Sudan University of Science and Technology

College of Graduate Studies

Evaluation of Radiation Protection in the X-ray Departments in the Blue Nile State Hospitals

تقويم الوقاية الإشعاعية في أقسام الأشعة بمستشفيات ولاية النيل الأزرق

A Thesis Submitted in Partial Fulfillment for the Requirements

Of Msc Degree in Medical Physics

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2017

الآيـة

قال الله تعالى :

﴿قَالُوا سُبْحَانَكَ لَا عِلْمَ لَنَا إِلَّا مَا عَلَّمْتَنَا ۖ إِنَّكَ أَنْتَ الْعَلِيمُ الْحَكِيمُ ﴾

صدق الله العظيم

سورة البقرة الآية (٣٢)

Dedication

To my mother who represents a candle that burns to light other people's life.

To my husband and sister who encouraged me to continue this study.

To the teachers and other workers of the College of Medical Radiation Science for their assistance and cooperation.

To all people who gave me support, advice and encouragement.

To my friends and my colleagues.

I dedicate this work

Acknowledgments

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I would also like to express my sincere gratitude to my supervisor **Dr: Salah Ali Fadlalla for** his suggestions, patience, guidance, encouragement, cooperation and supervision of this work.

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Abbreviations	**Meaning**
IAEA	International Atomic Energy Agency
ICRP	International Committee on Radiation Protection
ICRU	International Commission on Radiation Units
Φ	Fluency
Ψ	energy fluence
σ	Cross section
X	**Exposure**
K	kerma
D	Absorbed dose
D_T	Organ and Tissue Dose
W_R	weight factor
W_T	Tissue Weighting Factors
H_T	equivalent dose
E	effective dose
U	Use factor
T	Occupancy Factor
Rf	Risk factor
MD	manufacture date
FS	focal spot
TF	total filtration
M KvP	maximum kilo voltage
M mA	maximum mill ampere
NDT	Non Destructive Testing
SAEC	Sudan Atomic Energy Callibration

Abstract

The aim of this study was to evaluate the radiation protection in the x –ray departments of the Blue Nile State. Four x –ray departments were selected in four hospitals. The study was conducted during the period from March to July 2017. The radiation doses were measurement in the x -ray rooms, dark rooms, doors and offices adjacent to the x-ray rooms using a survey meter.

The final results showed that the doses received by the workers and public in these hospitals were within the scope of the international doses limt specified by the IAEA. However, the rate of doses was high in the Military and Damazin Teaching hospitals due to some errors in the walls and doors designs. Increased protection procedures and correction of departmental design as well as the provision of radiation protection tool should be considered.

المستخلص

تهدف هذه الدراسة لتقويم الوقاية الاشعاعية في أقسام الاشعة بولاية النيل الأزرق . وتم اختيار اربعة اقسام اشعة سينية باربعة مستشفيات في ولاية النيل الازرق . تمت قراءة الجرعة الاشعاعية في كل من غرفة الاشعة السينية والغرفة المظلمه والابواب والمكاتب المجاورة لاستقبال المرضى والمرافقين لقسم الاشعة بواسطة جهاز المسح الاشعاعي .

اثبت النتيجة النهائية ان نسبة الجرعات التي تعرض لها العاملون والجمهور في هذه المستشفيات كانت متوافقة مع المستويات العالمية المحدده بواسطة وكالة الطاقة الدرية . ولكن معدل الجرعة كان عاليا في مستشفي الجيش ومستشفى الدمازين التعليمي ولذلك اوصت الدراسة بزيادة الحماية وتصحيح الاخطاء التصميمية وتوفير ادوات الحماية الاشعاعية.

Chapter one:

Introduction

1.1 Radiation protection

Radiation protection, sometimes known as radiological protection, is defined by the International Atomic Energy Agency (IAEA) as "The protection of people from harmful effects of exposure to ionizing radiation, and the means for achieving this". The IAEA also states "The accepted understanding of the term radiation protection is restricted to protection of people. Suggestions to extend the definition to include the protection of non-human species or the protection of the environment are controversial". (IAEA Safety Glossary - draft 2016)

Ionizing radiation is widely used in industry and medicine, and can present a significant health hazard. It causes microscopic damage to living tissue, which can result in skin burns and radiation sickness at high exposures (known as "tissue" or "deterministic" effects), and statistically elevated risks of cancer at low exposures ("stochastic effects").(United States Nuclear Regulatory Commission 2010, Health and Safety 2011, Swensen etc. 121–124.)

Fundamental to radiation protection is the reduction of expected dose and the measurement of human dose uptake. For radiation protection and dosimetry assessment the International Committee on Radiation Protection (ICRP) and International Commission on Radiation Units and Measurements (ICRU) have published recommendations and data which is used to calculate the biological effects on the human body, and set regulatory and guidance limits. (ICRU and Measurements 2004)

Practical radiation protection tends to be a job of juggling the three factors to identify the most cost effective solution. (www.imagegently.org. 2016).

In most countries a national regulatory authority works towards ensuring a secure radiation environment in society by setting dose limitation requirements that are generally based on the recommendations of the International Commission on Radiological Protection (ICRP). These use the following overall principles:

Justification: No unnecessary use of radiation is permitted, which means that the advantages must outweigh the disadvantages.

Limitation: Each individual must be protected against risks that are far too large through individual radiation dose limits.

Optimization: Radiation doses should all be kept as low as reasonably achievable. This means that it is not enough to remain under the radiation dose limits. As permit holder, you are responsible for ensuring that radiation doses are as low as reasonably achievable, which means that the actual radiation doses are often much lower than the permitted limit. (http://www.oseh.umich.edu/ TrainP32.pdf)

1.2 The Problem of the study

To the best of the researcher's knowledge, and from the experience and observation by the researcher, it was noticed that radiation protection in the study area is totally ignored.

1.3 Objectives

1.3.1 General objective

To evaluate the radiation protection in the X-ray departments of the Blue Nile State hospitals.

1.3.2 Specific objectives

To measure the radiation doses at the supervised and control areas in four x-ray departments.

To compare the measured dose with international levels.

To find out the causes of higher radiation doses if any.

1.4 Thesis Outline

This thesis is concerned with the evaluation of x-ray protection in the Blue Nile State hospitals. Accordingly, it is divided into the following chapters:

Chapter one is the introduction to this thesis. This chapter discusses the objectives and scope of work and introduces necessary background. It also provides an outline of the thesis.

Chapter two contains the literature review with included previous studies and theoretical background.

Chapter three describes the materials and a methods used to measure and explain in details the methods used for calculation.

Chapter four reveals and demonstrates the results of this study.

