indicates that the protective barrier was sufficient to shield for the primary radiation in all the hospitals, while two hospitals have inadequate protection of secondary radiation for their darkrooms. The exposure time setting of all the hospitals were working within the tolerable limit. There is mismatch of alignment of light beam with radiation beam in all x-ray machines. X-ray beam alignment test gives satisfactory result except one hospital which no light beam diaphragm. The safe-light tested were in good conditions. The value of K and in was determined for use in estimating dose that would be received by patient in a particular examination at particular exposure parameter setting. The values for k were 0.189, 0.176, 10.0, 1.0128, and 0.00036 while the values for n were 1.752, 3.109, 2.22, 2.95 and 4.66 for Hosp. A Rm I and II, Hosp. E, G and H respectively. There are no qualified x-ray personnel except in one hospital. There is a poor darkroom procedure in all the hospitals.

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# LIST OF ABBREVIATION

| | | |
|---|---|---|
| ALARA | - | As Low as reasonably Achievable |
| CE | - | Compton Scattering Effect |
| FFD | - | Focus Film Distance |
| FOD | - | Focus Object Distance |
| Gy | - | Gray |
| HVL | - | Half value Layer |
| IAEA | - | International Atomic Energy Agency |
| ICRP | - | International Commission on Radiological Protection |
| ICRU | - | International Commission on Radiological Units |
| kVp | - | Peak Kilo-voltage |
| LBD | - | Light Beam Diaphram |
| mA | - | milliampere |
| mAs | - | milliampere-second |
| MeV | - | Mega electron Volt |
| MPD | - | Maximum Permissible Dose |
| mSv | - | Millisievert ($10^3$Sv) |
| NA | - | No information available |
| NCRP | - | National Council on Radiological Protection and Measurement |

| | | |
|---|---|---|
| OFD | - | Object Film Distance |
| PE | - | Photo Electric |
| PP | - | Pair Production |
| QA | - | Quality Assuarance |
| QC | - | Quality Control |
| SFD | - | Source Film Distance |
| SSD | - | Source Skin Distance |
| Sv | - | Sievert |
| TSD | - | Target Source Distance |
| TVL | - | Tenth Value layer |
| UNSCEAR | - | United Nation Scientific Committee on the Effects of Atomic Radiation. |
| WHO | - | World Health Organization. |
| Z | - | Atomic Number |
| 3P6 | - | Three Phase, Six Valve Rectification |
| 3P12 | - | Three Phase, Twelve Valve Rectification |

# CHAPTER ONE

## 1.0 GENERAL INTRODUCTION

Human lives are increasingly dependent on the quality of products and services. Serious human inconvenience, economic waste, loss of life and damage to the environment do occur as a result of quality failures of materials, products or services. Hence the need for manufacturers to build quality into their products and services cannot be over emphasised.

The problem brings the need to introduce quality assurance program during and after the World War II in Defence, (British Institute of Radiology, 1988).

Quality is defined as the totality of features and characteristics of product or service that bears upon its ability to satisfy a given need (British Standard 4778, 1979). Steffen (1988) define quality in medical field as the capacity to achieve goals. And Quality Assurance (QA) is the method of identifying and providing what is needed.

## 1.1 BACKGROUND TO PREVIOUS STUDIES

Pronounced increase in the use of x-rays in Nigeria is greatly witness rendering availability of its facilities in most of the urban hospitals. This is due to the fact that new Government, Specialist and General Hospitals, specialist (private) hospitals and private clinics, and teaching hospitals are open every day in the urban areas. However, the shortage of medical radiation technologist (Radiographers) in the country is affecting the efficient and safe operation of X-

ray machine in Radiology and Radiotherapy Department (Idehen 1974). Uusally Radiographers are only found in Teaching Hospitals and some public government hospitals while majority of the private clinics do not have trained personnel to handle the X-ray machines. There are also no good management and no period checks on the machine.

This appalling situation has led to the use of untrained or unqualified persons to man the facilities which in turn further degrade the already precarious safety standards in such hospitals. The poor image quality and consequent retakes results in unwanted radiation exposure and high collective doses to the population.

The exposure to a certain amount of x-ray dose has been reported to result in some biological damages on people causing cancer, turmour and eye cataract. In the diagnostic use of radiation, the facilities and procedure including personnel are controlled and employed to keep the radiation exposure (dose) to patients, x-ray personnel and the general public as low as reasonably achievable (ALARA). This process is called radiation protection.

The underlying principles in radiation protection is a three step process, namely: Justification, optimisation of protection and dose limitation. Justification of practice requires that the net benefit from radiation use be positive. This implies that, for diagnostic radiology, the information being sort for cannot be achieved by other methods which are associated with lower risks for patient. No diagnostic exposure is justified if it will not result in a net benefit to the patient.

The second step in radiation protection is optimisation of the protection. Once the diagnostic examination has been clinically justified, the subsequent imaging process must be optimised. ICRP (1996) recommend the use of

diagnostic reference level as an aid to optimisation of protection in medical exposure.

The principle of dose limitation does not apply to patients in diagnostic radiology. It is however, applicable to the personnel and members of the public. To achieve these objectives Quality Assurance (QA) program have been developed over a period of time to optimize the protection of radiation over the last few years and have been the subject of much interest (BIR 1988). However, at the moment, QA is confined mainly to monitoring the performance of equipment and to a subjective analysis of radiographs deemed to be of an unacceptable standard. QA is a procedure to exercise constant surveillance so that departure from standard can be detected early and corrected.

While QA and radiation protection have common aims, QA is much broader in its aim, because it helps not only the X-ray personnel and the general public but it also help the hospital management in reducing cost.

## 1.2 `THE PRESENT WORK

The main objective of this work is to assess the design and the procedures of x-ray Department in Zaria and S/Gari Local Government and the function of the x-ray machines through QA program in order to assess the dose received by the patient, personnel and the public.

The scope of the work covers firstly the measurement of the actual x-ray protective barriers for radiological units in the research areas and comparing them

with the expected values calculated on the basis of work load, distance of the machine with barrier and the maximum weekly permissible dose. Secondly determination of the accuracy of physical parameters of the exposure factors of the machine and assessing the darkroom procedures. Lastly to conduct reject film analysis so as to know the cause of repeat exposure.

## 1.3 OUTLINE OF THESIS

In chapter two, the physical and biological effect of x-rays is reviewed. Some work on quality assurance program already proposed in literature's are also reviewed. Chapter three and four contain the materials, method and results of the present investigation and chapter five contain discussion and summary of results.

# CHAPTER TWO

## 2.0 LITERATURE REVIEW

### 2.1 PRODUCTION OF X-RAYS

X-rays are, in general, produced when fast moving electrons strike metal target tungsten of high atomic mass such as walls or anode of low pressure discharge tube. The x-ray produced depends highly on the target material. The higher the atomic number (Z) of the target material, the more efficiently x-rays are produce. Most x-ray tubes use tungsten target because of its high Z (74) and high melting point (3400°C) (Chesney, 1971).

The main component of a modern x-ray units are (1) a source of electrons (a cathode) (2) an evacuated space in which accelerate the electrons (3) a high positive potential to accelerate the negative electrons (4) and a target which the electrons strike to produce x-rays as shown in fig. 2.1.

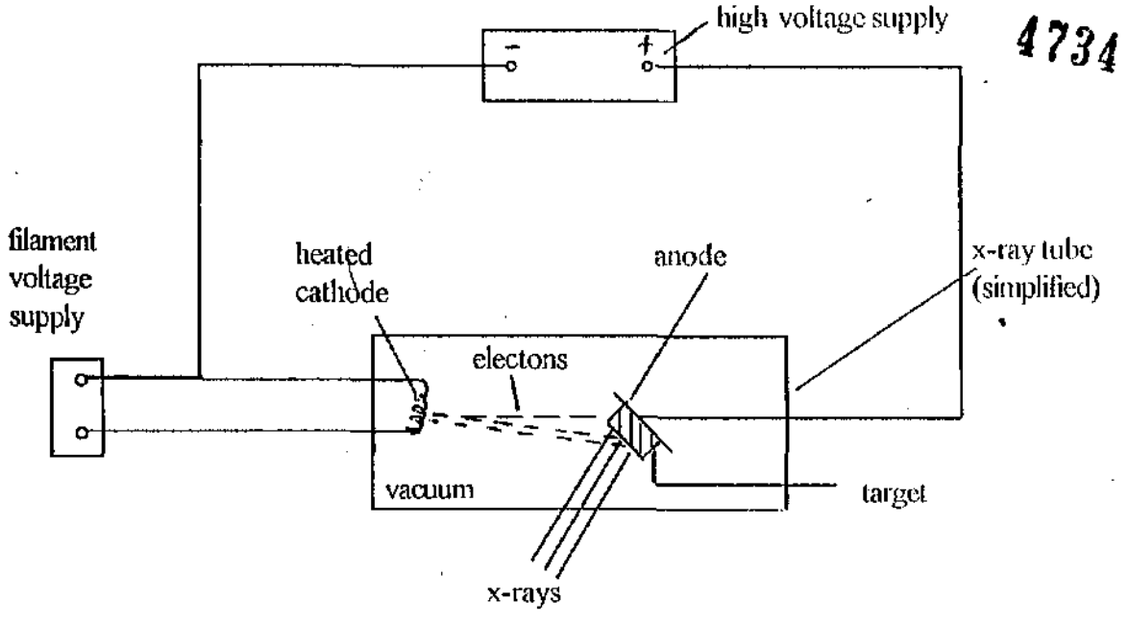


Fig. 2.1 Production of X-Rays (Pope 1973)

The x-ray beam produces two types of spectra. The characteristics x-ray spectrum which are emitted in atomic transition of bound electrons between the various electronic shell in the atom, and the continuous x-ray or bremsslrahlung emitted as a result of deceleration of electrons impinging a high positive nucleus, since free electrons do not have discrete allowed energy slates, the photos have continuous spectra and is called continuous x- rays.

The spectrum of an x- ray generator is shown in Fig. 2.2 the broad smooth curve is due to the bremsstrahlung and the spikes represent the characteristics x-rays.

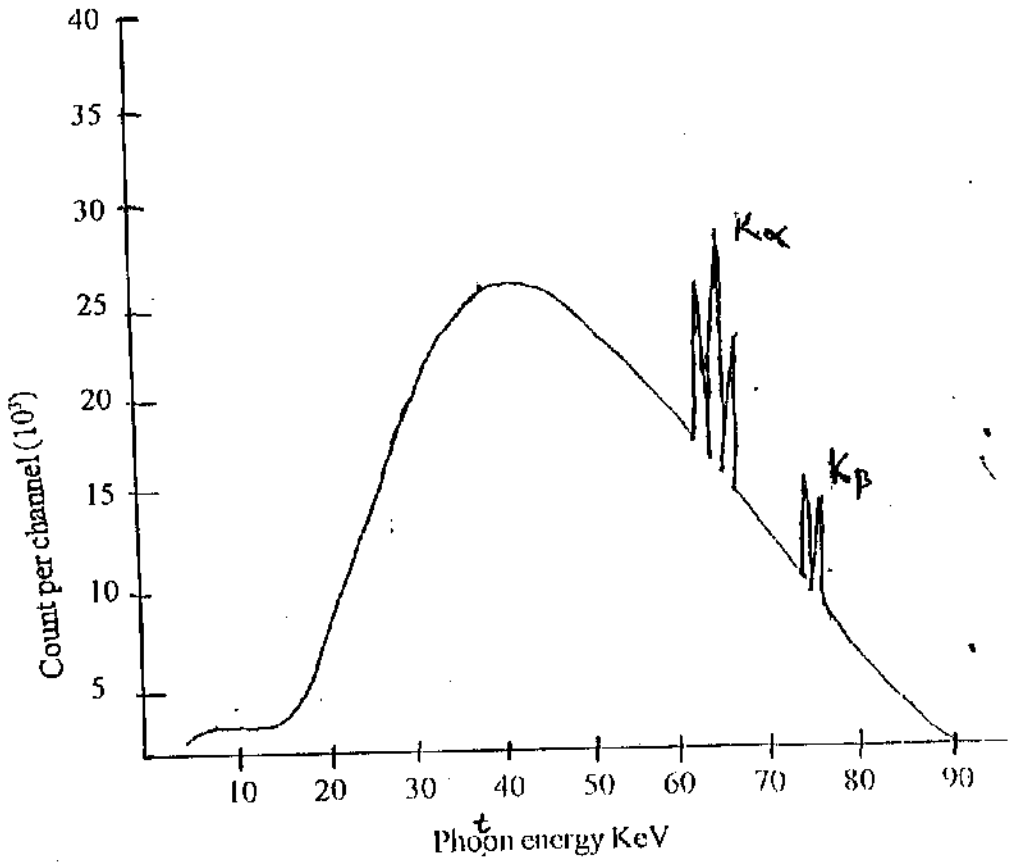


Fig: 2.2 The spectrum from a tungten target X-ray tube operated at 87 kVp (Hewitt, 1991).

## 2.2 ABSORPTION OF X-RAYS IN MATTER.

Various mechanisms are responsible for the absorption (attenuation) of x-ray beam in matter (Thompson et al 1965; Hewith, 1991; Profio 1979). The basic interactions are given by profio (1979) as; Photo electric (PE), Compton scattering (CE) and pair production (PP).

### 2.2.1 Photo Electric Effect (PE)

Photo Electric Effect occurs when the incoming x-ray energy is a little greater than the binding energy of electrons in the inner shells of the absorbing atoms. When the photon interacts with the electron it is absorbed completely. The energy absorbed by the electron is used in two ways; one is in overcoming the binding energy of the electron and the other in giving the electron sufficient kinetic energy (K.E.) to eject it from the atom. This electron that is released in the process is called a photoelectron.