Chapter five presents the discussion, conclusion and recommendations of the thesis.

Chapter Two:

Literature Review

2.1 Theoretical Background

2.1.1 Introduction

Radiography was the first medical imaging technology, made possible when the physicist Wilhelm Roentgen discovered x-rays on November 8, 1895. Roentgen also made the first radiographic images of human anatomy. Radiography (also called roentgenography) defined the field of radiology, and gave rise to radiologists, physicians who specialize in the interpretation of medical images. Radiography is performed with an x-ray source on one side of the patient, and a (typically flat) x-ray detector on the other side. A short duration (typically less than 1/2 second) pulse of x-rays is emitted by the x-ray tube, a large fraction of the x-rays interacts in the patient, and some of the x-rays pass through the patient and reach the detector, where a radiographic image is formed. The homogeneous distribution of x-rays that enter the patient is modified by the degree to which the x-rays are removed from the beam (i.e., attenuated) by scattering and absorption within the tissues. The attenuation properties of tissues such as bone, soft tissue, and air inside the patient are very different, resulting in the heterogeneous distribution of x-rays that emerges from the patient. The radiographic image is a picture of this x-ray distribution. The detector used in radiography can be photographic film (e.g., screen-film radiography) or an electronic detector system (i.e., digital radiography). (JERROLD T et al 2002)

2.1.2 X-ray production

X-rays are produced in a standard way: by accelerating electrons with a high voltage and allowing them to collide with a metal target. X-rays are produced when the electrons are suddenly decelerated upon collision with the metal target; these x-rays are commonly called bremsstrahlung or "braking radiation". If the bombarding electrons have sufficient energy, they can knock an electron out of an inner shell of the target metal atoms then electrons from higher states drop down to fill the vacancy, emitting x-ray photons with precise energies determined by the electron energy levels. These x-rays are called characteristic x-rays. (http://nobelprize.org)

2.1.3 Basic elements of an X- Ray source assembly

Generator it is power circuit supplying the required potential to the X- ray tube. Collimator it is device producing the x - ray beam.

2.1.3.1 X-ray generator

It supplies the X-ray tube with:

- Current to heat the cathode filament
- Potential to accelerate electrons
- Automatic control of exposure (power application time)
- Energy supply ≈ 1000 × X-ray beam energy (of which 99.9% is dissipated as Thermal energy) Peak voltage value has an influence on the beam hardness (. IAEA training material 2007)

2.1.3.2 X-ray tube

Consist of: Cathode (tungsten filament): heated filament which is the source of the electron beam directed towards the anode (stationary or rotating): impacted by electrons, emits X Rays Metal tube housing surrounding glass (or metal) x ray tube (electrons are travelling in vacuum) Shielding material (protection against scattered radiation).

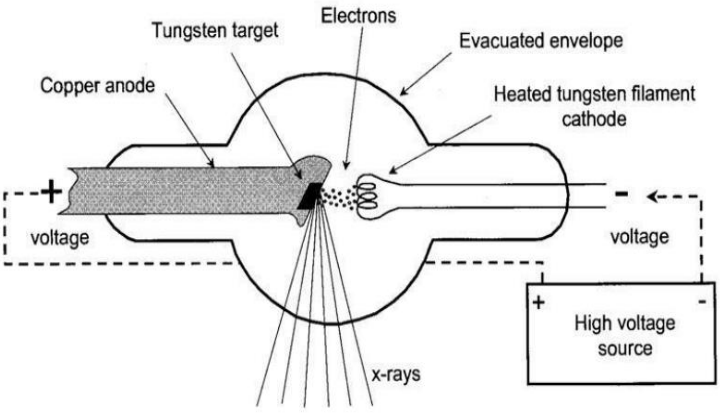

Figure2.1 x-ray tube

2.1.3.3 Cathode structure

- Cathode includes filament(s) and associated circuitry.
- The filament usually made of tungsten material because:
- Its high melting point (3370°C)
- Slow filament evaporation
- No arcing
- Minimum deposit of W on glass envelope.

Modern tubes have two filaments:

- A long one: higher current/lower resolution
- A short one: lower current/higher resolution

2.1.3.4 Anode mechanical constraints

Material, tungsten, rhenium, molybdenum, graphite

Focal spot, surface of anode impacted by electrons

Disk and annular track diameter (rotation frequency from 3,000 to 10,000 revolutions /minute)

Thickness mass and material (volume) heat capacity. (http://nobelprize.org)

2.2 Radiometric Quantities and Interaction Coefficients

2.2.1 Fluency

The fluence Φ, is the quotient dN by da, where dN is the number of Particles incident on a sphere of cross-sectional area da, thus

$$\Phi = \frac{dN}{da}$$

Unit in m^{-2}.

(dosimetry radiology, IAEA, Vienna 2007)

2.2.2 Energy fluency

The energy fluence Ψ, is the quotient dR by da, where dR is the radiant Energy incident on a sphere of cross-sectional area da, thus:

$$\Psi = \frac{dR}{da}$$

(HERMAN CEMBER 1997)

2.2.3 Cross section, σ

The Cross section, σ of a target entity, for a particular interaction produced by incident charged or ungarged particles, is the quotient of cross section for a single target entity when subjected to the particle fluence,Φ, thus

$$\boldsymbol{\sigma} = \frac{P}{\Phi}$$

2.2.4 Exposure (rate), X

Is the quotient of dQ by dm, where dQ is the absolute value of the total charge of the ions of on sign produced in air when all the electrons and positrons liberated or created by photons in air of mass dm are completely stopped in air, thus

$$\mathbf{X} = \frac{dQ}{dm}$$

Unit: c kg^{-1} (ICRU REPORT 60)

2.2.5 Kerma and kerma rate

2.2.5.1 The kerma, K

Is the quotient dEtr by dm, where dEtr is the sum of the Initial kinetic energies of all the charged particles liberated by uncharged Particles in a mass dm of material, thus:

$$K=\frac{dEtr}{dm}$$

Unit: J/kg. The special name for the unit of kerma is gray (Gy).

2.2.5.2 The kerma rate, Ḱ

Is the quotient dK by dt, where dK is the increment of Kerma in the time interval dt, thus.

$$\acute{K}=\frac{dK}{dt}$$

Unit: $J \cdot kg^{-1} \cdot s^{-1}$. If the special name gray is used, the unit of kerma rate is gray per second (Gy/s). (, IAEA, Vienna 2007)

2.2.6 Absorbed dose

The absorbed dose, D, is the quotient by dm, where dέ is the mean energy imparted

$$D=\frac{d\acute{\varepsilon}}{dm}$$

Unit: J/kg. The special name for the unit of absorbed dose is gray (Gy). (Dosimetery in diagnostic radiology, IAEA, Vienna 2007)

2.2.7 Organ and Tissue Dose D_T

The mean absorbed dose in a specified tissue or organ T is given the symbol, D_T. It is equal to the ratio of the energy imparted $\bar{\varepsilon}_T$ to the mass, m_T, of the tissue or organ, thus

$$D_T=\frac{\bar{\varepsilon}_T}{m_T}$$

Table 2.1 shows radiation weight factors from different energy

Type of energy	**weight factor (W_R)**
Photon: all energy	**1**
Electrons: all energy	**1**
Neutrons: energy< 10 KeV	**5**
Neutrons: 10 KeV to 100 KeV	**10**
Neutrons: >100 KeV to2 MeV	**20**
Neutrons: >2 MeV to 20 MeV	**10**
Neutrons: >20 MeV	**5**
Protons: >2 MeV	**5**
Alpha particles, fission fragments, heavy nuclei	**20**

2.2.8 Tissue Weighting Factors (WT)

W_T, for organ T represents the relative contribution of that organ to the total detriment arising from stochastic effects for uniform irradiation of the whole body. Account for fact that the probability of stochastic effects depends on the organ or tissue irradiated. New (W_T) values from ICRP 60 to ICRP 103: Breast: 0.05 → 0.12 increased due to the higher breast cancer risk in juveniles and young women. Gonads: 0.20 → 0.08 decreased due to the reduced hereditary risk Remainder tissues: 0.05 → 0.12 -- using a new additive system W_T values have been introduced for brain and salivary glands as such data for the cancer risks of brain and salivary gland are now available.

Table 2.2 shows tissue factor for some organs and the summation of them

Tissue	$\mathbf{W_T}$	$\sum \mathbf{W_T}$
Bone, breast, colon, lung, stomach, remainder tissues (14)	0.12	0.72
Gonads	0.08	0.08
Bladder, oesophagus, liver, thyroid	0.04	0.16
Bone surface, brain, Salivary gland, Skin	0.01	0.04

Where D_T, R is the absorbed dose averaged over the tissue or organ T, due to radiation R. W_R allows for differences in the relative biological effectiveness of the incident radiation in producing stochastic effects at low doses in tissue or organ, T. The unit of equivalent dose is the joule per kilogram (J kg-1) with the special name of Sievert (Sv)

2.2.9 Equivalent Dose

The equivalent dose, H_T, to an organ or tissue, for a type of radiation, R, it is the product of a Radiation Weighting Factor, W_R, for radiation R and the organ dose, D_T, thus:

$$H_T = \sum W_R D_{T,R}$$

2.2.10 Effective Dose

The effective dose, E, is the sum over all the organs and tissues of the body of the product of the equivalent dose, H_T, to the organ or tissue T and a tissue weighting factor, W_T, for that organ or tissue,

$$E = \sum W_T H_T$$

Where H_T is the equivalent dose in tissue or organ T and W_T is the weighting factor for tissue T**.** (ICRP report 60)

2.3 Radiation units

2.3.1 Gray

The gray (symbolized Gy) is the standard unit of absorbed ionizing-radiation dose, equivalent to one joule per kilogram (1 J · kg -1). Reduced to base units in the International System of Units (SI).

$$1\text{Gy}=1\text{J/kg}.$$

2.3.2 Rad

Before the introduction of the SI units. Radiation dose was measured by a unit called the rad (radiation absorbed dose). One rad is an absorbed radiation dose of 100 ergs per gram.

1rad =100ergs/g and Gy=100rads.

Although the gray is the newer unit and will eventually replace the rad, the rad nevertheless continues to be widely used..

2.3.3The coulomb per kilogram (C/kg)

The coulomb per kilogram (C/kg) is the SI unit of ionizing radiation exposure, and it is the amount of radiation required to create one coulomb of charge of each polarity in one kilogram of matter.. (IAEA training material 2007)]

2.3.4 Roentgen (R)

Is an obsolete traditional unit of exposure, which represented the amount of radiation, required to create one electrostatic unit of charge of each polarity in one cubic centimeter of dry air?

Roentgen = 2.58×10^{-4} C/kg.

2.3.5 Sievert (Sv)

The sievert is the SI unit of equivalent dose, which for X-rays is numerically equal to the gray (Gy).the traditional unit of equivalent dose. For X-rays it is equal to the rad or 10 mill joules of energy deposited per kilogram Sv (Ream) is = 100 rem. (IAEA Radiation oncology physics: 2005)

2.4 Shielding and X -ray room design

2.4.1 Purpose of Shielding

To protect the patients (when not being examined), the X- Ray department staff, visitors and the public and persons working adjacent to or near the X Ray room

2.4.2 Radiation Shielding - Design Concepts

- A floor plan including not only the x-ray room, but also surrounding areas (e.g. office, toilet, waiting room etc).
- The location of the x-ray table and the type and orientation of the equipment.
- The location of any upright bucky or chest stand (used to take x-rays of standing patients).
- Details of what lies above, below and adjacent to the x-ray room, and the nature of the floor, wall and ceiling construction.
- The distances (d) from the x-ray tube and patient to points which are to be used in the calculations.
- The target, or design, weekly radiation dose (P) at each calculation point.

  (IAEA Basic Safety Standards, Interim Edition (2011))

2.4.3 Data required include consideration of

- Type of x-ray equipment.
- Usage (workload).
- Positioning.

- Whether multiple tubes/receptors are being used.
- Primary beam access (vs. scatter only).
- Operator location.
- Occupancy of surrounding areas.

2.4.3.1 The type of equipment

The type of equipment is very important for the following reasons:

- where the x-ray beam will be directed
- the number and type of procedures performed
- the location of the radiographer (operator)
- the energy (kVp) of the X Rays

2.4.3.1 Equipment Positioning

The location and orientation of the x-ray unit is very important:

- Distances are measured from the equipment (inverse square law will affect dose).
- The directions the direct (primary) x-ray beam will be used depend on the position and orientation.
- The x-ray room must be designed with knowledge of the location and use of all rooms which adjoin the x-ray room.
- Obviously a toilet will need less shielding than an office.
- Obtain a plan of the x-ray room and surroundings (including level above and below).

2.4.3.3Types of Radiation beams

2.4.3.3.1 Primary Beam

Collimated from the x-ray tube. Intercepted by the patient, image receptor and some beam-stopping heavy shielding. In a well-designed facility, now seldom a problem.

2.4.3.3.2 Scattered or Secondary Radiation

Main source is the patient, and is normally main source of radiation in a room.