This effect occurs in the intense electric field near the nucleus than in the outer level of the atom and it is more common in elements with high atomic number (Z) than in those with low Z and PE proportional to $Z^3$. Its probability of occurring also decreases rapidly with the increase of photon energy.

### 2.2.2 Compton Scattering Effect (CE)

This is another important way x-ray loses energy in matter. In this effect the electron receive part of the energy and the remaining is given to a scattered

compton photon, which then travels in a direction different from that of the original x-ray photon and because its energy E is less than before, its wave length is increased. Because the photon is changed in both direction and energy, it is called modified scatter.

Unlike P.E., the Compton Effect is greatest in low Z elements. For example, in water or soft tissue, the Compton effect is more probable than P.E. at energies above 30 keV ( Hewith, 1991).

### 2.2.3 Pair Production (PP)

This is the third major way x-ray give up energy. When very energetic photon having energy in excess of 1 MeV passes through an atom, it approaches and interacts with the nucleus of the absorber atom. The photon disappear and two particles, electron and positron, emerge. Providing the mass for the two particles required a photon with energy of at least 1.02 MeV and the remainder of the energy is given to the particles as Kinetic Energy

Since a minimum of 1.02 MeV is necessary for pair production (PP), this type of interaction is only important at very high energies as can be seen in fig. 2.3 and is more likely to occur in high Z elements than in low Z elements. Because of this high energy needed for P.P to occur it is of no use in diagnostic radiology.

The photo electric effect (PE) is more useful in diagnostic radiology because it produces high contrast between the body tissues. To make further use of PE radiologist often inject high Z material or contrast media into different parts of the body. Example is the injection of barium compounds orally to see parts of the upper gastro intestinal track (upper G I) and barium enema to view the other

end of the digestive system (Lower G I). This shows that PE makes x-ray examination much more useful.

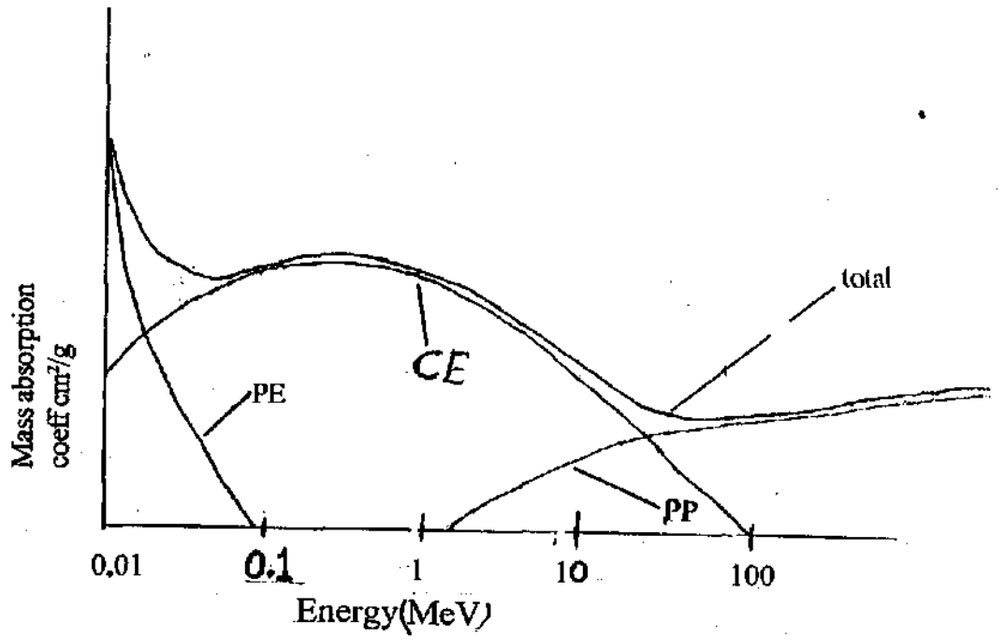


Fig 2.3. The mass absorption coefficient for water (Pope, 1973)

On the other hand , Compton scattering effect (CE) seriously degrades x-ray images of thick body parts since the scattered radiation that gets through the

patient and strikes the film reduces the useful information by reducing the contrast in the image. In the range of 80 - 100 kVp the ratio of scattering (Which has a deleterious effect on film quality) to photo electric absorption is optimal, and this seem to be the optimum range for diagnostic radiography, although other factors may influence the final choice of kilovoltage (Thompson et al 1965). The PE is hence more useful in diagnostic radiology, while CE contribute nothing much more than increases in scattered radiation and radiation dose to patients and personnel.

## 2.3 BIOLOGICAL EFFECT OF X-RAYS

Biological effects of radiation were first observed a year after the discovery of X-ray in some early X-ray workers. These workers noticed that their hair fell off and the skin that had been exposed to x-ray become red and some skin become ulcerated after receiving large amount of radiation. Skin cancer was found to develop a number of years later. The effect was poorly understood in the early days and consequently many radiation workers (medical and industrial) died or were seriously injured from over exposure to radiation.

The radiation either alters the function of the cell (mutation) or renders the cell incapable of reproduction and eventually dies.

Depending on the amount of radiation exposure and the time of exposure (dose absorbed), the radiation effect on living things particularly humans was expressed by Profio (1979) in the following ways: (1) Prompt personal effect (acute effect) (2) delay effect (late effect) and genetic effect. The first two effects

are also called somatic effect. Some common acute effects are reddening of the skin (erythema) at a dose of about 3.0Sv lost of hair at 2.5Sv, severe illness at over 1.25Sv (Meschan 1973). Acute effect begins to be observable at approximately l.0Sv. But these levels of radiation are not obtainable in routine conventional radiology. A single dose of 0.3Sv to test result in temporary sterility among men (genetic effect) and3.0 for women (Cember, 1989).

## 2.4 RADIATION PROTECTION

Radiation protection is the science of protecting workers and the general public from unnecessary radiation. Radiation safety, health physics radiation hygiene and radiological health are other terms that are used instead of radiation protection. It involves the design, measurements and methods used to reduce radiation to worker as well as the public.

There are two types of radiation protection, the external radiation protection and the internal radiation protection. The external radiation protection is the protection of radiation hazard which arises from sources of radiation outside the body and it is the type of protection to be considered in this research. While the internal radiation protection is the protection of radiation hazard that arises from the source that is inside the body.

Radiation protection exercise started as early as 1898 (about 100 years ago) when Roentgen Society set up a Committee to report on the alleged injurious effect of x-rays (Oliver, 1973). Seventeen years later the Society published a set of protection rules for x-ray operators.

There has been much controversy over the amount of radiation that is safe for the public. It is generally believed that even small amount of radiation may cause harm, that is, there is no absolute safe amount of radiation. In medical exposure, it is essential to ensure that the radiation dose received by patients in providing the necessary diagnostic information is minimum.

## 2.5 EXTERNAL RADIATION PROTECTION

The external radiation hazard can be controlled by applying the three principles:

- Minimising exposure time
- Maximising distance from the radiation source
- Shielding the radiation source

### 2.5.1 Time

The dose accumulated by a person working in an area having a particular dose rate is directly proportional to the amounts of time he spends in the area. This dose can thus be controlled by limiting the time he spends in the area.

Dose = Dose rate x time .....(2.1)

If the work to be done in a radiation area would exceed the time required to be exposed above workers permitted dose, some other means of reducing the dose rate would be employed, i.e. increasing the distance from source or use of shielding.

### 2.5.2 Distance

Distance is also used as means of protection from radiation hazard. It was shown that the flux of radiation beam at a distance, r, from a point source is inversely proportional to the square of the distance, and the radiation dose rate (D) is directly proportional to the flux (Martins and Harbison, 1972). It means that dose rate Da $1/r^2$

$Dr^2 = K$ .....(2.2)

Where K is a constant

### 2.5.3 Shielding

If the worker has to be done in close vicinity of the radiation source, then the method of shielding is used in reducing the radiation hazard. That is by using a radiation absorbent material that would absorb most of the radiation and transmit little.

The requirement for protective shielding depends on the type of radiation source and the energy of the radiation it produces. The amount of shielding required depends also on the degree of occupancy of nearby areas.

A sheet of paper can be used to stop alpha particles. Beta radiation required shielding of up to 1 cm of Perspex for complete absorption. While gamma and x-rays are attenuated exponentially when they pass through any material, under good condition of geometry, the attenuation of the radiation beam of the x-ray or gamma rays is given as

$$I = Io.e^{ut} \quad \text{.....(2.3)}$$

Where I is the intensity of radiation transmitted through an absorber of thickness t, $I_0$ is intensity at zero absorber thickness and \x is the slope of the absorption curve (the attenuation coefficient)

There are two types of X-ray shielding, source shielding and structural shielding. Source shielding is usually supplied by the manufacturer. The shielding is so constructed that the leakage radiation at a distance of lm from the source cannot

exceed 0.87 mGy in 1 hour at the highest rating of the machine (Blatz 1964, Gollmick 1985).

Structural shielding is designed to protect against the primary X-rays beam, leakage and scattered radiation. In any case structural shielding is designed to protect people in an area of high radiation intensity. The structural shielding requirements for a given installation are determined by :-

(i) The maximum x-ray tube voltage kVp or energy of radiation

(ii) The weekly workload, W, (mA-min/wk) which is the product of the number of patient exposed by the machine and the maximum mA-min setting. It is measured in mA-min/wk.

(iii) The type of radiation such as primary beam leakage or scattered

(iv) The distance from the radiation source or scattering source to the occupied area.

(v) The occupancy factor (T). It is the fraction of yearly irradiation time during which person is exposed.

(vi) The use factor (U). It is the fraction of workload during which primary beam is pointed in the direction under consideration.

The workload of the machine is calculated by using the following formula.

$$\text{Workload (W)} = \frac{\text{mA x S x weekly total exam}}{60} \quad \text{---------- (2.4)}$$

Where S is the time in seconds

The values for T given in Appendix 3 and 4 can be used as a guide in calculating the amount of shielding material.

The National Council on Radiation Protection (NCRP) derived formula for computing the required thickness of the structural shielding to reduce exposures to medical radiation workers and members of the general public. In it's issued report No. 49, NCRP (1976) the formula for the primary protective barrier is given as

$$Kp = \frac{(d_{prm)2P}}{WUT} \quad \text{----------(2.6)}$$

Where K is the attenuation factor for the primary bean, dprim is the distance from the X -rays tube to the position in question. P is the permissible average weekly exposure.

When the value of K is calculated, reference is made to a transmission curve for a particular radiation under consideration, the NCRP Report No. 49 includes graphs of the factor K as a function of the thickness of lead or concrete for various X-rays energies.

Secondary Protective Barrier: This is a barrier protection against scattered and leakage radiation. The two radiation have different spectral characteristics, hence the required barrier thickness are calculated separately. The formula given for calculating the leakage radiation is given (Cember, 1989) as

$$K1 = \frac{P(dsec)^2}{t.T} \quad \text{----------(2.7)}$$

Where t = number of hours per week of operation. The calculation is similar to the one discuss above.

The equation for calculation scattered radiation (Cembe 1989, NCRP, 1976) is

$$K_s = \frac{400\,P(dsea)^2(dsec)^2}{AWTF} \quad \text{---------- (2.8)}$$

where a = scatter to incident radiation ratio

F = scattering field size in $cm^2$

The scattering field size is assumed to be $400cm^2$ and the recommended values of the intensity ratio of the scattered to incident radiation at 1 meter from the scatterer, for a field size of $400cm^2$ are listed in table 2.2

Since F = $400cm^2$, the required attenuation factor for scattered radiation become

$$K_s = \frac{P(dsea)^2(dsec)^2}{AWT} \quad \text{----------(2.9)}$$

The resultant secondary barrier thickness must be sufficient to shield against both the scatter and leakage radiation. If the required thickness is about the same, a half-value layer is added to the greater thickness. But if the difference between the two calculated thickness is one tenth-value layer or more, the thicker value of the two would be used.

## 2.6 RADIATION PROTECTION STANDARD

By the year 1920, the number of victims afflicted with radio dermatitis made it evident that more adequate safety measured was needed for both workers and general public. Consequently International Radiation Protection Commission

was formed at the International Congress of Radiology which has since become known as the International commission on Radiological Protection, ICRP, (NRPB 1991). This Commission is the first to concern itself with radiation safety at the international level and it has been active ever since, issuing reports at the frequent intervals. Through the years, it has issued a series of handbooks on radiation protection and allied subjects which have been influential in guiding the safe use of radiation.

Safe working conditions are achieved if the doses received are such that the damage they produce is readily repaired by the body's defences. In such case the hazard from radiation exposure is acceptably small. Having taken into account all the available information, the ICRP recommended a series of maximum permissible dose (MPD) or dose limit, as is now called, for different body tissues for radiation workers and the general public.

The ICRP, in 1958 defined MPD as dose, accumulated over a long period of time or resulting from a single exposure, which in the light of present knowledge carries a negligible probability of severe somatic or genetic injuries. Further more, it is such a dose that any effect that ensure more frequently are limited to those of a minor nature that would not be considered unacceptably by the exposed individual and by competent medical authorities. Any severe somatic injuries (e.g. leukaemia) that might result from exposure of individual to the permissible dose would be limited to an exceedingly small fraction of the exposed group; effect such as shortening of life span, which might be expected to occur more frequently, would be very slight and would likely be hidden by normal

biological variations. The permissible doses can therefore be expected to produce effects that could be detected only by statistical methods applied to large groups.'

The problem in setting MPD values is to balance the expected benefits to be derived from the use of radiation against the 1902 when the first suggestion on MPD was made by Rollins (Blatz 1964) that individuals working with x-ray equipment should riot permit them to be expose beyond a certain level. He expressed the limit in terms of the fogging of a photographic emulsion. Since then there have been changes of the MPD to date, as can be seen in Table 2.1.