2.4.4 Primary Protective Barrier

A structural surface at which the useful x-ray beam may be directed. Wall A is a primary barrier. (show figure 2.2)

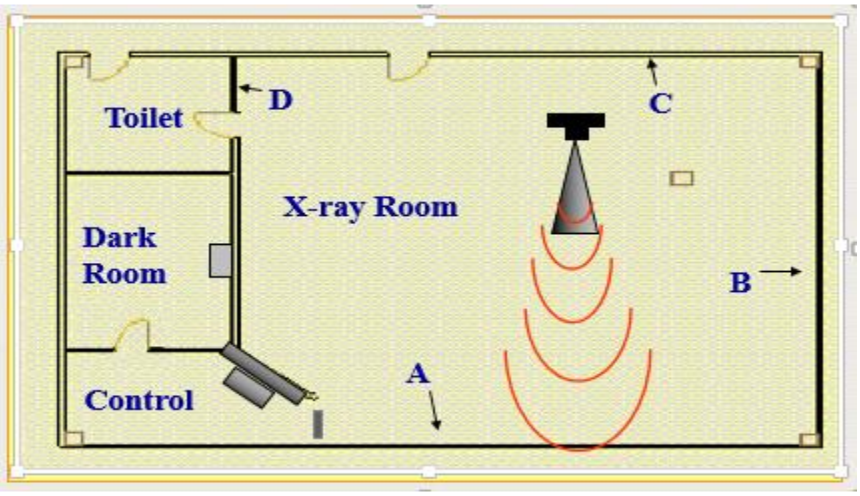

Figure 2.2 shows the Primary Protective Barrier Wall A

2.4.5 Secondary Protective Barrier

Secondary radiation i.e. scatter and leakage radiation show (figure 2.3)

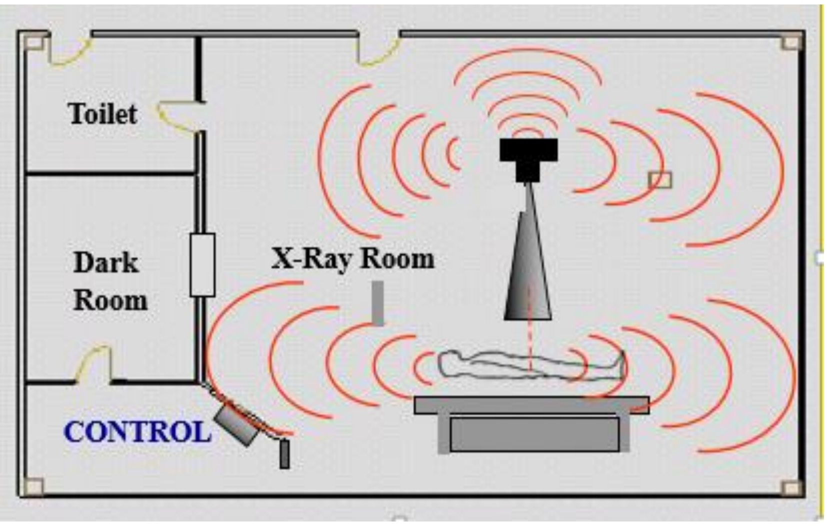

Figure 2.3 shows Secondary radiation i.e. scatter and leakage radiation.

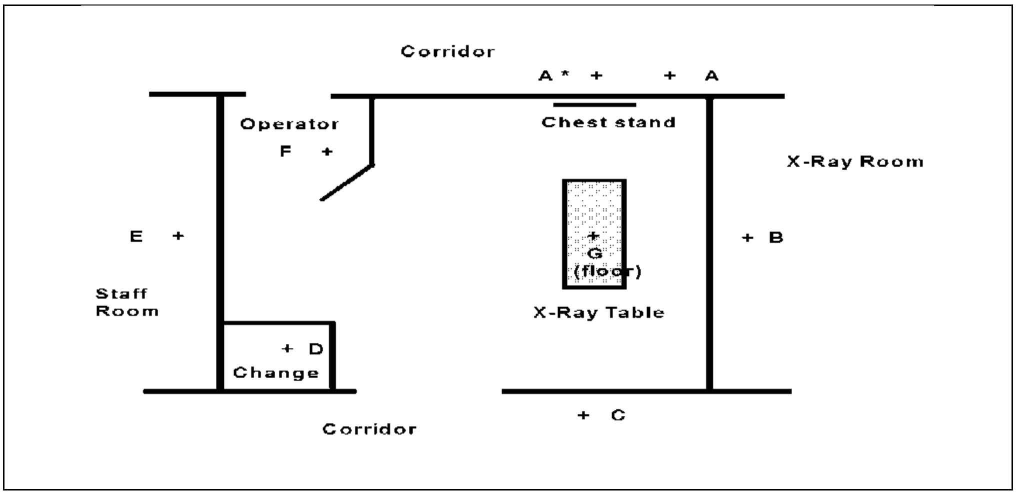

Figure 2.4 General Radiology Room Design/Layout: A to G are points used to calculate shielding

2.4.6 Radiation Shielding Parameters

2.4.6.1 Design dose per week (p) usually based on

5 mSv per year for occupationally exposed persons (25% of dose limit), This averages to 0.4 mSv per week, must only be used in controlled areas, i.e., for radiographers, radiologists, and other radiation workers, 1 mSv for public. Film storage areas (darkrooms) need special consideration long periods of exposure will affect film, but much shorter periods (i.e., lower doses) will fog film in cassettes. A simple rule is to allow 0.1 mGy for the period the film is in storage - if this is 1 month, the design dose is 0.025 mGy/week.

Remember we must shield against three sources of radiation in decreasing importance, these are:

- scattered radiation (from the patient)
- primary radiation (the X Ray beam)
- leakage radiation (from the X Ray tube)

2.4.6.2 Use factor (U)

Fraction of time the primary beam is in a particular direction i.e.: the chosen calculation point must allow for realistic use for all points, sum may exceed 1 for some X Ray equipment, the X Ray beam is always stopped by the image receptor, thus the use factor is 0 in other directions, e.g., CT, fluoroscopy, mammography. For general radiographic and fluoroscopic equipment the primary beam is usually intercepted by the image detector. This reduces shielding requirements for radiography, there will be certain directions where the x-ray beam will be pointed:

- Towards the floor
- Across the patient, usually only in one direction
- Toward the chest Bucky stand.

2.4.6.3 T - Occupancy Factor

- T = fraction of time a particular place is occupied by staff, patients or public
- Has to be conservative

Table 2.3 Ranges from 1 for adjacent offices and work areas, to 1/20 for public toilets and 1/40 for outdoor areas with transient traffic

Area	Occupancy
Work area, offices, staff rooms	**١**
Corridors	**1/5**
Toilets, unttended waiting rooms	**1/20**
Outdoor area with transient traffic	**1/40**

2.4.7 Shielding - Construction Problems

2.4.7.1 Some problems with shielding materials

- Brick walls - mortar joints.
- Use of lead sheets nailed to timber frame.

- Lead inadequately bonded to backing
- Joints between sheets with no overlap
- Use of hollow core brick or block
- Use of plate glass where lead glass specified

2.4.7.2 Problems in shielding - Brick Walls & Mortar Joints

- Bricks should be solid and not hollow
- Bricks have very variable X Ray attenuation
- Mortar is less attenuating than brick
- Mortar is often not applied across the full thickness of the brick

2.4.7.3 Problems in shielding - Lead inadequately bonded to backing

- Lead must be fully glued (bonded) to a backing such as wood or wallboard
- If the lead is not properly bonded, it may peel off after a few years
- Not all glues are suitable for lead (oxidization of the lead surface) Problems in shielding - Joins between sheets with no overlap
- There must be 10 - 15 mm overlap between adjoining sheets of lead
- Without an overlap, there may be relatively large gaps for the radiation to pass through
- Corners are a particular problem
- Penetrations for electrical boxes and ducts are of concern

2.4.7.4 Problems in shielding - Use of plate glass

- Leaded glass or acrylic should be used for windows.
- Laminated layers of plate glass can be used where radiation levels are low.

2.4.7.5 Radiation Shielding – Construction

- Continuity and integrity of shielding very important
- Problem areas:
    - joints

- penetrations in walls and floor
- window frames
- doors and frames

Table2.4 Shielding – Construction

Building Materials	**To shield**
Lead sheet and lead products	**Floors and CeilingsDoors**
Concrete and concrete Blocks	**Windows Staff Areas**
Gypsum Wallboard	**Joints, Services, Openings and Perforations**
Lead Glass	**Joints, Services, Openings and Perforations**
Lead Acrylic	**Joints, Services, Openings and Perforations**
Brick	**Assessment of Shielding**

2.4.8 Risk factor

The quotient of increase in probability of stochastic effect and received dose. It is measures sv^{-1}

$R_f = \Delta$ probability / Δ dose

2.4.9 Exposure

Exposure is Similar definitions to ICRP; Occupational Exposure, Public Exposure and Medical Exposure

2.4.9.1 Medical Exposure

"Radiation exposure of patients occurs in: Diagnostic, Interventional and Therapeutic procedures, while voluntarily helping in the support of patients; and by Volunteers in a programmer of biomedical research involving their exposure."

2.4.9.2 Public Exposure

All exposures of the public other than the occupational exposure and medical exposure.

- A broad range of different natural and manmade radiation sources contribute to the exposure of members of the public.
- The component of public exposure due to natural sources is by far the largest.

2.4.9.3 Occupational Exposure

“All exposures of workers incurred in the course of their work, with the exception of exposures excluded from the Standards”.

- From potassium-40 in the body,
- From cosmic rays at the earth’s surface, and
- From unmodified concentrations of radionuclides in raw materials.

2.5 Previous studies

There are many authors were made studies in this way for example Dindar S. Bari,, et; al April 2015, Measurement of the Effective Dose Radiation at Radiology Departments of Some Hospitals in Duhok Governorate.. Found that the most hospitals barriers (doors and walls) are not appropriate to the standards except 2 hospitals. Moreover, there are risks of high radiation for patients and people visiting X-rays departments of most hospitals as well as risks for clinical staff working at those X-rays departments. The maximum effective doses were measured in uncontrolled area of Khazer hospital which was 82.48 ± 0.73 mSv·yr−1 that was much more than the reference dose limits and in controlled area of Haval Banda Zaroka hospital which was 12.98 ± 0.16 mSv·yr−1. In result, the knowledge about the radiation dose affecting the radiologists and public in the selected hospitals was obtained, and by informing the radiologists and the hospitals managements, the necessary regulations would be planned. In addition, radiologists radiologists is not known. After data collections and analysis, it was found that radiation protection principles are neglected in most hospitals of Duhok governorate.

Another authors P.A. Oluwafisoye et; QUALITY CONTROL AND ENVIRONMENTAL ASSESSMENT OF EQUIPMENT USED IN DIAGNOSTIC RADIOLOGY May 2010 Found that the dose rate is high within the entrance door in GHL (m1) and NARH, it is greater than the background dose rate by a factor of 6 and 7.5 each. In addition, the dose rate measured at the waiting lobby of the patients is comparable with the background dose rate in PSH and NARH, but higher than the background dose rate by a factor of 10 in NOH. The high dose rate experienced in NOH could be attributed to damaged door of the X-ray units. Another possible explanation for the high dose rate at the waiting lobby is the direct link between the lobby and the X-ray machine. It is interesting to note that there were no leakages experienced in the five X-ray units investigated as reported in the earlier study carried out in Nigeria (Oluwafisoye et al., 2009).

Chapter Three:

Materials and Methods

3.1 Materials

3.1.1 X-ray departments: - used four X-ray departments include different X- ray machine. The characteristics of these machines are shown on table (3.1) below

Table (3.1) Type and main characteristics of X- ray machine

Center	Manufacturer	MD	Type	FS (mm)	TF(mm)	M KVp	M mA
Military	Siemens Spain	June 2006	Mobile	1.0	2.0 Al	125	50
Police	Shimadzu Japan	July 2014	Fixed(SFR)	1.2	1.5 Al	150	45
Insurance	Shimadzu Japan	Jan 2010	Fixed(SFR)	1.0	1.5 AI	150	15
DTH	Shimadzu Japan	Jan 2009	Fixed	1.0	1.0 Al	150	50

Where:

DTH is Damazeen teaching hospital, **MD is** manufacture date**, FS is** focal spot**, TF is** total filtration at125 kv, **M KvP is** maximum kilo voltage **and M mA is** maximum mill ampere**.**

3.1.2 Survey meter

Survey meter shown in figure (3.1) was used to measure the scatter radiation and leakage in the control unite,outside (door + receptions) and in the dark room to four hospitals by measure the dose in higher level of exposure practice in each hospitals.

Certificate No.: SAEC/44/017
Date of Calibration: 1/3/2017
Calibration Factor C_f = 1.00
Re-Calibration due: 1/3/2018
Khartoum-Sudan

Figure (3.1) shows X5C plus survey meter.