Table 2.1 Values of Maximum Permissible Occupational Exposure (Martins and Harbison 1972, ICRP 1991)

| | Dose Rate | Date Recommended | Comment |
|---|---|---|---|
| 1. | 0.1 of Eryhema dose per year (5.26 Gy/yr.) | 1925 | Proposed by the Mustcella A. and Sievert R.M. |
| 2. | 0.002 erythema dose (2mGy/wk) | 1927 | Recommended by the Dutch board of Heatthll |
| 3. | 0.46Gy/yr | 1934 | Recommended by ICRP |
| 4. | 150mSv/yr | 1950 | Recommended by ICRP |
| 5. | 50mSv | 1956 | Recommended ICRP |
| 6. | 50mSv/yr | 1977 | Recommended ICRP |
| 7. | 20mSv/yr | 1990 | Recommended ICRP |

No specific dose limit has been recommended for medical exposure. However, ICRP recommended that only necessary expose should be made, that

this exposure should be justifiable on the basis of benefit that would not

otherwise have been received, and that the doses actually administered should be limited to the minimum dose consistent with the medical benefit to the patient. In the absence of any dose limits for the patient's exposure, the protection of patient therefore entirely rest on the concepts of optimisation of protection. More concern become apparent with regard to the unwarranted dose variations, associated with common procedures. This ignites series of studies and seminars to review the progress of optimisation of protection in the medical field. The outcome of the studies shows that there is need to introduce reference dose values to identify an upper bound of patient exposures associated with particular procedures under good medical condition of practice.

In 1990 ICRP introduce the concept of dose constraints (reference dose), which would be regarded as the upper bound of patient doses under good medical practice. The dose constraints are expressed in terms of easily measured dose quantities triggering an internal investigation by the Department itself if the average dose for a particular type of examination is found to exceed the relevant reference dose. That is appropriate steps should be taken by the Department to improve practice, either by changes in techniques or equipment to reduce doses below reference level without compromising image quality.

Internationally adopted reference levels were published, for most frequent diagnostic procedures in radiology and nuclear medicine, in the Basic Safety Standards for Protection Against Ionizing Radiation. (IAEA 1994). The recommended levels for diagnostic radiology are summarised in table 2.2.

Table 2.2 Reference levels of entrance surface dose per radiology for some common X-ray examination on adult patients.

| **RADIOGRAPH** | | **REFERENCE DOSE (mGy)** |
|---|---|---|
| Lumbar spine | AP | 10 |
| Lat. | | 30 |
| LsJ | | 40 |
| Abdomen | AP | 10 |
| Pelvis | AP | 10 |
| Chest | PA | 0.3 |
| Lat | | 1.5 |
| Skull | AP | 5.0 |
| | PA | 5.0 |
| | Lat. | 3.0 |

(Adopted from IAEA safety series N0.115 1994)

The ICRP recommends that Radiological Departments should organize periodic surveys and measure the exposure doses in the Departments, so that the result of the survey would be compared with the reference dose as part of quality assurance programme.

## 2.7 IMAGE QUALITY

The quality of a radiographic image is its ability to reproduce in a clear pattern the object radiographed. The image is of the highest quality if the reproduction is exact and clear without omission, additions or distortions. A

technique which would produce a high quality image at the same time keep radiation dose minimum has to be employed. The following factors must then be taken into account.

(a) **Kilovoltage (kVp).**

For diagnostic radiography, the quality of the image is best expressed in terms of the kVp. kVp adjustment is used to achieved penetration of objects by X-ray beams and the penetrability of objects depend on the atomic number, Z, of the objects or its parts. The higher the Z or thickness (density) the less the penetration. The influence of Z and thickness of objects required a decision to be made on the level of kVp necessary to achieve proper penetration. Since selection of too high a kVp will result in a loss of image contrast. There will also be increase in the amount of scatter radiation which will also contribute in the lost of contrast. While low value of kVp will result in denser body structures being under penetrated. It also result in higher radiation doses to the patient.

(b) **Tube Current:**

As kVp determines the quality, The tube current (mA) determines the quantity of the X-ray beam. It helps in determining the degree of blackening on a film. Thus low value of mA result in under exposure (lack of optical density) or an over exposure (film to dark) if mA is too high.

**(c) Exposure Time(s)**

In clinical radiography the exposure time is a critical factor in determining the choice of the other two factors mentioned above. When examining the chest for example, it is necessary, in order to produce sharp image, to use extremely short exposure time. This is because it is necessary to arrest involuntary

movement of the heart, lungs and diaphragm. Hence the quantity of x-rays generated depends upon the product of the milliamperage and the time in seconds. The use of a fairly high mA will cut down the exposure time and this reduces the chances of repeat exposure.

The WHO (1986) recommend values for the exposure (kVp and mAs), for a range of basic radiographic technique which is sufficient to enable more than 90% of the problems diagnosable through radiography to be routinely examined. It added that if the instructions are followed exactly, the resulting radiographs will be of good quality and understood by physician and health workers throughout the world. Exposure charts were also supplied by the manufacturers for optimum used of the machine.

These three factors are called primary factors. There are other factors that are called the secondary factors which also contribute in production of good radiographic image. These include scattered radiation, the size of the focal spot and the relationship of the focal spot to focus/object and object/film distances which produce the geometrical unsharpness.

**(d) Scattered Radiation:**

In use of three primary factors in the production of a radiograph used in correct relationship to each other will produce a radiograph, but the optimum result will not be obtained unless steps are taken to the elimination of scattered radiation that is possible. These radiation are emitted in all direction but the maximum intensity is in the same direction as the primary beam. The method by

which the scattered radiation are reduced or eliminated is by the use of cones and diaphragms and grids.

**(e) Geometric Unsharpness**

A theoretical point focus would produce a well-define region on a film thus forming a clear image. However the focal spot of an x-ray tube produces an umbra which is surrounded by a blurred region of partial shadow called penumbra, this penumbra cause the geometric unsharpness. It was observed (Bryan, 1974) that the longer the focal spot the longer the penumbra and the longer the distance between the focal spot and the film, the smaller the penumbra.

Penumbra effect can be reduced by increasing the focus to film distance, decreasing object to film distance and decreasing the focal size. WHO (1986) recommended values of focus to object distance for optimum results. In practice a standard optimum distance often 90cm or 100cm, is used for each radiographic examination. Other distance (120cm, 150cm or 180cm) are employed in certain examinations e.g. radiography of the chest and lateral view of the cervical spine. (Bryan, 1974).

**(f) Darkroom Technique**

The film processing plays a significant role in the image quality. Possible changes of error exist leading to films of poor quality and resulting in increased retake rate. From a review of cause of film retake, the important role played by film processing technique is evident. Percentage of the reject films are due to processing fault.

Ayappen and Ambiger (1979) showed that one-third of the film they studied are produced with more than two times the dose expected to receive as a result of poor darkroom techniques. Goldman et al. (1977) also showed that 30% of all retakes, due to improper overall density, could be due to processing variation, which could be prevented through a QA program.

## 2.8 PREVIOUS WORK ON QUALITY ASSURANCE

Many people have carried out surveys in Diagnostic Radiology Department on Quality Assurance Program in many part of the world which include both the industrialised and the developing countries. (Watkinson et al 1983, Donagi et al 1980, Compos de Aranjo, 1980)

A comprehensive study at one of the University hospitals in one of the western pacific countries shows large deviations in the accuracy of the exposure timer of a number of x-ray machines. The deviations recorded ranged from 30 -to 250% (UNSCEAR 1982). Patients in developing countries could receive a much higher exposure than needed for a good quality of radiograph, simply because of malfunctioning of the x-ray machine.

Poor film storage and processing also contributed to a higher patient exposure in developing countries. Dark room facilities are not normally available in most of the x-ray departments, Ayappan and Ambiger (1979) made analyses of more than 150 x-ray Departments in India and found that 131 departments have no darkroom timers and 100 darkrooms have no temperature control system. In conclusion, they gave quantitative information on the excess of radiation resulting from poor darkroom techniques. They estimated that about 34.6% of the

radiographs are produced with more than 2 or 3 times the dose which could normally provide a good picture.

Bandele (1979) observed that many of the general hospitals and private clinics in Nigeria were built without adequate planning. He pointed out that on several occasions, many rooms that could not be put into use were converted to x-ray rooms. The location, size and structural construction of the rooms were not considered. As a result of this, radiation is constantly being directed to occupants of the adjacent rooms.

Henley (1978) observed that it is always cheaper and easier to take the trouble at the design stage and plan properly than to remove walls, re-site services or alter equipment which is much expensive. He then draws some figures of the average size of a radiology department as in Table 2.5.

Table 2.3 Average Size of Radiology Department, ("Architect" includes Access Corridors"Doctors" includes viewing and reporting area; "Patient" includes toilets, cubicles and waiting area.)

| **Allocated as** | |
|---|---|
| **Architect** | **60m$^2$** |
| **X-ray rooms** | **30-50m$^2$** |
| **Patient area** | **30m$^2$** |
| **Film handling** | **30m$^2$** |
| **Doctors** | **20m$^2$** |

A workshop on quality assurance in Europe was organised at the Middlesex Hospital London in 1981 (WHO 1981) and since then the program became of much concern in many countries including the African countries. In 1982, another training workshop was organised by the World Health Organisation

in colaboration with the Institute of Radiation Hygience, Neuherberg, Germany. In 1983, a course in QA was organised in Harare Zambabwe where some African countries attended including Kenya, Liberia, Mauritius Tanzania, Zambia and the host country Zambabwe. These workshops were set to train radiographer in carrying out QA program in their various Departments.

## 2.9 Reject Analysis

Analysis of the number of x-ray films rejected as unsuitable for diagnosis is one of the few quality assurance exercise which provides a quantitative measure of non productive cost (Watkinson, 1984). Recoveanu (1984) pointed out that one of the objective methods of justifying needs and identifying areas where a QA program should be oriented is reject or waste film analysis. The aim of the reject analysis is to identify factors responsible for high repeat rate and to ascertain the major causes of such re-exposure of patients (Jeatha et al 1990).

The factors that are responsible for the repeat exposure are over and under exposure (exposure fault), patient movement, positioning error, processing error, equipment fault, fogging, and miscellaneous.

The definition of these terms is as follows

i. Over exposure (OE). Image is visible but overall density is so high that diagnostic information may not be observed.

ii. Under exposure (UE). Image is visible but overall density is so low that diagnostic information may be missing.

iii. Positioning error (PE). Subject cassette or x-ray tube is improperly located relative to one another such that the area of clinical interest is not clearly demonstrated.

iv. Processing fault (PF). Potentially useful radiograph made unacceptable as a result of fault during the processing cycle.

v. Equipment fault (EF). Film rendered unacceptable due to malfunctions of x-ray equipment or accessory e.g. light beam diaphragm alignment intensifying screen, contact grid etc.

vi. Patient Movement, (PM). Poor resolution due to subject movement, respiratory or otherwise.

vii. Fogging (F). Partial or total darkening of the radiograph due to light or radiation such that diagnostic information may be lost.

viii. Miscellaneous. Film does not fit into existing categories or it is not possible to determine cause of the unacceptable radiograph.

The reject analysis has been made in a number of countries including Nigeria (Marodi 1983, Watkinson and Moores 1984, Bello 1982, Bassey 1997) with a percentage reject ranging from 4-13%. Incorrect exposure normally having the highest percentage followed by positioning error, patient movement and processing fault (Recoveanu, 1984). The studies made, by Recoveanu, on a number of reject analysis carried out in many countries show a dozens of the results studied. This conform the fact that despite its subjectivity, reject analysis can offer valuable information on the quality of radiological imaging.

If one in ten of the radiographs were repeated, the financial burden in United Kingdom (UK) would be 3-4 million pounds annually since the annual cost

of film is approximately 20-30 million pounds (Watkinson et al 1984). Then the reduction in this number of repeat exposure caused in diagnostic procedure could then reduce, significantly the cost and improvement in radiological service. Hendee (1977) shows that one way of reducing the problem of repeat exposure is through QA program which include procedures that help to ensure satisfactory performance of radiographic equipment on a day to day basis.

## 2.10 USE OF SPINNING TOP IN EXPOSURE TIME TEST

Electrical circuit valves, transistors, x-ray tubes, cathode ray tubes and Geiger muller tubes require direct current (d.c). But Alternating current (a.c.) is easier to distribute than direct current, because a.c. voltage can be transformed easily up or down. The d.c. can be obtained from a.c. supply by means of a rectifier, which is a device that only pass current in one direction.

When an x-ray tube is connected to an ax. source, current flows through the tube when the anode of the tube is positive and the cathode is negative. But when the anode change to negative and the cathode positive, the flow of current is then blocked (i.e. no current flows in the tube) and tube radiation is interrupted. This type of tube which prevents the flow of current in the other direction by itself is called a self-rectified tube.

If the a.c. voltage is connected to the tube with a frequency of say 50Hz, this interruption occurs 50 times per second because the tube will only be able to produce x-rays during the positive half of the cycle, namely positive half phase. A full-wave rectifying unit using a 50Hz single phase main supply will produce 100

pulses of current per second through the x-ray tube or one pulse of radiation each half cycle.

Very powerful x-ray units are usually connected to 3-phase main supply. These three a.c phases are fed to the primary winding of a three-phase transformer in which the supply voltages are transformed into high voltages. The secondary winding is connected to each other by means of star or triangular (delta) shaped circuit. The voltage is then directed by means of six rectifiers in such a way that the anode is always supplied with positive voltage and the cathode with negative voltage. During the period of one cycle six pulses occur.

Twelve rectifiers are also used with the secondary winding of a three-phase transformer in order to approach the ideal of a constant light voltage across the tube. This results in twelve half-waves (pulses) for the x-ray tube during the period of time occupied by one complete cycle.