3.1.2.1 Fields of application

NDT, Diagnostic radiology, Fire Brigades, Civil Defense, Authorities, Customs, Shipping Companies, Nuclear Medicine, Nuclear Technology, Industry, Chemistry, Research

3.1.2.2 Technical Data for survey meter

The survey meter which used in this study was made in Germany and calibration in Khartoum Sudan in SAEC on 1 - 3 - 2017 which has a fallowing technique as shown in table (3.2)

Table (3.2) shows the technical data for XC5 plus which used in the study

PTB-approved dose rate measuring range	1.0 µSv/h $\leq \dot{H}^*(10) \leq$ 20 mSv/h
Dose rate indication range	0 nSv/h $\leq \dot{H}^*(10) \leq$ 20 mSv/h
Dose indication range	0 nSv – 10 Sv
Energy range	40 keV up to 1.3 MeV
Dose alarm thresholds	4, free programmable in the range of 1 µSv up to 10 Sv, acknowledgeable
Dose rate alarm thresholds	4, free programmable in the range of 1 µSv/h up to 20 mSv/h, acknowledgeable
Temperature range	-30°C up to +60°C
Power supply	9V battery 6LR61 or optionally 9V accumulator
Acoustic alarm	80 dB(A) measured in 30 cm distance
Dimensions/Weight	(152 × 82 × 39) mm approx. 400 g (with battery)
PTB Approval No.	23.51/04.01
German Fire Brigades Approval No.	705488

3.1.3 Meter

Meter shown in figure (3.2) was used to measure the distance in departments under study. The meter (abbreviation, m; the British spelling is meter) is the International System of Units (SI) unit of displacement or length.

Figure (3.2) shows the meter used for measurement.

3.2 Methods

3.2.1 Methods of data collection

By using data sheet and questionnaires for staff and measuring the areas related to radiation (Reception, control room and proceeding room for films), Also drawing the x-ray rooms and the rooms around the x-ray department.

3.2.2 Methods of data analysis

The data was analyzed by statistical package for social studies (SPSS), Microsoft excel.

3.3 Place of study

This study was conducted in the X - ray departments at the Blue Nile State.

3.4 Duration of study

This study was conducted during the period from March to July 2017.

3.5 Sample of study

Four hospitals were involved in this study, namely Damazeen Teaching Hospital, Police Hospital, Insurance Health Hospital and Military Hospital.

Chapter four:

Results

4.1 Demographic data

Table 4.1 data collected in all hospitals

Hospital	Number of Staff		Number of Cases	Number of Shifts
	Male	female		
Military	2	0	15	3
Police	1	1	26	2
Insurance	1	1	30	2
DTH	1	6	15	3
Total	5	8	21.5±7.68	2.5±0.58
	13			

4.2 measured data

Table 4.2 shows the measured doses (per hour) at door and reception, control room, dark room and office around the x-ray department

Hospital	Door	Control	Dark room	Office
Military	565 µSv	187.5 µSv	73.8 µSv	73nsv
Police	94nsv	121nsv	45nsv	45 nsv
Insurance	252nsv	51nsv	48 nsv	45 nsv
DTH	129.8 µSv	177.3 µSv	69 nsv	70 nsv

Table 4.3 shows the measured doses (μSv) for staff per day (per number of cases), per year (240 day)

Hospital	Dose per hour	Dose per sec	Dose per time case	Dose per Day	Dose per Year $_{\text{case}}$
Military	187.5	0.05208	0.02604	0.1302	31.248
Police	0.121	0.00003	0.00002	0.00026	0.0624
Insurance	0.05	0.00001	0.00001	0.00015	0.036
DTH	177.3	0.04925	0.02463	0.12315	29.556

Table 4.4 measuring doses (μSv) for supervise area (public, door) per day (per number of cases), per year (240 day)

Hospital	Dose per hour	Dose per sec	Dose per time case(.5sec)	Dose per Day$_{\text{case}}$	Dose per Year $_{\text{case}}$
Military	565	0.15694	0.07847	0.39235	94.164
Police	0.094	0.00003	0.00002	0.00018	0.0432
Insurance	0.252	0.00007	0.00004	0.0004	0.096
DTH	129.8	0.03606	0.01803	0.09015	21.636

Table 4.5 measuring doses (μSv) for supervise area (public, office) per day (per number of cases), per year (240 day)

Hospital	Dose per hour	Dose per sec	Dose per time case(.5sec)	Dose per Day	Dose per Year $_{\text{case}}$
Military	0.073	0.00002	0.00001	0.00005	0.012
Police	0.045	0.00001	0.000005	0.00005	0.012
Insurance	0.045	0.00001	0.000005	0.00005	0.012
DTH	0.070	0.00002	0.00001	0.00005	0.012

Table 4.6 measuring doses rate (µSv) for staff per day, week and year

Hospital	Dose per hour	Dose * 8	Dose *8*6	Dose *8*6*50
Military	187.5	1500	900	450000
Police	0.121	.968	5.808	290.4
Insurance	0.05	.4	2.4	120
DTH	177.3	1418.4	8510.4	425520

Table 4.7 measuring doses rate (µSv) for supervise area (public, office) per day, week and year.

Hospital	Dose per hour	Dose * 8	Dose *8*6	Dose *8*6*50
Military	0.073	0.584	3.504	175.2
Police	0.045	0.36	2.16	108
Insurance	0.045	0.36	2.16	108
DTH	0.07	.56	3.36	168

Table 4.8 measuring doses rate (µSv) for supervise area (public, door) per day, week and year

Hospital	Dose per hour	Dose * 8	Dose *8*6	Dose *8*6*50
Military	565	4520	27120	135600
Police	0.09	0.72	4.32	216
Insurance	0.25	2.00	12.00	600
DTH	0.13	1.04	6.24	312

Table 4.9 measuring doses (mSv/sec) **per year per cases in day in hospitals**

Hospital	staff	**supervise area** (public,door)	**supervise area (public, office)**
Military	0.03125	0.09417	0.000012
Police	0.00006	0.00004	0.000012
Insurance	0.00004	0.000069	0.000012
DTH	0.02956	0.02154	0.000012

Table 4.10 measuring doses rate (mSv) **per year**

Hospital	Staff	**supervise area** (public,door)	supervise area (public office**)**
Military	450	135.6	0.1752
Police	0.2904	0.216	0.108
Insurance	0.12	0.6	0.108
DTH	425.52	0.312	0.168

Table 4.11 measuring doses rate (mSv) **per year in the Blue Nile Stata**

Staff	**supervise area** (public,door)	**supervise area (public office)**
218.98 ±252.82	34.18 ±67.61	0.14 ±0.04

Chapter five:

Discussion, Conclusion and Recommendation

5.1. Discussion

This study was done on four X- ray departments in Blue Nile state. The main objective was to evaluate the radiation protection at four x-ray department.

From table (4.1), were show the hospital and number of staff according to number of cases and shift, in Military hospital two male with 15 cases and three shifts. In police hospital male and female with 26 cases and two shifts. In Insurance hospital male and female with 30 cases and two shifts. In Damazin Teaching Hospital male and six female with 15 cases and three shifts. In this table was noticed that the repeated images in the Military hospital was higher than other hospitals and this gives an extra unjustified dose to the patient.

Table (4.2), represented the measurement of radiation at the variables door, control panel, dark room and offices around the x- ray department. As for the military hospital, the measurements were 565 µSv, 187.5 µSv, 73.8 µSv, and 73nsv respectively. In police hospital the measurements were 94nsv, 121nsv, 45nsv, 45 nsv respectively. In Insurance hospital the measurement was 252nsv, 51nsv, 48 nsv, 45 nsv respectively. In Damazin Teaching Hospital the measurements were 129.8 µSv, 177.3 µSv, 69 nsv, 70 nsv respectively. In this table it was noticed that the doses in the control and door in the Military hospital and Damazin Teaching Hospital were high compared to the police and Insurance hospitals because there were some defects inside the x – ray rooms, for example, the window in the control room had no glass or lead and there were gaps in the doors. The radiation technologists were exposed to high radiation as shown on the above mentioned table. In the same table, the dose was measured in the offices adjacent to the x – ray rooms in the four hospitals, which was very low, which indicates good design and increased protection in the wall between them..

Table (4.9), represented the measurement for staff and the public. In four hospital, the doses received by the staff and public were at the background level.

In table (4.10), the radiation doses were estimated - if the work time was assumed to be 8 hours in 6 days per week in 50 weeks per year, the measurement for staff and public (supervised area(door, office)– to be as follows: in military hospital measurements was 450, 135.6 and 0.1752 mSv respectively. In the police hospital, the measurements were 0.2904, 0.216 and 0.108 mSv respectively. In the Insurance hospital the measurements were 0.12, 0.6 and 0.108 mSv respectively. In the Damazin Teaching Hospital the measurements were 425.52, 0.312 and 0.168 mSv respectively. That table showed that the dose rates in the Military hospital and Damazin Teaching Hospital were higher than the international dose allowed by report of ICRP 147 for the staff and public, and also worst than what was reported in a similar study in Duhok Governorate, from the effective doses were measured in uncontrolled area of Khazer hospital which was 82.48 ± 0.73 mSv·yr−1 that was much more than the reference dose limits and in controlled area of Haval Banda Zaroka hospital which was 12.98 ± 0.16 mSv·yr−1. In result, the knowledge about the radiation dose affecting the radiologists and public in the selected hospitals was obtained. But in the police and Insurance hospitals were better than that study in Duhok.

Table (4.11), such as the doses rate (mSv) per year measured in the Blue Nile Stata hospitals for staff and public (supervised area (door, office) were 218.98, and 17.16 mSv·yr−1. In this table it was noticed that the doses rate in the Blue Nile Stata hospitals were much more than the reference dose limits.

5.2. Conclusion

This study was conducted in four Blue Nile state hospitals to evaluate the radiation protection, during the period from March to July 2017. The study showed that the dose rates in the Military hospital and Damazin Teaching Hospital were higher than the international dose allowed by the report of ICRP 147 for the staff and public. Other radiation dose rates to the staff in the Police and Insurance hospitals were within the standard doses according to the researcher estimation which may be different to the real doses received by the staff and public i.e. lower than the estimated doses. The estimation was based on the assumption that each member of the staff works 8 hour, 6 days per week, and 50 weeks per year.

5.3. Recommendations

A medical physicist and / or a radiation safety officer in all departments of radiation should be appointed and radiation protection tools and measurement devices should be provided.

Health provider should support and encourage staff in radiology department to consider the importance of an effective radiation protection program which should be designed for each department.

The radiation protection regulations and laws in Sudan should be updated to be more flexible and progressive than they are now to encourage and facilitate the research procedure.

The radiation technologists and other staff members should undergo regular training courses to be updated to the radiation protection developments.

All radiation buildings should be designed in such a way as to meet the requirements of the international radiation protection rules.

-To ensure the quality of the design, a periodic of the doors and walls should be done in the x –ray department.

-The future studies should include large number of x-ray departments in Blue Nile State and in other areas in Sudan in order to obtain more reliable results in radiation protection field.

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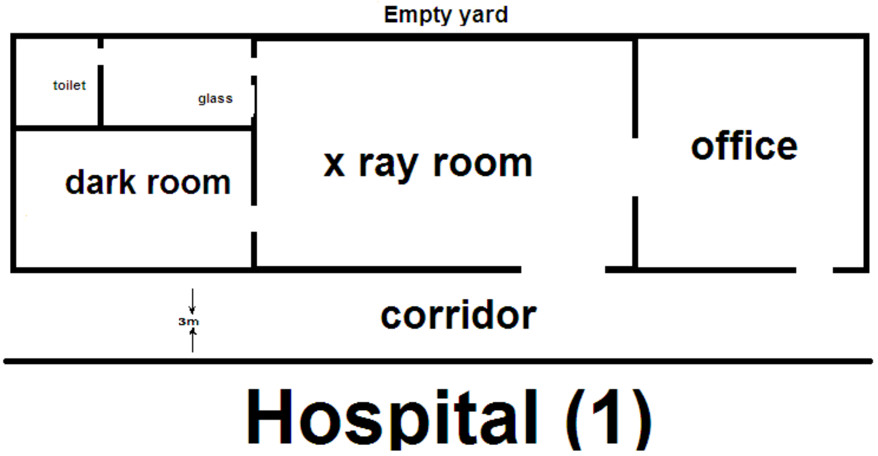
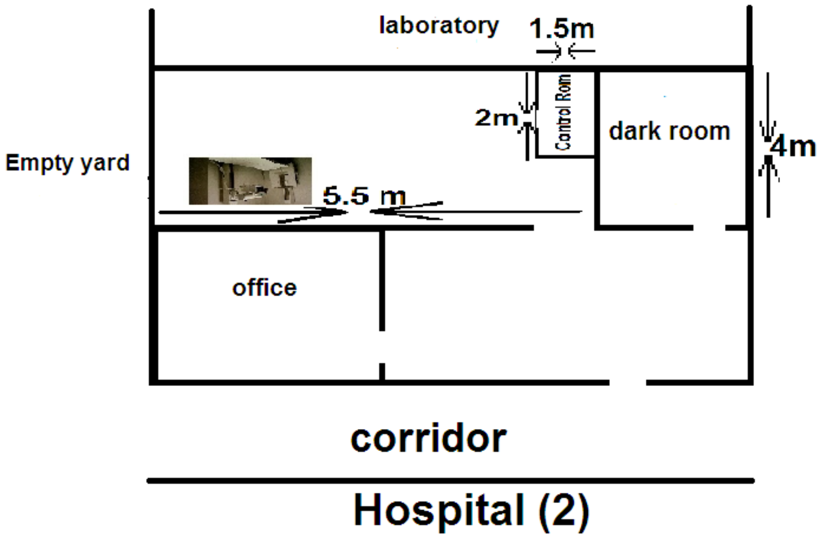
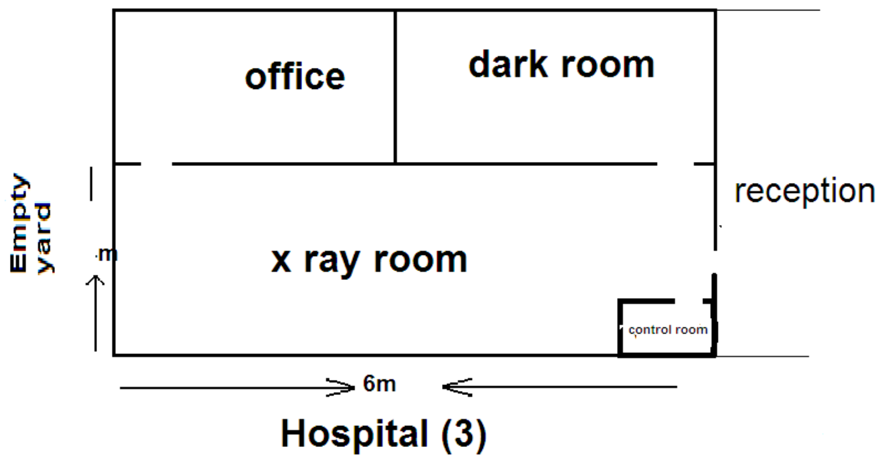
Appendices