In summary the self-rectified (or half-wave) generator supplied one pulse, the full-wave four-rectifier single-phase generator supplies 2 pulses per cycle, the full-wave six-rectifier three-phase generator supplies 12 pulses per cycle. These facts have led to the generators being described by convenient shorthand expression as one-pulse, two pulses, and six pulses and twelve-pulse generator respectively. Fig.2.5 shows the wave form for the various generators.

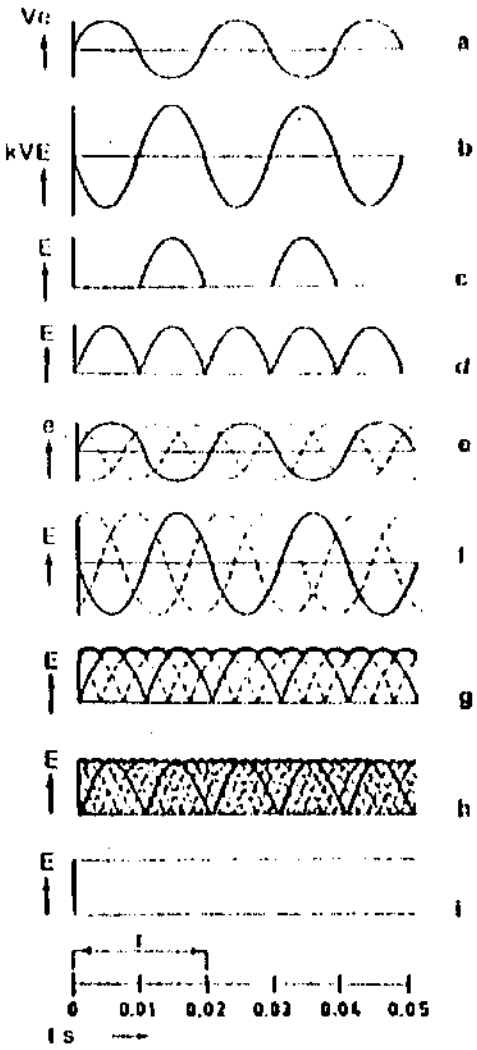


Fig. 2.5 Reproduction of various voltage forms

a. Single-phase primary voltage.
b. Secondary single-phase high voltage without rectification.
c. Half-wave voltage (single-pulse voltage).
d. With four-valve rectification (two-pulse voltge)
e. Primary three-phase voltage
f. Secondary three-phase high voltage without rectification.
g. Six-valve rectification
h. Twelve-valve rectification
i. Pure constant high voltage

The use of these a.c. generators in x-ray machines helps in measuring the accuracy of the exposure time using a spinning top. A spinning top is a simple device capable of providing information about the performance of an x-ray unit.

It involves the use of a radio-opaque disc (the spinning top) with a hole in it as seen in fig.2.6.

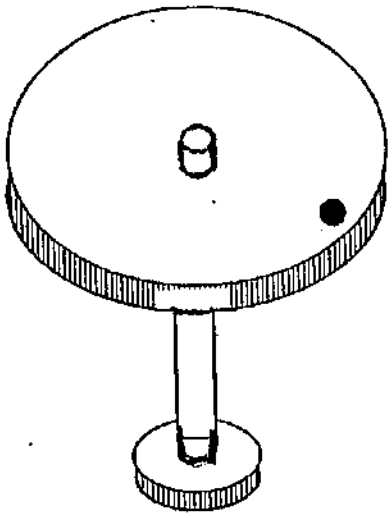

Fig. 2.6 A Spining Top.

A radiograph is made of the top when it is spinning and the pulsation of the x-ray generator is registered on the film as a series of black spot (dots). Each dot has been produced by a single electrical impulse through the x-ray tube, that is, each dot represents a peak in the sine wave or one half-cycle of the supply.

The first pulse of radiation will pass through the hole in the disc to the film. Since the disc is rotating, the second pulse will pass through the hole and fall over different part of the film. The pulse of radiation will therefore be recorded at different position round the circular track described by the hole.

In Nigeria, National Electric Power Authority (NEPA) operates at 50Hz and therefore in 0.1s the machine would record on the film five electrical pulses. Remembering that each dot is a half-cycle, there will be five dots with self-rectified (or half-wave) tube, ten dots with full-wave (four-valve) generator, thirty dots with three-phase (six-valve) generator and sixty dots with (twelve-value) generator.

If the number of dots recorded on the film is greater or less than the expected number then the timer is faulty. Bearing in mind that each single dot represents 0.01s in time, the existence and the extent of the timer fault can be found.

## 2.11 RADIATION DOSE MEASUREMENT

One of the important step in keeping radiation dose to a minimum (ALARA) is to estimate the radiation exposure (doses) received by patient in diagnostic radiology prior to examination. This dose as a function the radiographic parameters (kVp,mAs,TSD and filteration) have been published for the estimation in form of chart and nomogram (ICRP, 1969; McCullough and Cameroon, 1970).

About 20 years ago a set of calculation of skin dose base on the radiographic parameters have become available (Birch et al 1979) since then

many researcher have used this relation (some with little modification) to estimate the dose that will be received by the patient, (Edmonds, 1984; Arun Kumar et al 1991) Kumar et al. 1996). The general formular for the exposure was given by Kumar (1996) as

$$\text{exposure mSv} = \frac{K \times (kVp)^n \times mAs}{(TSD)^2 \times F \times T} \qquad \text{----------(2.10)}$$

where F = total filtration of the machine,

T = type of generator (rectification).

The empirical relationship between output and the other radiographic parameter in equation 2.10. has two constant K and n. Experimentally measured values of output exposure of an X- ray machine at different kVp setting can be put in the equation to calculate the value of the constants (K and n).

The equation can also be written as exposure.

$$mSv\ /mAs = C\,(kVp)^n \qquad \text{----------2.11}$$

where $C = K / \left[(TSD)^2 \times F \times T\right]$

plotting the exposure (mSv /mAs) with kVp the values of K and n can be determined.

# CHAPTER THREE

## 3.0 MATERIALS AND METHOD

### 3.1 MATERIAL USED

**Questionnaires:** the questions covered area such as care of patient, processing procedures, technique in x-ray exposure, equipment management policies e.t.c. as can be see in appendix 4

**Spinning top:** A metal disc which is few millimetres of thickness and is few millimetres of thickness and is designed to revolve easily up a central peg. A point near the periphery of the disc is drilled a small hole. The commonest use of the spinning top is to test the accuracy of operation of the x-ray exposure timer.

**Step wedge:** It is stair way of metal. It is made of aluminium and has fourteen steps, each of about 3mm thick. It is used in investigating consistency of mAs setting.

**Four metal wires (straight wire):** they are used to test light beam diaphragm.

**X-ray Beam Alignment Tool:** It consist of 12.25 cm (6 inch) metal rod which is 1.6 mm (1/6 inch) in diameter. The rod is made to stand vertically on a plastic support.

X-ray films, lead strip, measuring tape, dark room timer and cardboard.

All the test tool used in this research were locally constructed,

(viii) **Densitometer:** - It is a simple densitometer constructed to carry out simple Quality Assurance tests in Radiology units (Oladipupo 2000). It consist of Light Dependent Resistor (L.D.R) that was coupled with Ohm -meter (Multimeter).

## 3.2 METHOD

Numerous publications have described procedures for diagnostic quality assurance progaamme (Hendee et al., 1977, FDA 1979, Hospital Physicist Association (HPA) 1980, Recoveanu, 1981). Some of these procedures as employed in the work are detailed in this chapter.

### 3.2.2 Population

There are twelve (12) hospitals and clinics that have X-ray machines in the survey area. The hospitals were named as Hosp. A, Hosp. B to Hosp. K.

### 3.2.3 Sample Selection

As it is difficult to carry out test in the entire population because of the time and cost, a sample from the population was chosen. A stratified random sampling was employed, in order to obtain the result with better representativeness considering the type of hospitals in the area viz. Teaching Hospitals, Government General Hospitals, and Private Clinics. There are five government hospitals in which two are teaching hospitals and three general hospitals. The rest are private clinics and nursing home.

A sample of hospitals at different levels was selected. Five hospitals, one from the teaching hospitals, two from government hospitals and two from private clinics, were randomly selected. The hospitals selected are Hosp. A.G.H.L.

### 3.2.5 Protective Barrier

A technique for computing the required thickness of structural shielding to reduce exposure to medical radiation workers and members of the general population are already available in literature ICRP Comm. III Report 1960, Gollnick 1985, Cember 1989). The barrier thickness was calculated using equation. 2.7 for the primary protective barrier and equation. 2.9 for calculating secondary protective barrier (barrier for personnel, darkroom and the general public). Measuring tape and meter rule were used in measuring the thickness of protective barriers and the dimension of the radiographic rooms.

### 3.2.6 Test For Exposure Timer

This was checked using spinning top. The timer of an x-ray machine was set for o.l/s and the other factors were also selected at 200 mA and 75kvp. A loaded cassette was placed on the x-ray table and the x-ray tube positioned over it. The film was divided off by means of lead strip, into three sections, of which only one is exposed at a time. The spinning top was placed in the first section and spun with hand. An exposure was then made as the test tool is spinning and the pulsation of the x-ray generator was registered on the film as a series of black dots.

Two further exposures were made each in a different section of the prepared film by changing the exposure time and keeping the other factors constant. The exposures were made at 0.1, 0.2 and 0.5 seconds for the portable

machines and 0.01, 0.02 and 0.04 seconds for high power generators (3 phase). The film was processed as usual and viewed.

A series of dark spot were observed on the x-ray films. The number of spots was counted and this gives the duration of the exposure time.

### 3.2.7 Test for light Beam Diaphragm.

When the tube housing was equipped with a light beam collimator, the congruence of light field with radiation field was checked by exposing a film.

A loaded cassette was placed beneath the x-ray tube. The tube was centered upon the cassette and the diaphragms are closed sufficiently to provide a radiation field which can be contained within the area of the film. The delineator's lamp was then switched on and the edges of the light field were carefully outlined by means of some suitable markers (four straight wires were used). A radiographic exposure was then made at 100m and the film processed. The position of the two field was then compared by observation of the resultant radiograph, as it is easy to observe whether the radiation fields coincides (or fail to coincide) with the position of the markers. The presence, extent and direction of any misalignment are made obvious and the value of misalignment was quantified by measurement.

Ideally the two should superimpose. In practice misalignment by up to 1cm is allowable. (Rehani, 1995). If the misalignment is greater than this value the light beam diaphragm need to be checked by a competent person.

### 3.2.7 Test for Radiographic Beam Alignment

According to National Centre for Devices and Radiological Health, (NCDRH) specification (1988), the x-rays should be perpendicularity to the plane of the film (or to the cassette). If the film is parallel to the label top, the perpendicular of the x-ray beam can be checked using the beam alignment test tool.

The table top was set perpendicular with the x-ray so that the beam will be perpendicular to the table using a spirit level. The tube head was focused on the table at a distance of one meter. The beam alignment tool was then placed in the centre of the light field. A loaded cassette was place on the centre of the bulky tray and the tray was aligned to the tube. The film was exposed at 60kVp and 10 mAs. After the exposure the film was processed. The length of the image formed by the test tool was measured. Perpendicular to within 0.5° if the length of the image is about 1cm. It is within 1° if the image is about 1.7cm and 3° if the image is about 5.2 cm. At lm the misalignment should not be greater than 1.2 (2cm of the image length).

### 3.2.8 Test for the Consistency of the Milliamphere setting.

Any given milliamphere second (mAs) value is expected to give a reasonably constant radiation exposure of x-ray and result in reasonable constant radiographic density whatever the individual value of milliampere and seconds. A procedure for using a step wedge with many steps to test the consistency of the milliampere setting was employed.

A cassette loaded with film was placed on table and the step wedge was placed on one section of the cassette. The rest of the cassette was covered with lead so that it may be used for further exposure in the series of the test. The x-ray tube was then centred on the test tool and the beam collimated just to cover the tool.

The tube head was placed at a distance of one meter from the film and the kilo-voltage at 75kVp. These exposure factors were kept constant throughout the experiment. An exposure was made with one of the set of factors in the series given below:

| | | |
|---|---|---|
| 0.1 sec | 100mA | = 10mAs |
| 0.2 sec | 50mA | = 10mAs |
| 0.5 sec | 20mA | = 10mAs |
| 0.05 sec | 200mA | =10mAs |

After the first exposure was made, other sets of factors in the series were used to make three other exposures with the tool positioned on a different area of the cassette, all other areas being covered with lead. The film was then processed and the results were viewed.

All the images of the step-wedge were assessed by observing the step of each image to see whether they match in density with the corresponding steps in all the radiographs. This was done by visual assessment carefully made on the X-ray illuminator. But to eliminate the uncertainties of subjective judgment a densitometer was also used to measure the densities of each step.

The setting of mAs is faulty if the density in any of the images is out of correspondence by more than one step (Chesney, 1979).

### 3.2.9 Test for Safe-light Illumination

Several methods for checking the safety of darkroom illumination have been reported in literature (van der plaats 1980, Bruce 1980, Crooks 1980, Cahoon 1961, Chesney 1984). But the following procedure is the one chosen for use in this work as described by Chesney (1984), it test the safe light illumination for both exposed and unexposed films.

A cardboard holder that would accommodate a film 18x24 was prepared for making the test. The two edge of the holder were folded over so that the side edges of the film each have a narrow strip which is covered by a folded edge of the cardboard holder and thus shielded from exposure to the safe-lighting as the test is made.

The film to be used was loaded in a cassette. A sheet of lead was used to cover half of the cassette length wise so that the area of film beneath those mask received no x-ray exposure. The other half of the film was given a slight exposure to x-rays at 50kvp, 0.5 mAs and SFD 1.8m (Van der plaat 1980).