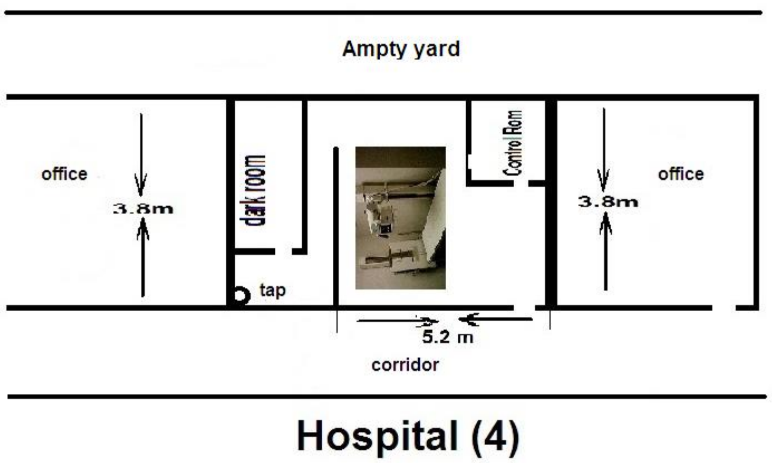
Appendix 4.1 shows the design of X- ray department at the military hospital



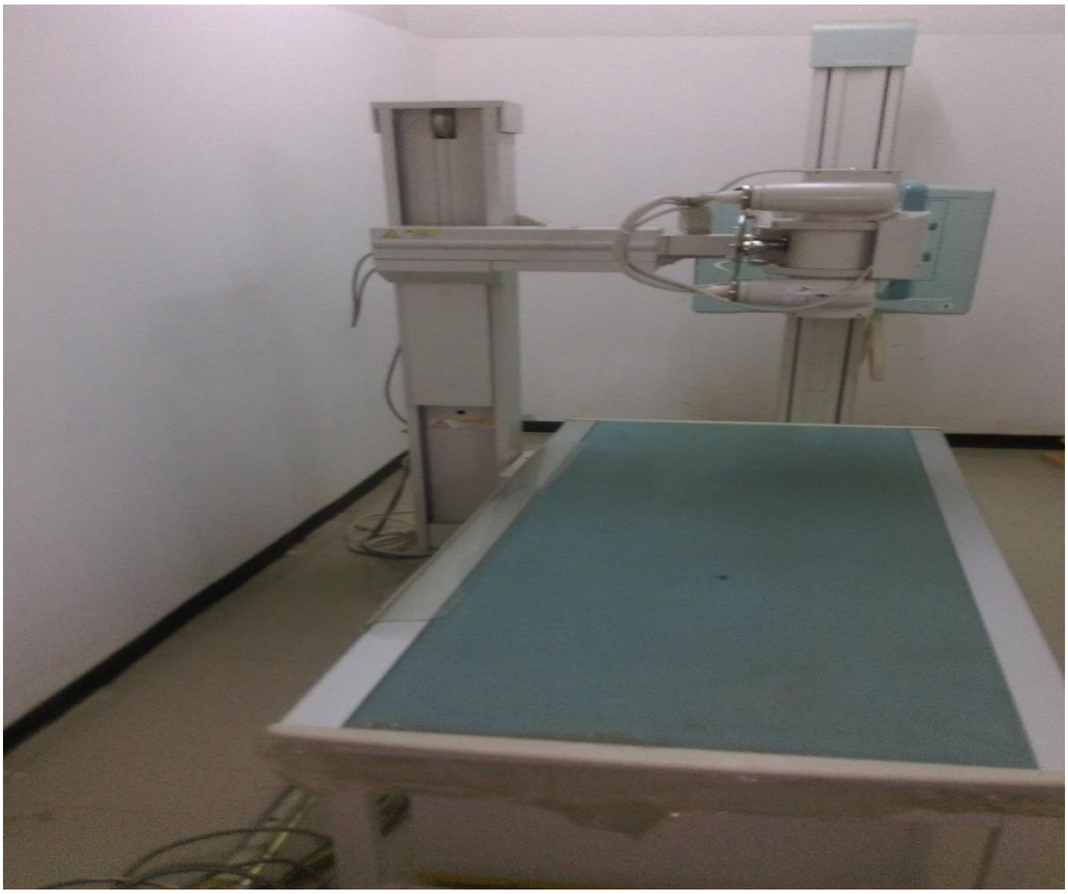
Appendix 4.2 shows the design of X- ray department at the Police hospital



Appendix 4.3 shows the design of X- ray department at the Insurance hospital.



Appendix 4.4 shows the design of X- ray department at the DT hospital.



Appendix 4.5 shows the X- ray machine at the Police hospital