All the light on the darkroom were switched off. The cassette was opened in darkness and the film was taken from it and placed in the cardboard holder. The holder was placed on the loading bench at the normal working position. The holder was then covered completely by a large piece of card. The safe-lights were switched on and the card was withdrawn to expose a strip at the upper edge of the film for four minutes. The card was further withdrawn to expose another strip for

two minutes. A series of withdrawal of the card was repeated for one minute, 30 sec, 15 sec and 10 sec. The film was then processed immediately after the last strip exposure for 10 sec, in darkness. It was then examined for the results of the test.

### 3.2. 10 Machine Output Exposure

Five x-ray machines were included in the measurement from four hospitals. Two of the machines were from the teaching hospitals. Pocket dosimeter was employed for the measurement of the output (mSv) at different combination of kVp and mAs. It is a pocket-type quartz-fiber electroscope with an ion chamber. It has accuracy within 110% of the true dose.

The dosimeter was placed at 100cm from the x-ray source to measure the skin-entrance exposure dose. The beam was then collimated to cover the dosimeter. The reading on the dosimeter were noted for different kVp setting, keeping other parameters (like mAs and TSD) constant and then at four mAs settings, e.g. 16, 20, 32 and 40, for each kVp. The mAs were changed by changing exposure time only and keeping mA constant.

# CHAPTER FOUR

## 4.0 RESULTS

### 4.1 INTRODUCTION

This chapter contains the results of the survey. The data collected from the questionnaires distributed were presented here in tabular form. The calculated and measured protective barriers of personnel and general public were also tabulated. Finally the result of the tests conducted on the sampled hospitals was presented.

### 4.2 RADIOGRAPHIC INFORMATION

This is the result of the information obtained from the questionnaires filled in by the radiographers/radiologist as shown in Table 4.1 shows the type and age of the x-ray machines and the time used in developing the films radiographed. The x-ray machines of Hosp. A, D, K and D are made from GEC Medical, Hosp. L, G and E uses Philips while Hosp. B and F uses Medico Budapest.

All the machines are portable (single phase and self rectified) except Hosp. A which has 3 phase x-ray machines. The film used in the hospitals are fast films manufactured from any of the following companies; Agfa, Kodak, Fuji and Konica. The developer and the fixer are also from the same companies. All the hospitals developed their films by inspection; hence they do not have any specific developing time but ranges from 1 min to 5 min depending on the strength of the developer.

They X-ray machines have been in used for more than 10 years except Hosp. G and B machines which are 4 and 2 years respectively. The machines have even been used somewhere before they are installed in the hospitals except Hosp. A and

Table 4.1 Radiographic Information. *

| Hospital | Make of x-ray Machine | Film developing time (min) | Age of x-ray machine(yr.) | Type of machine/phase |
|---|---|---|---|---|
| Arm 1 | G.E.C medical | 3-4 | 22 | High power/ Three phase |
| ARm2 | G.E.C. medical. | 3-4 | 16 | High power/ Three phase |
| B | Medico Budapest | 2-5 | 2 | Portable/single |
| C | G.E.C medical | 2-6 | NA | Portable/single |
| G | Philips | 2-4 | 4 | Portable/single |
| H | G.E.C medical | 1-4 | 16 | Portable/single |
| I | Medico Budapest | 2-4 | 8 | Portable/single |
| D | G.E.C. medical | 2-4 | 27 | Mobile/single |
| E | Philips | 1-3 | 17 | Portable/single |
| K | G.E.C. medical | 2-4 | NA | Portable/single |
| L | Philips | 1-5 | 12 | Portable/single |

### 4.2.2 Parameters of Radiographic Rooms

The length, width, height, thickness of the walls, material used and the type of point or plaster used in the radiographic rooms are tabulated in Table 4.2. Hosp. Has the highest parameter followed by Hosp. while Hosp have the least. All the walls of the x-ray rooms are not made from pure concrete. They are either made from solid blocks or hollow block

Table 4.2 parameters of Radiographic rooms

| Hospital | Length of Floor (m) | Width of floor (m) | Height of Ceiling (m) | Area of Floor ($m^2$) | Thickness of the Wall (cm) | Material of the Wall | Type of Paint/Plaster on Wall |
|---|---|---|---|---|---|---|---|
| ARml | 6.67 | 5.55 | 3.00 | 37.02 | 28.00 | Concrete | Barium plaster |
| A Rm2 | 6.67 | 5.80 | 3.00 | 38.68 | 28.00 | Concrete | Barium plaster |
| B | 3.34 | 2.27 | 2.90 | 6.58 | 28.00 | Block | Barium plaster |
| C | 2.80 | 2.85 | | 7.98 | 25.00 | Block | N.A. |
| G | 4.26 | 2.74 | 2.78 | 11.67 | 28.00 | Block | Barium plaster |
| H | 3.80 | 1.35 | 3.00 | 5.13 | 26.00 | Block | N.A. |
| E | 5.00 | 3.91 | 3.26 | 19.55 | 26.00 | Block | N.A. |
| K | 9.00 | 7.24 | 6.00 | 65.16 | 29.00 | Concrete | Barium plaster |
| L | 4.16 | 3.88 | 2.50 | 16.14 | 25.00 | Block | Barium plaster |

N.A. No Information Available

### 4.3.0 X- RAY PROTECTIVE BARRIER

In calculating the protective shielding requirement, knowing the machine work load of each radiological unit is important. Hence the workload of the machines were calculated using equation 3.9 and the values recorded as shown in Table 4.3

### 4.3.1 Work Load

Table 4.3 shows the information's need to calculate the workload of the various machines. It also shows the result of the workload. It can be seen that the work load is generally low in all the hospitals except Hospital A which has 5,500 mA - min/wk. The low value of the work loads is due to the fact that the machine used are portable ones with maximum milliampere (mA) of 30 mA or less and there is also low patronage of the public for x-ray examination in the x-ray units.

Table 4.3 x-Ray machines work loads.

| Hospital | Max. volt, (k Vp) | Max. current (mA) | Exposure time (s) | Weekly total exam | Workload (mA-min/wk) |
|---|---|---|---|---|---|
| ARml | 125 | 300 | 4 | 275 | 5500.00 |
| ARm2 | 125 | 300 | 4 | 275 | 5500.00 |
| | | | | | |
| B | 100 | 20 | 4 | 75 | 100 |
| C | 85 | 20 | 4 | 7 | 9.33 |
| E | 100 | 20 | 10 | 18 | 60.00 |
| G | 80 | 30 | 8 | 25 | 100 |
| H | 85 | 20 | 4 | 100 | 133.33 |
| K | 100 | 15 | 4 | 3 | 3.00 |
| L | 100 | 20 | 10 | 7 | 23.33 |

### 4.3.2 Primary Protective Barrier Assessment.

Any wall at which the useful beam is normally pointed is designated as primary protective barriers. This is the wall-mounted film holder, which the x-ray beam is sometimes directed when taking chest x-Ray examination. The thickness of these walls was measured and the expected thickness was calculated as in Table 4.4.

All the protective barrier measured are much greater than the calculated value except Hospital A which have the same value.

Table 4.4 primary protectiv e Barrier for the x-ray machines.

| Hospital | Workload (mA-min/wk) | Distance dprim.(m) | K(mSv/mA-min) | Calculated thickness (cm concrete) | Measured thickness (cm concrete) |
|---|---|---|---|---|---|
| A Rm 1&2 | 5500 | 1.80 | $2.36 \times 10^{-6}$ | 28.00 | 28.00 |
| B | 100 | 1.00 | $6.4X10^{-4}$ | 9.00 | 28.00 |
| C | 9.33 | 1.45 | $9.01xl0^{-4}$ | 7.00 | 25.00 |
| E | 60.00 | 2.00 | $4.27xl0^{-3}$ | 5.00 | 26.00 |
| G | 100.00 | 1.50 | $3.60X10^{-4}$ | 12.00 | 28.00 |
| H | 133.33 | 1.20 | $6.91x1^{-4}$ | 8.00 | 26.00 |
| K | 3.00 | 1.60 | $1.37xl0^{-2}$ | 2.00 | 29.00 |
| L | 23.33 | 1.80 | $8.89xl0^{-2}$ | 3.00 | 25.00 |

P=0. 1mSv for uncontrolled and 1 msv for controlled area, U= 25%.

### 4.3.3 Protective Barrier Assessment For X-Ray Personnel

Table 4.5 shows the calculated and the measured thickness of the cubicles required to shield the personnel due to secondary radiation.

The cubicles in the surveyed areas are within the x-ray room and have open tops. Hosp, E, and L are made of concrete while the rest have a 1.5 mm Pb equivalent cubicle, except Hospital A which have both concrete and the lead equivalent.

Table 4.5 protective barrier for x-ray personnel.

| Hospital | Worklord (mA-min/wk) | Distance $d_{sec}$(m) | Ax $10^{-4}$ | K(mSv)/m A-min | Calculated thickness (cm concrete) | Measured thickness (cm concrete) |
|---|---|---|---|---|---|---|
| A | 5500 | 4.00 | 15.0 | $4.85X10^{-1}$ | 8.0 | 25cm+1.5 mmPb |
| B | 100 | 1.50 | 13.0 | $4.33x10^{0}$ | 0.5 | 1.5mmPb |
| C | 9.33 | 1.48 | 10.0 | $5.87x10^{-1}$ | 5.0 | 1.5mmPb |
| E | 60.00 | 2.30 | 13.0 | $1.7x10^{1}$ | <1 | 26 |
| G | 100.00 | 4.00 | 5.0 | 8.0x10* | <1 | NIL |
| H | 133.33 | 0.80 | 10.0 | $1.2xl0^{2}$ | 1.0 | 1.5mmPb |
| K | 3.00 | 1.4 | 13.0 | $1.26xl0^{2}$ | <1 | 1.5mmPb |
| L | 23.33 | 2.53 | 13.0 | $5.28x100^{1}$ | <1 | 25 |

P=1.0mSv U=l,T=l, F=1,F = $400cm^{2}$ dsca =0.5m

### 4.3.4 Dark Room Protective Barrier

As loaded films on cassettes are stored in the dark room for sometimes before use, the need to protect them from stray radiation is necessary. Dealer (1962) reported that the maximum dose in a dark room should be 0.0lmSv/wk (1.0 mrad/wk). Table 4.6 shows the measured and the calculated thickness of the dark room wall. Equation 2.9 was used in calculating the thickness. It is only Hosp.A and H that have calculated value greater or equal to the measured dark room wall thickness.

Table 4.6 protective barrier for dark room

| Hospital | Worklord( mA-min/wk | Distance $d_{sec}$(m) | $Ax10^{-4}$ | K(mSv/mA - min) | Calculated thickness(c m concrete) | Measured thickness(c m concrete) |
|---|---|---|---|---|---|---|
| A | 5500 | 2.94 | 15 | 5.24 $xl0^{-3}$ | 19 | 17.5 |
| B | 100 | 2.5 | 13 | 1.20 $xl0^{-1}$ | 7 | 17.4 |
| C | 9.33 | 1.30 | 10 | 9.06 $x10^{-1}$ | 3 | 17.4 |
| E | 60 | 0.8 | 13 | 2.31 $xl0^{-2}$ | 11 | 17.6 |
| G | 100 | 2.0 | 5 | 2.0 $x10^{-1}$ | 6 | 17.8 |
| H | 133.33 | 0.25 | 10 | 1.20 $xl0^{-3}$ | 18 | 17 |
| K | 3 | 2.0 | 13 | 2.56x10° | 1 | 30.0 |
| L | 23.33 | 1.4 | 13 | $1.6x10^{-1}$ | 6 | 17.8 |

P= 1 m rad (0.01 mSv)

### 4.3.5 Secondary Radiation Protection for General Public

This is the protection of people from scattered radiation, in the waiting rooms, those living in offices adjacent to the radiographic room, those in the houses nearby or people staying in the parking lots. Table 4.7 shows that the calculated wall thicknesss are all less than the measured thickness of the wall. The values of work load (mA-min/wk) and the scattering angle, a, in table 4.6 were used here.

Table 4.7 Secondary protective barrier for the public

| Hospital | Distance $d_{sec}$(m) | K(mSv/mA - min | Calculated thickness(cm | Measured thickness(cm concrete) |
|---|---|---|---|---|
| A | 1.88 | 1.07 $xl0^{-2}$ | 15 | 27 |
| B | 2.1 | 3.40x10° | 1 | 28 |
| C | 1.7 | 7.74x10° | <1 | 25 |
| E | 2.30 | 1.70x10° | 2 | 26 |
| G | 0.35 | 6.13 $x10^{2}$ | 9 | 27 |
| H | 1.10 | 2.27 $xl0^{-1}$ | 6 | 26 |
| K | 4.5 | 1.2$xl0^{0}$ | <l | 29 |
| L | 0.82 | 5.54 $xl0^{-1}$ | 4 | 28 |

Table 4.8 protective barrier for room above the X-ray rooms

| Hospital | Distance dsecCm) | K(mSv/mA - min | Calculated thickness(cm) | Measured thickness of Concrete (cm) |
|---|---|---|---|---|
| A | 2.00 | $6.81 \times 10^{-0}$ | 18.0 | *Zn/Ab |
| B | 1.90 | $6.9 \times 10^{-1}$ | 4.0 | 20 |
| C | 2.07 | $6.61 \times 10^{1}$ | 0.0 | 18 |
| E | 2.26 | $9.92 \times 10^{-1}$ | 2.0 | 21 |
| G | 1.78 | $8.19 \times 10^{-1}$ | 3.0 | Zn/Ab |
| H | 2.00 | $7.5 \times 10^{-1}$ | 3.0 | Zn/Ab |
| K | 5.00 | $1.3 \times 10^{2}$ | 0.0 | Zn/Ab |
| L | 2.50 | 5.2x10° | 1.0 | 17 |

*Zn/Ab Means that the roofing is made with zinc sheets and asbestos ceiling not concrete

For people living in rooms above the x- ray rooms, the required barrier needed to protect the public from the x-radiation was tabulated in table 4.8. It was found that the protective barrier for the people are adequate since the calculate values are all less than the measured values and some of the radiological units (all the government hospitals) were not storey buildings. Hence the hospitals do not have concrete roofings. This would not have any hazard to the public since no one is living above the building.

### 4.3.6 Reject Analysis

Only two of the hospital responds to the request. The hospitals are Hosp. A and G.

In the Hosp. A the analysis was carried out for a period of six weeks. A total film of 1187 was exposed and 134 films were rejected. This gives 11.3% of the rejected films with over exposure of 34%, under exposure of 27%, positioning error 12% processing fault 4%, patient fault 8% fogging 1% and other faults not mention 14%. No any rejected films were found to be due to equipment fault.

In Hosp. G the percentage of the rejected films was 4.2% this was found from a total of 260 films exposed for a period of six month. The reason being; over exposure 9% under exposure 18%, processing fault 27%, equipment fault 9%, patience fault 18%, fogging 9% and other faults 9%.

## 4.4 RESULT OF THE X-RAY MACHINE PARAMETER SETTING TESTS.

The X-ray machine parameters and the darkroom safe light test results are carried in Tables 4.9 to 4.13. The results include the test for exposure time, dark room test, light beam alignment, x-ray beam alignment and the consistency of milliampere second.

### 4.4.1 Exposure Time

Table 4.9 shows the result of the exposure time test carried out. The time exposure setting of 0.1s, for Hosp F, G, E and L, tested showed consistency with the time delivered by the machines; while for the other exposure times tested the time delivered by the machines were greater by 0.02 second. All exposure settings in Hosp. A were found to be the same as the calculated value

Table 4.9 Exposure time setting

| Hospital | Exposure Time Setting(s) | No. of dots | Calculated time delivered by the Machine(s) | Phase/rectification |
|---|---|---|---|---|
| A Room 1 | 0.04<br>0.08<br>0.1 | 4<br>8<br>10 | 0.04<br>0.08<br>0.10 | Three/six valve rectification (3p6) |
| A Room 2 | 0.04<br>0.08<br>0.1 | 8<br>16<br>20 | 0.04<br>0.08<br>0.10 | Three/twelve valve rectification (3P16) |
| E | 0.1<br>0.5<br>1.0 | 5<br>26<br>51 | 0.10<br>0.52<br>1.02 | Single/self-rectified (SP/SR) |
| G | 0.1<br>0.2<br>0.3 | 5<br>11<br>16 | 0.1<br>0.22<br>0.32 | Single/self-rectified (SP/SR) |
| H | 0.1<br>0.4<br>0.6 | 5<br>20<br>31 | 0.10<br>0.40<br>0.62 | Single/self-rectified (SP/SR) |
| L | 0.1<br>0.5<br>1.0 | 5<br>25<br>51 | 0.10<br>0.50<br>1.00 | Single/Self rectified. (SP/SR) |

### 4.4.2 Consistency of milliampere-second

The density of various steps of the radiograph step wedges taken for various mA and exposure time were found to be the same using the subjective assessment and when the simple densitometer was use the optical density of a particular step was found to remain constant in the different mA and S setting within 10% as in Table 4.10

Table 4.10 Optical Density of a Step wedge

| HOSP | $I_0$ | $I_2$ | $I_2$ | $I_3$ | $I_4$ | $I_5$ | $I_6$ | $I_7$ | $I_8$ | $I_9$ | $I_{10}$ | $I_{11}$ | $I_{12}$ | $I_{13}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H | 30.20 | 5.20 | 6.32 | 9.05 | 11.15 | 13.82 | 16.05 | 17.02 | 17.30 | 17.80 | 18.02 | 18.42 | 18.52 | 18.40 |
| | 30.10 | 5.20 | 6.31 | 9.06 | 11.13 | 13.79 | 16.06 | 17.02 | 17.32 | 17.84 | 18.04 | 18.43 | 18.52 | 18.40 |
| | 30.0 | 5.10 | 6.30 | 9.00 | 11.11 | 13.75 | 16.01 | 17.00 | 17.29 | 17.78 | 18.00 | 18.36 | 18.45 | 18.37 |
| G | 28.30 | 11.90 | 13.20 | 14.30 | 15.83 | 17.34 | 18.52 | 19.93 | 20.84 | 21.64 | 22.05 | 22.06 | 22.23 | 22.40 |
| | 28.30 | 11.90 | 13.21 | 14.32 | 15.83 | 17.33 | 18.52 | 19.93 | 20.83 | 21.63 | 22.05 | 22.05 | 22.22 | 22.39 |
| | 28.22 | 11.83 | 13.13 | 14.23 | 15.74 | 17.24 | 18.43 | 19.83 | 20.73 | 21.52 | 22.00 | 22.00 | 22.15 | 22.28 |
| A | 26.61 | 5.93 | 7.33 | 9.24 | 11.54 | 13.53 | 13.65 | 16.13 | 17.04 | 18.19 | 18.78 | 19.13 | 19.12 | 19.32 |
| | 26.60 | 5.92 | 7.33 | 9.23 | 11.54 | 13.53 | 13.66 | 16.15 | 17.05 | 18.19 | 18.77 | 19.13 | 19.12 | 19.32 |
| | 26.60 | 5.92 | 7.33 | 9.22 | 11.53 | 13.52 | 13.66 | 16.14 | 17.03 | 18.18 | 18.76 | 19.12 | 19.12 | 19.31 |
| E | 25.62 | 3.25 | 3.44 | 3.63 | 3.82 | 4.19 | 4.70 | 5.14 | 5.61 | 6.26 | 7.08 | 7.50 | 8.12 | 8.93 |
| | 25.61 | 3.24 | 3.42 | 3.61 | 3.81 | 3.18 | 4.70 | 5.12 | 5.60 | 6.24 | 7.07 | 7.50 | 8.11 | 8.92 |
| | 25.60 | 3.43 | 3.42 | 3.60 | 3.80 | 3.16 | 4.68 | 5.11 | 5.59 | 6.24 | 7.06 | 7.50 | 8.10 | 8.92 |
| L | 27.45 | 6.48 | 7.04 | 8.85 | 11.13 | 13.13 | 14.36 | 16.07 | 16.92 | 18.01 | 18.57 | 19.00 | 19.02 | 19.30 |
| | 27.44 | 6.45 | 7.03 | 8.85 | 11.12 | 13.13 | 14.34 | 16.02 | 16.91 | 18.00 | 18.56 | 19.00 | 19.02 | 19.26 |
| | 27.44 | 6.45 | 7.02 | 8.81 | 11.11 | 13.12 | 14.33 | 16.02 | 19.90 | 18.00 | 18.54 | 19.00 | 19.01 | 19.25 |

### 4.4.3 Light Beam Alignment (L.B.A)

Table 4.11 Mismatch of light and radiation beam at 100cm

| Hospital | A | | E | G | H | L |
|---|---|---|---|---|---|---|
| | Rm1 | Rm2 | | | | |
| X-axis | 1.6 | 1.4 | 1.2 | 3.0 | No L.B.A. | 1.5 |
| Y-axis | 1.4 | 1.2 | 1.0 | 1.2 | No L.B.A. | 1.7 |

Hosp. A; E and L have adjustable diaphragm, Hosp. G has a fixed diaphragm and Hosp. H has no light beam diaphragm attached to it. Table 4.10 shows the mismatch of the light and radiation beam at FFD of 100cm Hosp. G has the highest misalignment with 3cm on x-axis and 1.2cm on y-axis while Hosp. E has the least the mismatch of the beams are all more than the accepted limit of 0.5cm on each axis as quoted by British Institute of Radiology (BIR 1988). Ideally the two should superimpose but a misalignment of up to 0.5cm in practice is allowable.

### 4.4.4 X-Ray Alignment

The length of the images formed by the test object at the hospitals were given in Table 4.12

Table 4.12 Misalignment of X-ray

| Hospitals | ARml | ARm2 | E | G | H | L |
|---|---|---|---|---|---|---|
| Misalignment (cm) | 0.4 | 0.2 | **1.5** | 2.0 | 2.4 | 0.8S |

The test object should ideally, form a dot image on the film if the tube is perpendicular to the film, but if the image formed is not a dot then the e-ray beam is not perpendicular. The central ray is perpendicular to within 0.5 ° if the length of the image is about 1cm. It is within 1° if the image is about 1.7cm and 3° if the image is about 5.2cm at lm the misalignment should not be greater than 1.2°. The result of the rest of the X-ray units is all within the tolerable limit.

### 4.4.5 Darkroom Test.

Table 4.13 shows the first appearance of density increase above the basic fog for exposed and unexposed films in the sample hospitals.

Table 4.13 Darkroom Test Result

| Hospitals | A | E | G | H | L |
|---|---|---|---|---|---|
| Time for unexposed films (s) | 130 | 130 | 70 | 40 | 70 |
| Time for expose films (s) | 130 | 130 | 70 | 40 | 70 |

**4.4.6 Radiation Exposure**

Table 4.14 X-ray exposure out put for the X-ray machine

| X-ray Unit | General or type | Total filter | MSv/mAsx$10^{-2}$atkVp | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 50 | 55 | 56 | 60 | 65 | 66 | 70 | 75 | 76 | 80 | 90 |
| Hosp. A Rml | 3pl2 | 2.7 | 0.73 | - | - | 0.92 | 1.13 | - | 1.24 | 1.46 | - | 1.64 | - |
| Hosp.A Rm II | 3p6 | 2.2 | 1.31 | - | 2.64 | 3.56 | - | 4.06 | 3.29 | - | 6.33 | - | - |
| Hosp.E | SP/SR | 2.5 | 1.24 | - | - | 1.76 | - | - | 2.52 | - | - | 3.28 | 4.65 |
| Hosp.F | SP/SR | 2.0 | 0.22 | - | - | 0.29 | 0.44 | - | 0.65 | - | 0.67 | - | - |
| Hosp.H | SP/SR | 3.0 | * kVp 46 0.33 | KVp 49 0.33 | KVp 52 0.83 | kVp 591.5 | Wp 651.67 | kVp 713.0 | kVp 733.5 | kVp 762.5 | | | |

* The kVp used with Hosp. H is written below the exposure value.

* 3p6 / 3pl2 = Three phase six valve or twelve valve

* SP/SR = single phase /self rectified.

Table 4.14 shows the X-ray exposure output of the X-ray machines determines determined at different kVp setting. The experimental data of the machines were used to determine the values of the constants k and n in the general formula.

Table 14.15 shows the k and n determine from the graphs plotted (appendix 5) with the data collected in table 4.14.

Table 4.15 values of K and n deyermine from the graph

| Hospital | ARml | ARm2 | E | G | H |
|---|---|---|---|---|---|
| K | 0.189 | 0.176 | 10 | 1.0128 | 0.00036 |
| n | 1.752 | 3.109 | 2.22 | 2.95 | 4.66 |

The value of K and n were found to differ from machine to machine

# CHAPTER FIVE

## 5.0 DISCUSSION, CONCLUSION AND RECOMMENDATION

### 5.1.0 Discussion

All the machines surveyed were old models as can be seen in Table 4.1. Most of them were out of stock in the market and their spare part is difficult to get since the manufacturers were not producing them now. This is the reason why Hosp.B, D and J were not able to repair their machines up to the time of the report. The machines were also portable except Hosp A, they have minimum exposure time of 0.1s. Because of this minimum exposure time they cannot carry some special investigations that needed smaller exposure time lower than 0.1s.

The darkroom procedures in all the hospitals investigated were poor. Standard procedure was not properly followed in developing the film radiographed. The films were processed manually and they were not developed according to the chemical manufacturer's instruction or what was written in literature (cahoon 1963, chesney 1969, May and Baker 1971). The standard developing time for optimum result is 4 minutes at 20°C, 3min at 22°C and 2min at 24°C. This is normally what is written at the back of the developer container of Kodak, Agfa and Konica. The developing time for developing films used in the survey area was l-2min for fresh solution (no specific developing time since there is no darkroom timer). There is also no temperature regulator which means that there is no constant temperature at which development is taken place. Processing chemicals were also not replenished when

exhausted. Exposure factors (kVp,mA or S) were then have to be increased in order to get the same quality of good radiograph when the chemical start exhausting. This means increasing the dose received by the patient.

There is need then to standardise the darkroom procedure in order to produce good radiographs and minimise doses receive by the patients. As stated by Donagi et al. (1980), lack of standardisation in the darkroom condition is responsible for over doses to patient.

Cahoon (1963) also shows that errors in judgement introduced as a result of variations in eye accommodation of the low level of illumination and of the opacity of unclear film were much in the processing done by inspection. Therefore developing of films by inspection should be stopped as the use of test exposure charts and the time-temperature method of processing are the optimum procedures for routinely producing radiographs of suitable and uniform quality.

### 5.1.1 Protection

The protection of the primary source of an x-radiation in all the hospitals is less than the calculated values. This means that the barriers were adequate except in Hosp.A where the calculated value was the same as the measured. If the wall was concrete the shielding can be enough, since barium plaster was added to it. But as most of walls were built with solid blocks or hollow blocks which have less attenuation factor than concrete (Blatz, 1964), Lead paint should be added to the wall.

Hosp. G, H and C has windows on the side of the primary beam. These windows can produce leakage of radiation to the public than the value accepted.

Table 4.5 shows the provision of the personnel protection. It is obvious to see that the personnel were adequately protected from the Hosp G does not necessary need any protective barrier, but there is need to build a cubicle so as to optimise the exposure dose (ALARA).

The thickness of barrier that is required to protect darkroom from the x-radiation were presented in Table 4.6. The measurements show that there is inadequate protection in Hosp.A. This is due to the large amount of workload in Hosp.A and the closeness of the x-ray tube with the darkroom wall in Hosp H. When films are kept for some days in these darkrooms the sensitivity of the films to radiation reduce which would result in over exposure of the patient in order to obtain image of acceptable quality. But with the presence of barium plaster on Hosp.A wall it would be adequate. Shifting of the x-ray table in Hosp.H to the other side of the wall (Opposite to darkroom wall) would reduce the scattered rays reaching the darkroom.

The secondary barrier protection requirement was met for the people in waiting room, non- radiation workers living in adjacent offices, houses near by and darkroom lots as was seen on Tables 4.7 and 4.8. This means that the protective barrier for the general public were adequate, except the walls where windows or entrance doors were located. The windows were made from ordinary glass and the doors from plywood except Hosp A that has additional lead sheets on the door.

### 5.1.2 Reject Analysis

The percentage of the reject films found in Hosp A was 11.3%. This value was high but it is within the tolerable value mention by Mazzaferro et al. (1974) but effort can be made to reduce it to a minimum in order to reduce unnecessary dose to the patient. Among the cause of reject, exposure fault has the highest percentage with value of 61% that is more than half of the rejected films. These films may not be actually rejected due to the exposure fault since the processing procedure is not standardised in all the hospitals. Some of the reject may be due to processing fault. Use of exposure chart or automatic exposure time control reduces reject due to exposure fault.

Hosp. G has only 4.4%, this is a very small value obtained when compared with Hosp A. This may be due to the high precision of Hosp. A as it is a teaching Hospital with qualified radiologist and radiographers which analysed the films and they tried to maintain a high standard of radiography and radiology. So a film that is accepted in Hosp.G may be rejected in Hosp A.

There is a close relation with the result of most of the data mentioned in literature (Mazzaferro and et al 1974, Bello 1982, Maldom 1983 Watkinson and Moors 1984) with high percentage of exposure fault, followed by positioning error.

A reject analysis should be conducted regularly. It will provide the information necessary to reduce causes of film wastage and therefore patient dose.

### 5.1.3 Radiographic Tests

(a) For the exposure time test, the machines' timers were in good condition as was shown in Table 4.9. Even though there was increase in some time setting tested of the exposure of 0.0 IS (increase of one dot), this increase appears when the time of exposure was equal to or greater than 0.25. The increase in time does not matter much if very short exposure is not being used (Chesney 1971). This means that all the machines were within the acceptable limit of ± 0.02.

(b) With regard to consistency of mAs all the machines tested were found to have consistent results for the various mAs settings. But it should be noted that Hosp.G and L have a fixed mA setting of 20mA. Hence all the radiographs taken are at 20mA and 0.5 seconds, since the values of mA could not be varied.

(c) There is need for immediate repairs of the light beam alignment to reduce unnecessary dose that would be received. The dose that were received in the surveyed hospitals were large considering the implication of 1cm error in misalignment in terms of volume of tissue unnecessary irradiated for an average patient having PA-AP size of 28cm and 25cm LL-LR, the total chest is between 600 - 900$cm^3$ an error of 1cm mis alignment could have an average over exposure of 700$cm^3$ .This imply unnecessary irradiation of this much volume. The normally occur 2-3 times in a year by a single machine (Rehani, 1995). Hence there is need to carry out this test quarterly so that quick repair can be made if the misalignment exceed the acceptable limit. The principal cause of unnecessary patient exposure in diagnostic radiology was

also shown to be excessive beam size and it can result in gonadal dose many times that which could be delivered by properly collimated x-ray beam (NRPB, 1983 and Morgan, 1966)

(d). If the x-ray beam alignment is not perpendicular to the film, the images may be distorted and diffused. This distortion may be magnified if a grid is used and may cause repeat exposure.

(e). Exposed films are more sensitive to light than those, which have had no exposure. As films, in the darkroom, are found handled under safelight where cassettes are unloaded and reloaded; test for safelight for both exposed and unexposed films were made. The result of the darkroom test shows that the safe lights in the darkrooms were safe for the average period required to process a film. This time include loading and unloading a film into cassette.

(f). The values of K and n were determined as in Table 4.15. These values differ from one machine to the other machine even from the same manufacturer, (eg. 2 machines of Hosp A). The values were found to be significant with the ones found in literature with values of k and n as:

| | K | n |
|---|---|---|
| Edmonds (1984) | 836 | 1.74 |
| Arum Kumar (1991) | 0.0129 | 2.558 |
| Chongule (1993) | 107 | 1.985 |
| Kumar (1996) | 0.00867 | 2.749 |
| | 0.867 | 2.79 |
| | 0.239 | 2.0 |

Previous studies have also shown that variation in K and n occur as the tube ages (HPA, 1977). Uncertainties in accuracy of kVp and mAs would add to these variations. The change in total filtration also adds to the variations.

The values of K and n in Table 14.15 can now be substituted in equation 2.10 eg. For Hosp. A Rm 1 the machine would have a formula.

$$mSv = \frac{0.189\,(kVp)^{1.75} \cdot mAs}{(TsD)^2 \cdot F \cdot T} \quad \text{----------5.1}$$

This formula will be used in estimating the exposure dose for a particular examination at selected parameters, as this is most appropriate since it will not be possible to make it a routine practice to measure the exposure of an X-ray machine always. The formula could also be of help in making a quick comparison of different radiographic technique. For example Air gap technique with conventional technique. Such comparison was made by Edmond (1984) for a particular machine that has been

used by Weather burn (1983) and found that there is a dose reduction by a factor of 10 on adopting the air gap technique.

The value of the dose calculated can also be used to compare with the reference dose. If the dose estimated is higher than the reference dose, then other values of the parameter can be chosen that may give exposure value less than the reference dose.

## 5.2 CONCLUSION

From the work carried out the following conclusion were made based on the information collected and the test carried out.

(i) The distribution of the questionnaire revealed that the developing time for the X-ray units are not constants but ranges from 1 - 6 minutes. It also revealed that that dimension of X-ray rooms of Hosp. B,C,E,G,H and L are not of standard size with values in area 6.58$m^2$, 7.98$m^2$. 19.55$m^2$, 11.67$m^2$ 5.13$m^2$ and 16.14$m^2$ respectively. While Hosp. A and K have standard size of 37.02$m^2$ and 38.68 in Hosp. A, Rm I and Rm II and 65.16$m^2$ in Hosp.K.

(ii) The reject analysis shows that Hosp.A has 11.3% while Hosp.G has 4.2%

(iii) The test carried out for exposure time darkroom test and perpendicularity of X-ray beam tests show that the misalignment of light beam in all the hospitals shows an increase in time of 0.025 for exposure setting of 0.5s and above except in Hosp A. where no sign of increase in time setting was

Shown, all hospitals except in Hosp.H, produces satisfactory results with perpendicularity of X -ray beam Alignment. They have misalignments of 0.4cm, 0.2cm, 2.0cm, 1.5 and 0.8 in Hosp. A,E,G, and L respectively and Hosp. H has 2.4 above the tolerance value.

The misalignment of light beam with X-ray beam in all the hospitals were above the tolerance limit. Finally the value of K and n were found. The values can be used in estimating exposure dose at a particular setting.

## 5.3 LIMITATIONS

1. The study was limited to conventional X-ray machines design for diagnostic purpose only. It does not include other diagnostic machines like CT scanner, Ultrasound and X-ray Therapy machines.

1. The study was also limited to some certain quality control test because of their importance and the availability of test tools.

## 5.4 RECOMMENDATION

1. Further research can be carried out on the test that have not been done on quality assurance test like test on kVp setting ,test and Focus Film distance (FFD) and tightness of cassettes.

2. Detailed studies on the darkroom procedure can also be carried out.

3 Annual workshop and training on radiographic procedures and radiation protection should be organised for the x-ray personnel and dark room technician in order to up date personnel with the current trend in diagnostic radiology.

4. To remove guess work from exposure selection, routine use of exposure charts or Automatic exposure time control should be installed in the machine to ensure consistence exposure. The chart should be regularly up dated.

5. Comparative studies of the actual dose received by patients and the estimated dose could be made for various examinations normally carried out in radiology department

7. A health physicist must be available in every Teaching hospital (medical college) and smaller hospitals should be attached to the medical college for regular check-up.

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# APPENDICES

## Appendix 1:

Occupying Factor for Non-Occupationally Exposed Persons

| |
|---|
| Full Occupancy (T=1) |
| Work area such as offices , laboratories, shops, wards, nurses' stations, living quarters, children's play areas and occupied space in nearby buildings. |
| Partial Occupancy (T=1/4) |
| Corridors, rest rooms, elevators using operators, unattended parking lots. |
| Occasional Occupancy (T/1/16) |
| Waiting rooms, toilets, stairways, unattended elevators, janitors' closets, outside areas used only for pedestrians or vehicular traffic. |

**Appendix 2:**

Use Factors for Primary Protective Barriers (U)

| | Radiographic Installations | Therapy Installations |
|---|---|---|
| Floor | 1 | 1 |
| Walls | ¼ | 1/4 |
| Ceiling | -a | -b |

-a The shielding requirements for the ceiling of a radiographic installation are determined by the secondary barrier requirements rather than by the factor which is generally extremely low.

-b The use factor for the ceiling of a therapy installation depends on the type of equipment and techniques used, but usually is not more than 1/4.

**Appendix 3:**

Ratio, a, of Scattered to Incident Radiation From Trout and Kelley (1972)

| Source | Scattering Angle (From Central Ray) | | | | | |
|---|---|---|---|---|---|---|
| | 30 | 45 | 60 | 90 | 120 | 135 |
| X Rays | | | | | | |
| 50kV | 0.0005 | 0.0002 | 0.00025 | 0.00035 | 0.0008 | 0.0010 |
| 70kV | 0.00065 | 0.00035 | 0.00035 | 0.0005 | 0.0010 | 0.0013 |
| 100kV | 0.0015 | 0.0012 | 0.0012 | 0.0013 | 0.0020 | 0.0022 |
| 125kV | 0.0018 | 0.0015 | 0.0015 | 0.0015 | 0.0023 | 0.0025 |
| 150kV | 0.0020 | 0.0016 | 0.0016 | 0.0016 | 0.0024 | 0.0026 |
| 200kV | 0.0024 | 0.0020 | 0.0019 | 0.0019 | 0.0027 | 0.0028 |
| 250kV | 0.0025 | 0.0021 | 0.0019 | 0.0019 | 0.0027 | 0.0028 |
| 300kV | 0.0025 | 0.0022 | 0.0020 | 0.0019 | 0.0026 | 0.0028 |

**APPENDIX 4**

TOPIC: QUALITY EVALUATION OF DIAGNOSTIC RADIOLOGY DEPARTMENTS IN ZARIA AND SABON GARI LOCAL GOVERNMEN.

RESEARCHER: ALIYU SA'IDU, DEPARTMENT OF PHYSICS ABU, Zaria.

What are the technical specifications of the radiographic machine?

Manufacturer:_____

Type of generator ----------

Tube type _____

Total tube filtration (mmAL)_____

Single or 3 phase:_____

Target angle _____

2. What are the exposure factors?

| Part of Body | FED (cm) | | FSD (cm) | | KVP Range | | mAs range | |
|---|---|---|---|---|---|---|---|---|
| | Adult | Child | Adult | Child | Adult | Child | Adult | Child |
| Chest | | | | | | | | |
| Abdomen | | | | | | | | |
| Shoulder | | | | | | | | |
| Dental | | | | | | | | |
| Skull | | | | | | | | |
| Extremities | | | | | | | | |
| Contrast Studies | | | | | | | | |
| Spine | | | | | | | | |
| Others | | | | | | | | |

If you have more than one x-ray, do you use the same exposure factors for a particular examination?

_____

What is the type of film used?

(I) Screen film

(II) Non-screen film

(III) Both

What is the type of developer used?

_____

What is the time used to develop a film?

_____

What type of shielding is use on the walls of the room in which x-ray is operated?

(I) Lead

(II) Iron

(III) Concrete

(IV) Other (specify)

(V) None

What is the thickness of the shielding material?

_____

What is the area of the floor of the room in which the x-ray is operated?

What is the height of ceiling of the room?

What type of auxiliary apparatus is used in conjunction with x-ray machine to reduce unwanted radiation?

(I) Cones

(II) Diaphragms (fixed or adjustable) *

11. What method is used to stop the scatter radiation, once formed, from the radiograph?

(I) Using secondary grids

(II) Others (specify)

12. What is the load work of a radiographer per day?

13. How many radiographers do you have in the department?

14. What are his/their

qualifications?_____

How many days does a radiographer works per week?

Radiation Badges

*

Are badges available in the department?_____

Are badges worn during exposure? _____

Warning Sign

Is safety information on the machine available? _____

Is there beam on indication? _____

Is the radiation area posted? _____

Do you have any Health physicist?

How many films did you use from February 1998 to February 1999? _____

When was the machine installed?

Appendix 5:

Hospital _____

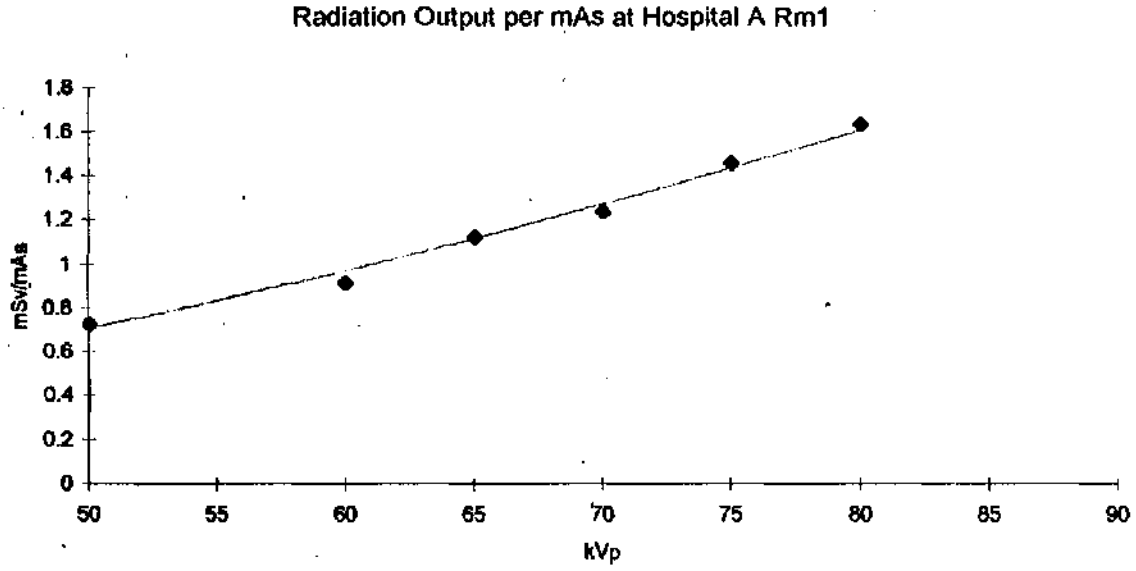
X-ray room _____

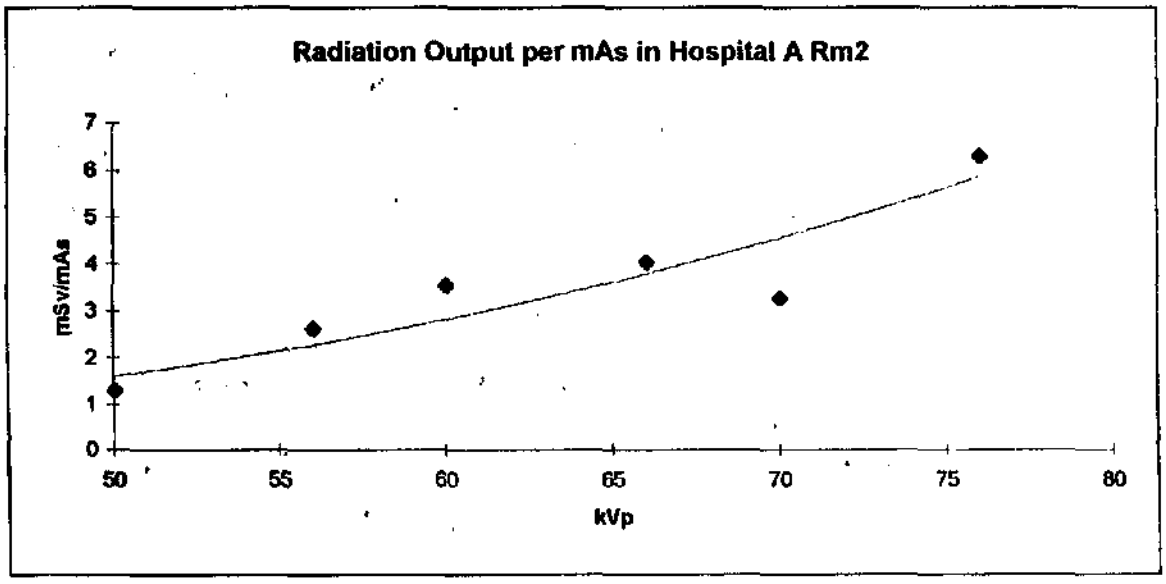
Date _____

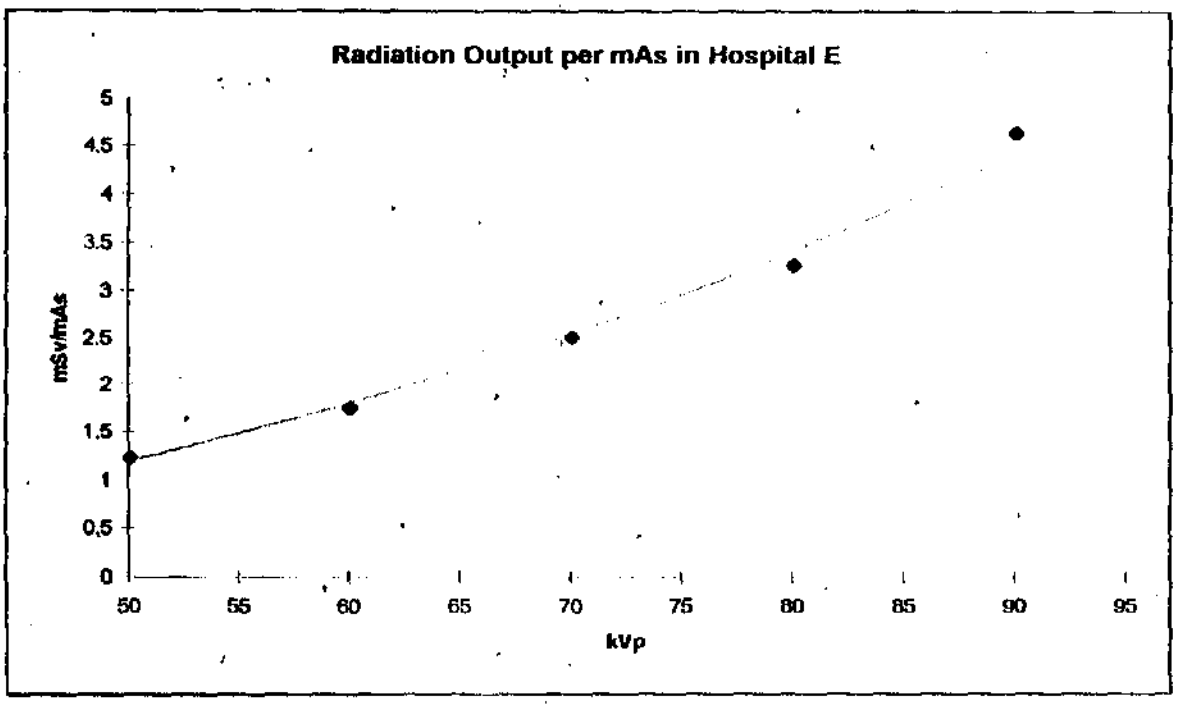
| | over exposure | under exposure | positioning error | processing fault | equipment fault | patient fault | fogging | miscella-neous | total | % |
|---|---|---|---|---|---|---|---|---|---|---|
| Chest | | | | | | | | | | |
| Skull | | | | | | | | | | |
| Abdomen | | | | | | | | | | |
| Spine | | | | | | | | | | |
| Extremities | | | | | | | | | | |
| Contrast Std. | | | | | | | | | | |
| Others | | | | | | | | | | |
| Total | | | | | | | | | | |
| % | | | | | | | | | | |

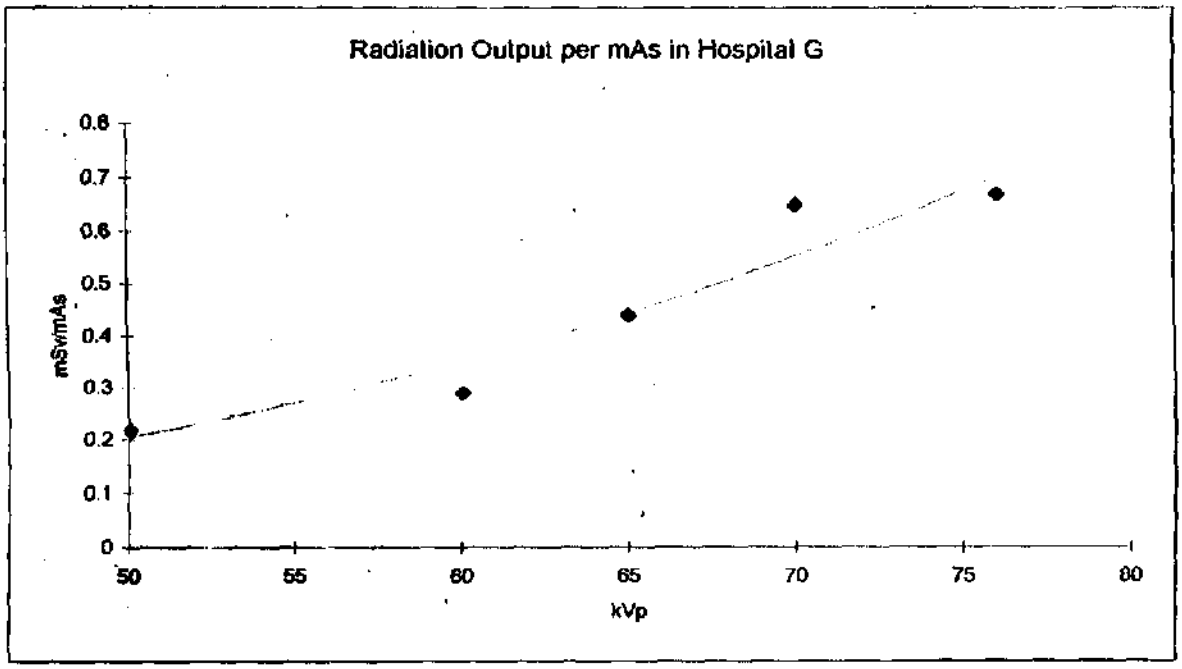
Number of films taken within the period _____

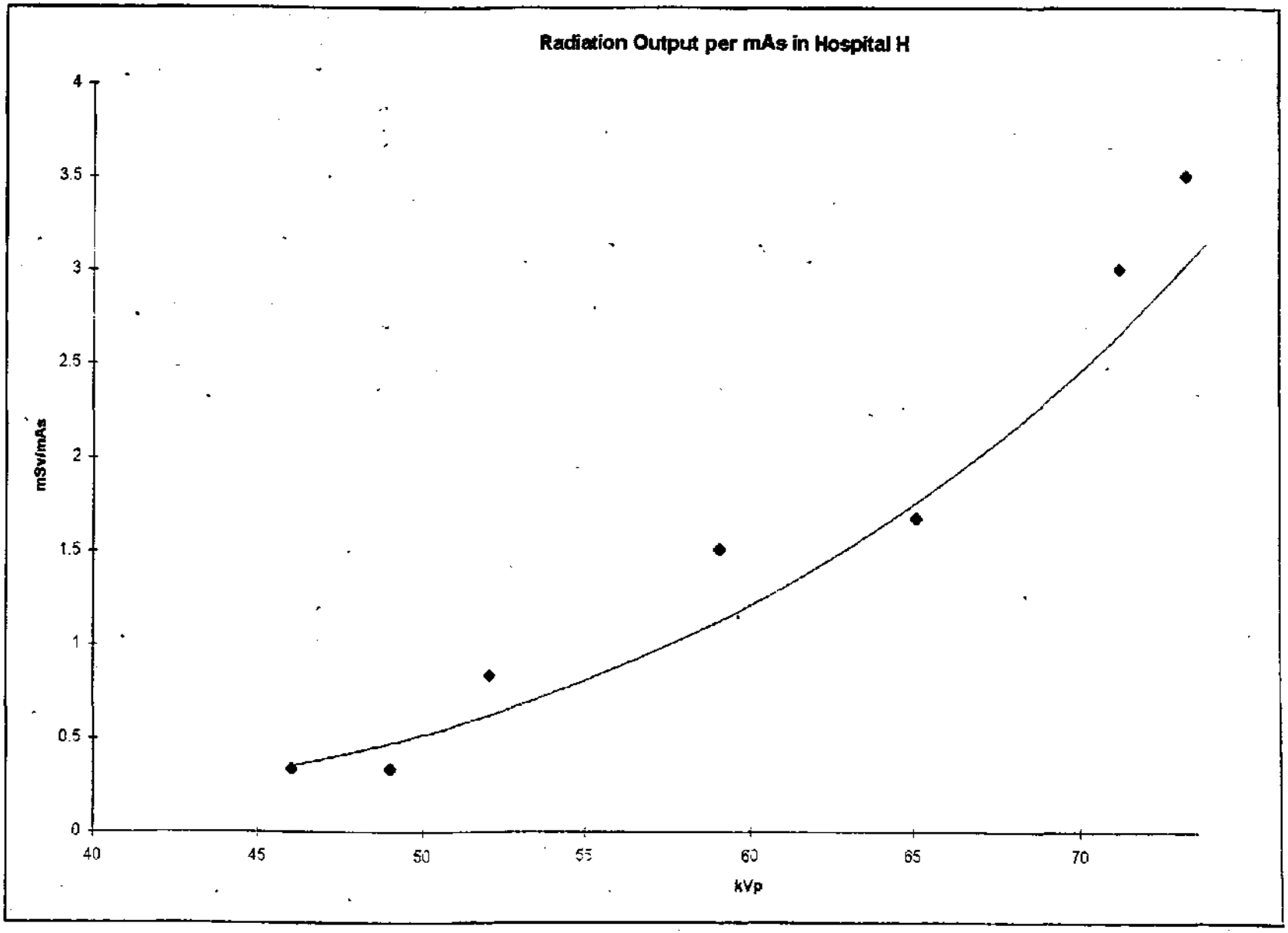
**Appendix 6**


Radiation Output per mAs at Hospital A Rm1
mSv/mAs
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
50
55
60
65
70
75
80
85
90
kVp


Radiation Output per mAs in Hospital A Rm2
mSv/mAs
7
6
5
4
3
2
1
0
50
55
60
65
70
75
80
kVp


Radiation Output per mAs in Hospital E
mSv/mAs
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
50
55
60
65
70
75
80
85
90
95
kVp


Radiation Output per mAs in Hospital G
mSv/mAs
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
50
55
60
65
70
75
80
kVp


Radiation Output per mAs in Hospital H
mSv/mAs
kVp
0
0.5
1
1.5
2
2.5
3
3.5
4
40
45
50
55
60
65
70

Appendix 5: