



Sudan University of Science and Technology
College of Graduate Studies



Evaluation of Radiation Safety in Nuclear Medicine

Departments at Khartoum State

تقويم السلامة الإشعاعية في أقسام الطب النووي بولاية الخرطوم

**Thesis Submitted for Partial Fulfillment of the
Requirements of M.Sc. Degree in Medical Physics**

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الآية

قال تعالى:

﴿فتعالى الله الملك الحق ولا تعجل بالقرآن من قبل أن يلقى إليك وحيه وقل

ربي زدني علماً﴾

صدق الله العظيم

سورة طه الآية (114)

Dedication

I dedicate this work to my parents for their patience and encouragement.

To my brothers and sisters for their support.

To my friends for being there whenever I needed them.

and I can never forget my doctors who supported me more than I can ever ask for and for being there for every consultation, question and self-doubt.

Acknowledgement

Sure, I would like to thank Allah first for making such work possible.

It is a great pleasure to acknowledge all those people who have given me tremendous help and support in completing this study, especially to my supervisor, **Dr. Awad Abdallah Adlan** for his guidance and assistance throughout the whole period of this study.

I also would like to thank all heads and staff of departments of diagnostic imaging in hospitals that were involved in this study for their permissions and assistance during the data collection.

Lastly, I would like to thank my family for their consistent support.

Abstract

The aim of this study was to evaluate radiation safety in two departments of nuclear medicine in Khartoum state. The study was conducted at Alnelein Medical Diagnostic Center and Khartoum Oncology Hospital (RICK). (The study was done to assess the degree of compliance of those departments with what is stated in the code of practice approved by the Sudanese Atomic Energy Agency.

Measurements of the dose rate were taken using a calibrated survey meter in the hot Laboratory, gamma camera room, injection room and waiting room. The dose rate at these areas was found respectively in hospital (A ,1.19), (,0.04 ,0.03 and 0.02)($\mu\text{Sv/h}$). and in hospital (B), (1.64, 0.04, 0.05, and)($0.02\mu\text{Sv/h}$), whereas the standard stated in the code of practice is (1.5,0.04,0.05,0.03) $\mu\text{Sv/h}$.

The results of this study showed that the level of radiation safety in the departments was adequate but needs additional attention and development in the programs of staff training and emergency management plans and the RPO should be given the full authority and adequate time to enable him to do his duties effectively & improve the status of radiation protection in nuclear medicine department.

المستخلص

الهدف من هذه الدراسة هو تقييم السلامة من الإشعاع في أقسام الطب النووي لولاية الخرطوم.

أجريت الدراسة في مركز أنبيلين للتشخيص الطبي ومستشفى الخرطوم للأورام، يشمل الجزء العملي من هذه الدراسة تقييم درجة امتثال تلك الأقسام لما هو منصوص عليه في قواعد الممارسة المعتمدة من قبل الوكالة السودانية للطاقة الذرية.

أخذت قياسات معدل الجرعة باستخدام مقياس مسح معايرة في مختبرالنشاط الاشعاعي، وغرفة جاما كاميرا، وغرفة الحقن، وغرفة الانتظار. تم العثور على معدل الجرعة في هذه المناطق مرتبة بالتوالي في المستشفى (أ)، $(0.02, 0.04, 0.03, 1.19) \mu\text{Sv/h}$, وبالتوالي في المستشفى (ب)، $(0.02, 0.05, 0.04, 1.64) \mu\text{Sv/h}$, حيث ان المقياس المحدد في الممارسة المعتمدة $(0.03, 0.05, 0.04, 1.5) \mu\text{Sv/h}$

أظهرت نتائج هذه الدراسة أن مستوى السلامة من الإشعاع في الإدارات كان كافيا ولاكن يحتاج إلى مزيد من الاهتمام والتطوير في برامج تدريب الموظفين وخطط إدارة الطوارئ وضرورة منح مسؤل الحماية الاشعاعية السلطة الكاملة والوقت الكافي لتمكينه من القيام بواجباته على نحو فعال وتحسين حالة الحماية والسلامة من الإشعاع في قسم الطب النووي.

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List of Abbreviations

ALARA	As Low As Reasonably Achievable
NM	Nuclear medicine
RPP	Radiation Protection plan
RPO	Radiation Protection Officer
DNA	De oxy Ribonucleic Acid
LET	Liner energy transfer
IAEA	International Atomic Energy Agency
TLDs	Thermo luminescent Dosimeters
Bq	Becquerel
MBq	Mille Becquerel
μBq	Micro Becquerel
mSv	Mille sever
μSv	Micro sever
QA	Quality Assurant
SPSS	Statistical Package Social Sciences
Lab	Laboratory

Chapter One

Introduction

Chapter One

Introduction

1.1 General Introduction:

Nuclear medicine is a branch of medicine and medical imaging that uses unsealed radioactive substances in diagnosis and therapy. These substances of radionuclides or pharmaceuticals that have been labeled with radionuclides (pharmaceuticals). In diagnosis radioactive substances are administered to patients and the radiation emitted is measured.

The majority of these diagnostic tests involved the formation of an image using gamma camera. Imaging may also be referred to as radionuclide imaging or nuclear scintigraphy.

Other diagnostic tests use probes acquire measurements from parts of the body, or counters for the measurement of sample taken from the patient. Nuclear medicine imaging tests differ from most other imaging modalities in that the tests primarily show the physiological function of the system being investigated as opposed to the anatomy. In some centers, Nuclear medicine imaging can be superimposed on images is from modalities such as CT or MRI to highlight which part of the body the radio pharmaceuticals is concentrated in. this practice is often referred to as image fusion.(Protection, 2006)

Diagnostic Radiopharmaceuticals: The radionuclides used in Nuclear Medicine for diagnostic procedures emit gamma rays, which are a penetrating radiation, like X-rays. This penetrating quality allows images of internal structures to be obtained. The radionuclides remain in the patient after the study is over, but have short half-lives, so the patient and the people around him or her are not exposed for a long period of time. Diagnostic radiopharmaceuticals have half-lives from six hours to eight days.

Therapeutic Radionuclides: When therapeutic radiopharmaceuticals or sealed sources are used, relatively large doses are involved. The patient can be a significant source of radiation family and visitors. When procedures require that radiation precautions be put into effect, a radiation sign and a precaution sheet will in therapy, radionuclides are administered to treat disease or provide palliative pain relief. For example, administration of iodine-131 is often used for the treatment of thyrotoxicosis and thyroid cancer. be posted on the door to the patient's room (Protection, 2006).

1.2 Problem of the Study

Since there was no clear data and devices monitor concerning the radiation dose levels received by the radiation workers according to the researcher, it is essential to evaluate the radiation dose level and design of the Nuclear Medicine dep play main role of protection for both technical and public.

1.3 Objectives of the studies

1.3.1 General objective

To evaluate radiation Safety in Nuclear Medicine Departments at Khartoum State.

1.3.2 Specific objectives

- To study the present radiation protection and safety programs in two departments of Nuclear Medicine.
- To measure dose rate in the hot laboratory, outside door of camera room, inside the injection room, control room, on the floor, on the bench, on the shielded working surface.
- To asses radiation Level in the nuclear medicine department in Khartoum state.
- Compare the present study with international recommendation.

1.4 Important of the study

(ALARA) principle for optimization of radiation protection of workers and patients. Developing radiation safety program will reduce the probability of potential exposure.

1.5 Outline of the study

Chapter one is the introduction to this thesis, Problem of study, objective of study, Specific objective, Important of study.

Chapter two biological effects of the radiation, and principles of radiation protection, occupational exposure and protection, medical exposure, optimization of patient doses, public exposure and safety of sources, layout, and design of facilities.

Chapter three Materials, Method of the research

Chapter four results of this study.

Chapter five presents the discussion, conclusion and recommendations as well as suggestions for future work.

Chapter Two

Literature Review

Chapter Two

Literature Review

2.1 Theoretical Background

Study conducted to review Radiation Protection Program in Nuclear Medicine facility for diagnostic procedures, which will provide guide for meeting the standard and regulatory requirements in diagnostic nuclear medicine.

The main objective of medicine this project is to keep dose to staff, patient and public as low as reasonably achievable (ALARA). The specific objectives were to review that Radiation Protection Program (RPP) in diagnostic nuclear and to make some recommendation for improving the level of radiation protection in diagnostic mitigate nuclear medicine that will help to control normal exposure and pervert or point al exposure. The methodology used is review of various documents. The review showed that if the Radiation Protection Program is inadequate it leads to unjustified exposure to radiation. Finally, this study stated some recommendations that i: implemented could improve the level of radiation protection in nuclear medicine department. One of the most important recommendations is that qualities RPO (Sharp et al., 2005)

2.1.1 Biological effects of radiation

A number of important biological effects of radiation must be considered in any review of radiation protection procedures.

Living organisms were consisted of a complex systems of many symbiotic parts arranged and packaged in a manner to allow maintenance of their internal environment and self-reproduction. The basic units are composed of cells. Cells of similar origin and structure are further grouped to form tissues. The four main groups of tissues are muscle, nerve, connective and epithelial

tissues. Associated cells and tissues form organs which, taken collectively, function to create and control the necessary internal conditions suitable for life. A great diversity exists among the different kinds of cells found in the body. Many have a brief lifespan, undergoing division (a process called mitosis) in a period of hours, while others (such as nerve cells) do not divide at all after birth. Mitosis represents the production of the chromosome, on which the genes containing all the genetic information necessary for cell function resides. Any alteration of the genetic information carried by the genes or of the processes associated with mitosis can result in a permanent change either in the nature of the cell (mutation), or in the cell's death. When a cellular component is damaged by any agent e.g. Chemicals, radiation, excessive heat, etc.) A multitude of measurable effects can result. The changes may initially be restricted to a single or a few types of cells. In time, whole organs or organ systems may be effected due to the absence of a required function that upsets the equilibrium or control of the whole interrelated system. Gross physiological or morphological changes may result from an initial damage to a sufficient number of many kinds of cells. The type of cell damage will depend upon what the specific agent is that the cell is exposed to, and the amount of damage will be related to how much of the agent reaches that particular kind of cell. Biological effects from radiation are produced as a result of the transfer of energy from the radiation to the cells through ionization and excitation as described in the next section(Sharp et al., 2005)

2.1.1.1 Radio sensitivity cell

Radiation passing through living cells causes ionization and excitation of atoms and molecules contained in the cell. Since most of the human body is water, water molecules are likely target.

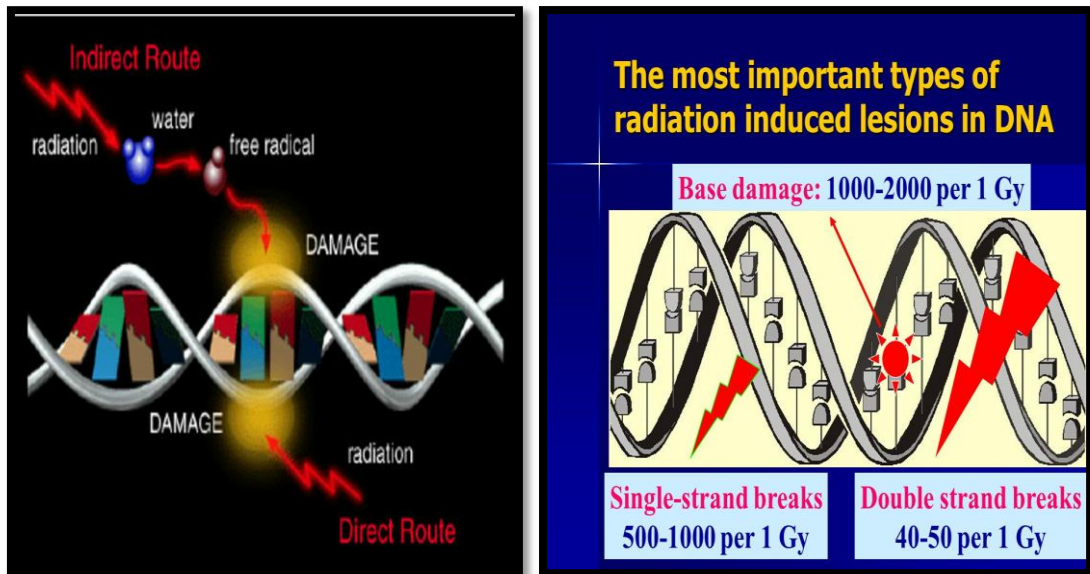
2.1.1.2 Radiation damage to the DNA

As it is mentioned previously, the larger a molecule is the better target it makes. Since DNA is the largest molecule in the cell as well as the site of all the genetic information, its response has a central role in the mediation of radiation effects. Depending on how it's damaged, different results will occur. Ionizing radiation can cause deletions or substitutions of bases and/or actual breaks in the DNA chain. DNA strand breaks, if not repaired, can cause abnormalities in chromosomes that may result in cell death. Single breaks, caused by low LET radiation given at low dose rate, are relatively easily repaired by using the other strand of DNA as a template. Radiation of relatively high LET, or a high dose rate of low LET, may produce single breaks in close proximity to each other in both strands (called double or multiple strand breaks) which are more difficult to repair (Sharp et al., 2005)

2.1.1.3 Chromosomal Aberrations

Direct evidence that ionizing radiation can damage DNA comes from well-documented information on chromosomal aberrations. When samples of human peripheral blood are cultured in such a way that the lymphocytes are stimulated into cell division and chromosome spreads are prepared during mitosis, a variety of abnormalities are observed if the blood has been irradiated either *in vivo* or *in vitro*. Amongst the most common observations are chromosomes with a shortened chromatid arm and acentric fragments (single break in one chromosome), ring structures (two breaks in the same chromosome and faulty rejoining) and chromosomes with two centromeres (dicentric) resulting from two breaks in different chromosomes and faulty rejoining. (Sharp et al., 2005)

For a good account of radiation-induced, chromosomal aberrations see



*Fig (2.1): Damage to the DNA by the radiation Direct & indirect effect
&Single damages double break*

2.1.1.4 Type of radiation effects

Deterministic effects: Existence of a dose threshold value (below this dose, the effect is not observable), Severity of the effect increases with dose, A large number of cells are involved, Threshold Doses for Deterministic Effects

Stochastic effects: No threshold, Probability of the effect increases with dose, generally occurs with a single cell, e.g. Cancer, genetic effects

2.1.1.5 Radiation protection program

Principles of Radiation Protection main objective of radiation protection is to avoid the deterministic effects by keeping the doses bel much as reasonably achievable. The principles of radiation the Basic Safety Standards (BSS), as follows low the relevant threshold and to reduce the probability of stochastic effect protection were summarized in:

Justification of practices: No practice or source within a practice should be authorized unless the practice produces sufficient benefit to exposed individuals or to society to offset the radiation harm that it might cause; that is unless the practice is justified, taking into account social, economic and other relevant factors". The process of determining whether the practice is justified involves the consideration of all the radiation doses received by workers and members of the public(Organization, 1996).

Dose limitation: The normal exposure of individuals shall be restricted so that neither the total effective dose nor the total equivalent dose to the relevant organs or tissue, caused by the possible combination of exposures from authorized practices. Exceeds any relevant dose limit specified except in special circumstances provided for” The limit on effective dose represents the level above which the risk of stochastic effects due to radiation is considered unacceptable. For localized exposure to the lens of the eye, extremities and the skin, this limit of effective dose is not sufficient to ensure the avoidance of deterministic effects, and therefore limits on equivalent dose are specified for such situations(Organization, 1996).

Optimization of protection and safety: In relation to exposures from any particular source within a practice, except for therapeutic medical exposures, protection and safety shall be optimized in order that the magnitude of individual doses, the number of people exposed and the likelihood of incurring exposure all be kept as low as reasonable achievable, economic and social factors being taken into account, with the restriction that the doses to individuals delivered by the source subject to dose constraints(Organization, 1996).

2.1.2 Occupational exposure

2.1.2.1 Classification of areas

Area in a nuclear medicine department should be clearly defined as part of the (RPP) and their classification should result from safety assessment.

Two types of area may be defined: controlled area & supervised area

- **Controlled areas:** Any area in which specific measures for protection and safety are or could be required for

(a) Controlling exposures or preventing the spread of contamination in normal operation;

(b) Preventing or limiting the likelihood and magnitude of exposures in anticipated operational occurrences and accident conditions (Sharp et al., 2005).

- **Supervised areas:** Any area not already designated as a controlled area but for which occupational exposure conditions need to be kept under review, even though specific measures for protection and safety are not normally needed (Sharp et al., 2005).

2.1.3 Dose limitation and monitoring

- **Dose limitation**

The BSS states the normal exposure of individuals shall be restricted so that neither the total effective dose nor the total equivalent dose to the relevant organs or tissue, caused by the possible combination of exposures from authorized practices, exceeds any relevant dose limit specified except in special circumstances provided for

“The occupational exposure of any worker shall be so controlled that the following limits are not exceeded.

- (a) An effective dose of 20 mSv per year averaged over five consecutive years.
- (b) An effective dose of 50 mSv in any single year.
- (c) An effective dose to the lens of the eye of 150 mSv in year.

- (d) An equivalent dose to the extremities (hand and feet) or the skin of 500 mSv in a year.

According to the Basic Safety Standards; "A female worker should, on becoming aware pregnant, notify the employer in order that her working conditions may be modified if necessary.

The notification of pregnancy shall not be considered a reason to exclude a female worker from work, however, the employer of a female worker who has been notified of the pregnancy shall adapt the working conditions in respect of occupational exposure so as to ensure that the embryo or fetus is afforded the same broad level of protection as required for members of the public. This means that the dose to the embryo or fetus should not normally exceed 1mSv.)(Organization, 1996)

▪ **Thermo luminescent Dosimeters (TLDs)**

TLDs are small chips (1/8" x 1/8" x 1/32") of lithium fluoride or calcium fluoride. The chips absorb energy from radiation, which excites atoms to higher energy levels within the crystal lattice. Heating the chip releases the excitation energy as light. Proportional to the amount of radiation received. Chips are placed in badge holders containing filters to distinguish between energy and type.(Organization, 1996)

Advantages of TLDs are:

- . They are small and can be used as extremity monitors.
- . They can be read on-site or through a disinterested third party
- . They are reusable.

▪ **Personnel Monitoring Devices**

Personnel monitoring devices measure external radiation exposure.

Three major type of monitoring devices in use today are the pocket dosimeter, the film badge, and the thermoluminescent dosimeter (TLD). Personnel monitoring is required when it is likely that an individual will be exposed during any calendar year to a dose of 50 mSv to the whole body (head and trunk, active blood forming organs, gonads); 150 mSv to the lens of eye), 500 mSv to extremities (hands, forearms, feet, leg below the knee, ankles), 500 mSv to the skin of the whole body, or in any work area where you can receive 1 mSv in any hour at 30 cm from the source or source container. Personnel monitoring provides a permanent, legal record of an individual's occupational exposure to radiation. (Ojovan and Lee, 2013)

2.1.4 Design of a Nuclear Medicine Facility

General Layout of a Nuclear Medicine Department should take into account a possible separation of the work areas and patient areas Fig (2.3)

Imaging room after the technologist completes the procedure, the patient is returned to the reception area unit the study is reviewed by Nuclear physician responsible for the examination

The general rule:

- separate high activity areas from low activity areas
- separate working areas from patient areas

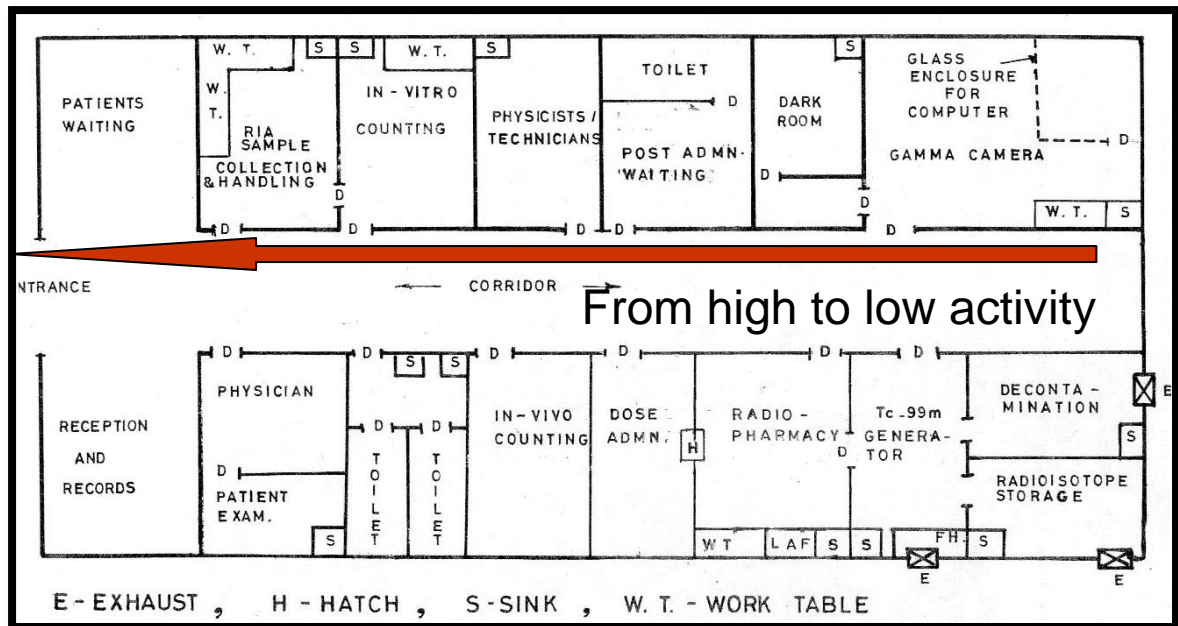


Fig (2.2) Floor plan of department of Nuclear Medicine Department

The design of the facility should take into consideration the type of work and the radionuclides and their activities intended to be used.

The concept of “categorization of hazard” should be used in order to determine the special needs. The layout, construction, and finish of the building housing the nuclear medicine department are all influenced by radiation protection considerations. In nuclear medicine, work risks arise from the radioactive materials used, the patients who have received radiopharmaceuticals, and the radioactive waste produced. The hazards to personnel are due to external exposure, surface contamination. High hazard Room for administration of Radiopharmaceuticals, Examination room, Isolation ward Medium hazard Waiting room, Patient toilet Low Hazard Reception (Malone et al., 2009)

2.1.4.1 Buildings

all rooms where radioactivity is present must show the familiar radiation warning sign. A system of designation of areas with restrictions on who may enter will usually be a legal requirement. The largest activities are handled during the preparation of the radiopharmaceuticals, and detailed consideration of radio pharmacy design is given in Separate areas for the administration of radiopharmaceuticals and the performance of in vivo tests (imaging rooms and other patient counting facilities), and possibly laboratories for in vitro tests, are needed. Waiting areas with designated toilets should be provided for radioactive patients. Space for the safe storage of radioactive waste will also be needed. Careful consideration should be given to layout in order to reduce the movement of radioactivity within the department. All materials used should allow for easy decontamination should inadvertent dispersal of radioactive liquids occur. The use of radioactive gases presents an additional hazard, and suitable extraction or forced ventilation should be provided. Hand washing facilities must be providing in areas where unsealed radioactive materials are handled(Malone et al., 2009)

Table (2.1): Building Requirements

Category of Hazard	Structural Shielding	Floors	Worktop Surfaces, Walls, Ceiling
Low	No	Cleanable	Cleanable
Medium	No	Continuous sheet	Cleanable
High	Possibly	Continuous one sheet folded to walls	Cleanable

Category of Hazard	Fume Hood	Ventilation of Hazard	Plumbing	First Aid
Low	No	Normal	Standard	Washing
Medium	Yes	Good	Standard	Washing & decontamination facilities
High	Yes	May need special forced ventilation facilities	May need special plumbing facilities	Washing & decontamination facilities

2.1.4.2 Floors

Impervious material, Washable, Chemical-resistant, Curved to the walls, all joints sealed, Glued to the floor.



Fig (2.3): Floors

2.1.4.3 Walls and ceiling

Should be finished in a smooth and washable surface with joints being -ith washable ,non sealed, wherever practicable ,walls should be painted w porous paint .(Malone et al., 2009)

2.1.4.4 Worktop surfaces

Worktop surfaces must be finished in a smooth ,washable and chemical certain resistant surfaces with all joints sealed some laminates do not resist chemicals ,and the supplier should be consulted with regard to the specific chemicals to be use in the laboratory ,Open shelving should be kept to a minimum to prevent dust accumulation, Services(e g. gas ,electricity vacuum,)ted on top of the bench but on on walls or up should not be moun stands .Light fixtures should be easy to clean and of an enclosed type in order to minimize dust accumulation Structural reinforcement may be necessary

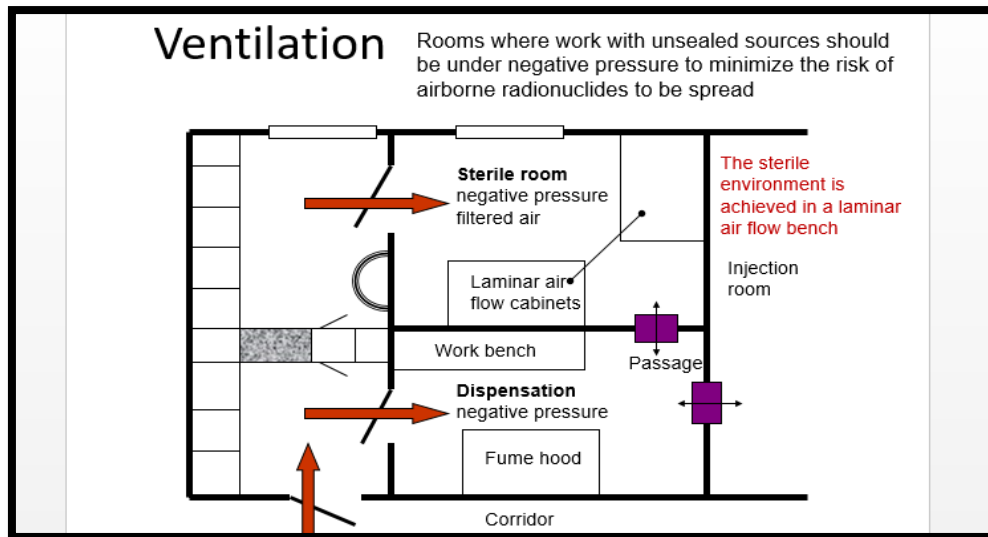


Fig (2.5): Ventilation system in nuclear medicine department

2.1.4.6 Fume hood

The fume hood must be constructed of smooth, impervious, washable and resistant. The working surface should have a slightly raised lip to contain any spills and must be strong enough to bear the weight of any lead shielding that may be required. The air velocity should be such that the linear face velocity is between 0.5 and 1.0 meters/second with the sash in the normal working position. This should be checked regularly. Rooms where work with unsealed sources should be under negative pressure to minimize the risk of airborne radionuclides to be spread. If there are regulations about air pressure gradients, they should be continuously monitored and an alarm system introduced (Malone et al., 2009)



Fig (2.6) Fume Hood

2.1.4.7 Washing facilities

tra fic area adjacent to the work -up sink should be located in a low-The wash without direct hand contact and disposable area.Taps should be operable wash should -towels or hot air dryer should be available.An emergency eye be installed near the hand washing sink and there should be access to an emergency shower in or near the laboratory (Malone et al., 2009)



Fig (2.7) Washing facilities

2.1.4.8 Patient toilet

A separate toilet room for the exclusive use of injected patients is recommended. A sign requesting patients to flush the toilet well and wash their hands should be displayed to ensure adequate dilution of excreted radionuclides. The facilities shall include a sink as a normal hygiene measure. Washrooms designated for use by nuclear medicine patients should be finished in materials that are easily decontaminated. The patient washing facilities should not be used by hospital staff as it is likely that the floor, toilet seat and sink faucet handles will be contaminated frequently. (Malone et al., 2009)



Fig (2.8) Patient toilet

2.1.4.9 Pipes

Pipes from the radioisotope laboratory sink should go as directly as possible to the main building sewer

- The final plans of the drainage system that are supplied to maintenance personnel must show which drains are from radioisotope laboratories.

- Drain-pipes from isolation wards for patients undergoing radionuclide therapy shall end up in a delay tank. (Malone et al., 2009)

2.1.4.10 Shielding

Much cheaper and more convenient to shield the source, where possible, rather than the room or the person. Structural shielding is generally not necessary in a nuclear medicine department. However, the need for wall shielding should be assessed e.g. in the design of a therapy ward (to protect other patients and staff) and in the design of a laboratory housing sensitive equipment (to keep a low background in a well counter, gamma camera, instruments etc. (Malone et al., 2009)

2.1.4.11 Hot lab

a facility handling large quantities of volatile radioisotopes, to as a small side room off a main laboratory where all the radioactive work in a department takes place (which may only involve the use of limited quantities of radioactive materials

rooms An inpatient treated with more than 400MBq should be isolated located in a single bedroom equipped with its own toilet and shower or absorbent bathroom. The flooring should be smooth, continuous, and non-adsorbent surface for ease of decontamination. The bed should be located as remotely as possible from other hospital beds in neighboring rooms. Depending on the wall construction some extra shielding may be necessary. The design should be such that a patient in the nearest neighboring bed for all the time a radioactive therapy patient is present receives less than 0.3mSv/procedure. Containers should be provided for storage of used utensils and linen before they leave the room. Bathrooms should be checked for contamination, Drainpipes terminating in a delay tank. Rooms should be equipped with movable shield for temporary (Malone et al., 2009)

2.1.4.12 Imaging room

area of imaging room shall depends on the size of gamma camera and other associated equipment and accessories that may present in the room howeve: typically the room area should about 25meter squire . The imaging room shall be a separate room from the dispensing laboratory and shall be well shielded from any radiation source other than the patient the loor (Malone et al., 2009)

2.1.5 Radioactive waste and storage :

2.1.5.1 Waste

The use of unscaled saurces in diagnosis and therapy will generate examination radioactive weste of different kinds during preparation, patient and care.Radicactive waste needs to be safely managed because it is potentially hazardous to human health and the environment .Inadequate management after use or loss of Radioactive material especially sealed radiation exposure of members of the radiation sources, has resulted in public or extensive contamiration of equipmen bui.dings or land .In some cases unconrolled radiation exposure has been lethal.The oactive waste in ity hospitals comprises many different ype of waste .It may be of high aciv generator and sources used in radionuclides therapy, or low activity waste from biomedical procedures or research It may be in solid, liquid or gaseous form ll these aspects must beaccounted for in the planning of waste treatment in ahospital.(Ojovan and Lee, 2013)

2.1.5.2 Types of waste

include cover papers ,gloves empty vials and syringes, :Solid waste generators jitems used by hospitalized patients after radionuclides - radionuclides therapy, sealed sources used for calibration of instruments

residues of radionuclides patient excreta liquid scintillation : Liquid waste ..solutions

patients in nuclear medicine The Gaseous waste: Exhausted gas from registrant and the licensee shall develop and implement a program for safe disposal of radioactive waste or return of sources when their use is nagement of radicactive discontinued, as required by the regulation of ma waste.(Ojovan and Lee, 2013)

2.1.5.3 Storage

Source stores must: Provide protection against environmental conditions, Be radioactive materials ,Provide sufficient shielding, Be resistant to only or fire, Be secure (Cooper and Woollett, 2010)

2.1.6 Emergency plans

2.1.6.1 Safety Assessment

In nuclcar medicine safety assessment deals with tinding out ,what can go at every step wrong (the steps include ordering transport and receipt of unsealed sources, unpacking, storage, preparation and administration of the radiopharmaceuticals to the patient, examination or treatment ,care of torage and handling therapy patients with high amounts of radioactivity and s of radioactive waste) and how this can be prevented and in case it occurs, how it can be mitigated.The safety assessment needs to be documented and,

if appropriate , independently reviewed, within the quality assurance al reviews shall be performed as necessaryprogram .addition

Safety may be compromised as a result of modifications of the facilities or of the proccdures , Operational experience or information on accidents or errors anges to relevant indicates that a review is necessary, Any significant ch guidclincs or standards are envisaged or have been made.(Cooper and Woollett, 2010)

2.1.6.2 planning for accidents and Emergencies

The employer shall preparc emrcrgency procedures.The procedures should be clear, concise and unambiguous and shall be posted visibly in places where anticipated their need is (Organization, 1996).

2.2 Previous studies

Vahid Karami et al (2016) was reported study of Radiation Protection in Diagnostic X-Ray Imaging Departments in Iran: A Systematic Review of Published Articles were used , some databases including SID, Magiran, IranMedex, Irandoc, Google-Scholar, Medlin, Embase and PubMed were searched. A total of 122 articles was obtained during the primary research. After elimination of duplicate and irrelevant articles, 39 articles (published in 1997 to 2015) were selected for final review. Were our result of The researches were performed in conventional radiology centers (n=24), dental radiography (n= 8), nuclear medicine (n=2), mammography (n= 1), computed tomography (n=1), dental radiography and radiology (n= 1), and total diagnostic X-ray departments (n= 2). Totally, 874 diagnostic centers and 1677 radiographers were studied. These studies revealed undesirable level of radiation protection regarding the use of shielding tools for patients, radiation collimation, use of film bag in dental radiography, and

quality control programs. But, environmental radiation doses and the use of film bag in radiology centers were found to be in appropriate level.

Were concluded Despite increasing application of x-ray in medical diagnosis, radiation protection did not considerably change in Iran. So a national strategic program on radiation protection seems to be necessary. Such programs must be developed by ministry of health and radiation protection affairs of national atomic energy organization and its administration must be monitored permanently.(Karami and Zabihzadeh, 2016).

Afaf Mohamed et al (2015) was reported study of Radiation Safety Awareness and Practice in Sudanese Medical Facilities. Were Despite the recent wide radiation applications in medicine, it can be hazardous if not properly handled. The aims of this study were to determine radiographers' awareness and performance about radiation safety in Sudanese governmental and private medical facilities located at Khartoum State, Sudan. In addition, to assess the work place safety requirements in Sudanese medical facilities from the radiographer point of view. A descriptive cross section study was performed in six governmental and private hospitals with a simple random sample of 50 radiographers working in them. Study tool was a questionnaire distributed to radiographers to collect data. Results showed that radiographers within Khartoum state showed a good knowledge of radiation hazards and protection. However, adherence to radiation protection practices among these radiographers was poor. There is inadequate radiation protection devices (ex. FBDs availability was only 12%) and monitoring (ex. environmental monitoring availability was only 38%) in both functional government and private hospitals. There are radiation accidents due to overexposure as injuries, abortion and sickness cases. The study recommended conducting continuous in service training for radiology staff

at all levels about radiation protection and safety. Also disseminate the culture of wearing personal protective equipment (PPE) and all possible safety measures including the equipment for measuring radiation. Radiographers in Khartoum, Sudan should embrace current trends in radiation protection and make more concerted efforts to apply their knowledge in protecting themselves and patients from harmful effects of ionizing radiation.

O.I. ELAMIN. et al (1996) was reported study of RADIATION PROTECTION IN SUDAN and were The regulatory framework as established by the Sudan Atomic Energy Commission (SAEC) Act, promulgated in 1996, is described in the report. Three levels of responsibility in meeting radiation protection requirements are established: The Board, the Radiation Protection Technical Committee as the competent authority in the field of radiation protection, and the SAEC Department of Radiation Protection and Environmental Monitoring as the implementing technical body. The report also refers to environmental activities, patient doses in diagnostic radiology, the management of disused sources, emergency preparedness and orphan sources, and the national training activities in the radiation protection field.

Chapter Three

Materials and Methods

Chapter Three

Materials & Methods

3.1 Materials

Different types of dose monitors were used to measure the dose rate and contamination in two different nuclear medicine departments.

Equipment used to measure the dose rate

3.1.1 Survey meter specification:

Made in Finland, Dose rate: (0.05 micro Sv/h-10Sv/h), Dose: (0.01 micro Sv/h-10Sv/h) Serial number: (70934).

3.1.2 contamination monitors:

Measuring time: Approx. 150 h with batteries at background radiation.

Model: FHT 111 Thermo

Detectors: xenon counter tubes with permanent gas filling, windows area 100 or 166 cm²

3.2 Methods

In this side the explanation the methods and technique that's using to implementing for this study, including: description population of study, statistical techniques and measures have been using for analytical data in the Two Departments of Nuclear Medicine Depends on the questionnaire to know that the differences in result and degree of differentiability. Measurement were taken from two different hospital (A) and (B) using the devices Survey meter and contamination monitor.

The dose rate and contamination level were measured in different location hot lab, outside door of camera, inside the injection room, control room, on

the floor, on the bench, on the shielded working surface within the nuclear medicine departments. The measurement were repeated and the averages were taken.

3.2.1 Data Analysis: The data were analyzed using computer programs including excel and Statistical Package Social Sciences

3.2.2 Direct measurement: the dose rate and contamination level were measured in different locations with in the nuclear medicine departments. The measurements were repeated and the averages were taken.

3.2.3 Description of questionnaire

A statement has been attached to this questionnaire for questing subjects over objectives of study.

3.2.4 Statistical techniques

- 1- Reliability:
- 2- Frequency distribution.
- 3- Percentages.
- 4- Chi square Test.

Chapter four

Results

Chapter four

Results

4.1 Results

Table (4.1) Description of radioactive materials in use

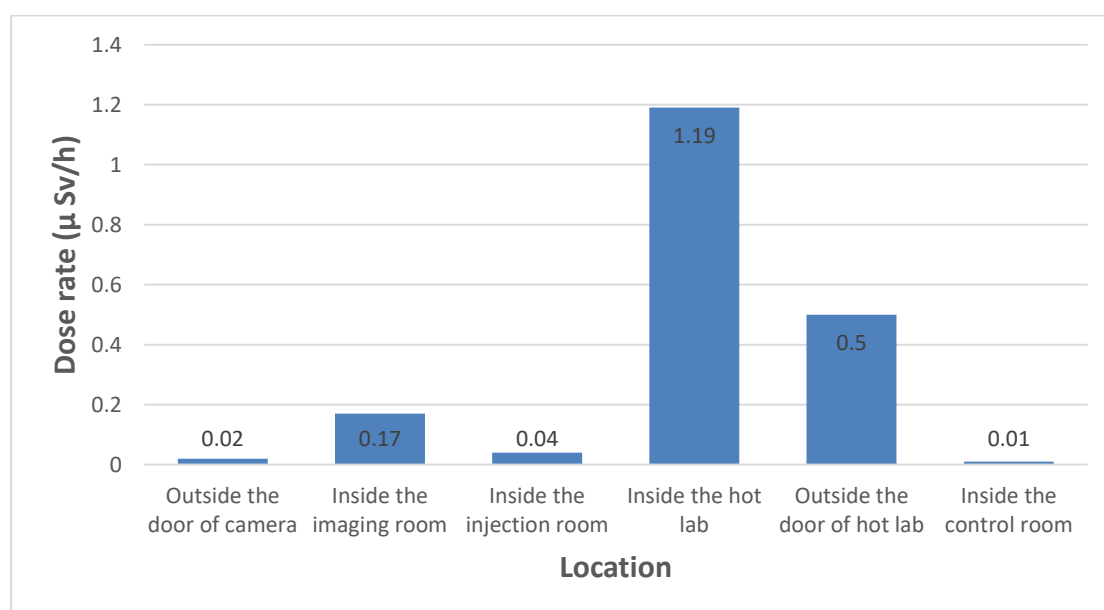
Radionuclide/ Pharmaceutical	Maximum activity at one time (Bq)	Physical/ chemical form	application
Tc-99m generator	30 GBq	sodium pertechnetate	Tissue function
(I ¹³¹)Therapy Capsule	30 MBq	Sodium iodide	Tissue function

Background: 0.04 μ Sv/h

Table (4.2) dose rate measurement for department-hospital (A)

Measurement location	Cross dose rate D(μ Sv/h)			Average (μ Sv/h)
	D1	D2	D3	
Outside the door of camera	0.04	0.03	0.01	0.02
Inside the imaging room	0.15	0.17	0.18	0.17
Inside the injection room	0.04	0.03	0.04	0.04
Inside the hot lab	1.18	1.19	1.20	1.19
Outside the door of hot lab	0.4	0.6	0.5	0.5
Inside the control room	0.02	0.01	0.01	0.01

Figure: 4.1 Relation between the dose rate and location in hospital (A)



Background: 0.06(**Bq/cm²**)

Table (4.3) contamination level measurement for hospital (A)

Measurement location	Cross dose rate D(Bq/cm ²)			Average (Bq/cm ²)
	D1	D2	D3	
On the table of injection room	1.2	1.3	1.3	1.3
On the floor of injection room	1.06	1.08	1.07	1.07
On the floor hot lab	1.2	1.21	1.24	1.21
On the bench hot lab	12.7	12.2	12.0	12.3
On the shielded working surface	6.71	6.75	6.63	6.69

Figure: 4.2 Relation between the contamination and location in hospital (A)

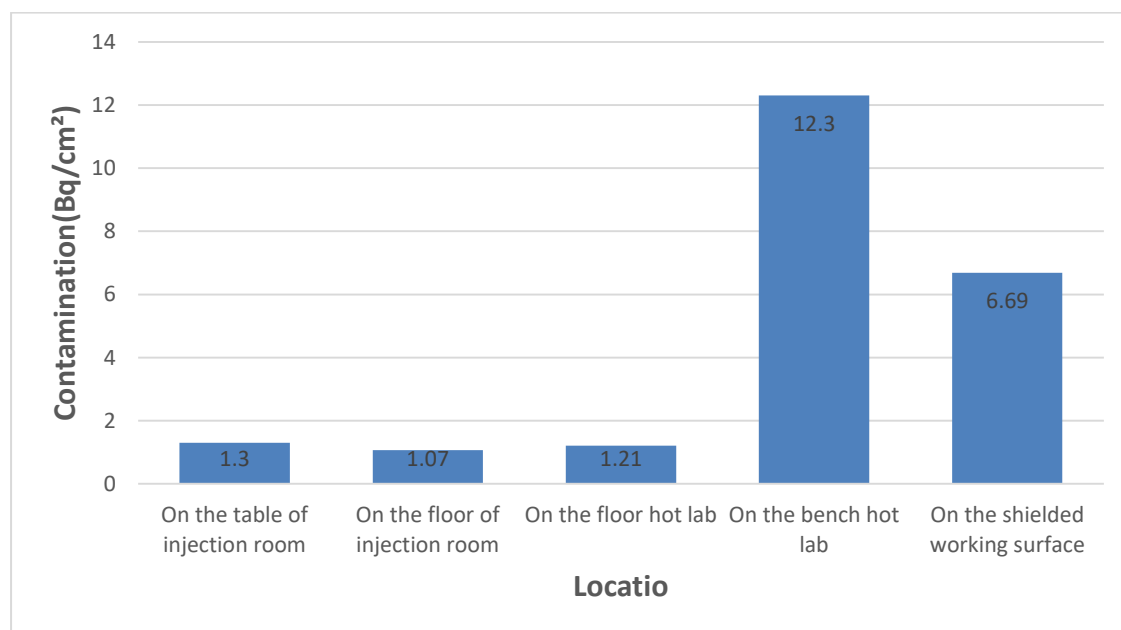
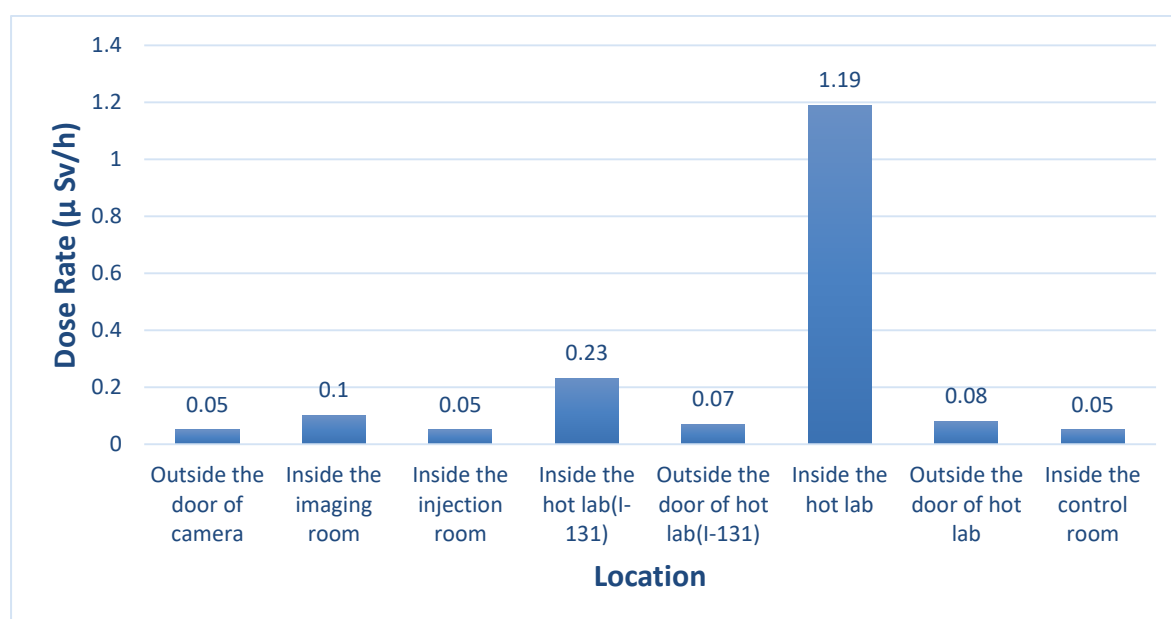


Table (4.4) dose rate measurement for department-hospital (B)

Measurement location	Cross dose rate D(μ Sv/h)			Average (μ Sv/h)
	D1	D2	D3	
Outside the door of camera	0.04	0.05	0.06	0.05
Inside the imaging room	0.09	0.10	0.11	0.1
Inside the injection room	0.04	0.05	0.05	0.05
Inside the hot lab(I-131)	0.22	0.25	0.23	0.23
Outside the door of hot lab(I-131)	0.07	0.06	0.08	0.07
Inside the hot lab	1.18 1.20	1.19		1.19
Outside the door of hot lab	0.08	0.08	0.09	0.08
Inside the control room	0.04	0.05	0.06	0.05

Figure: 4.3 Relation between the dose rate and location in hospital (B)



Background: 0.08(Bq/cm²)

Table (4.5) contamination level measurement for hospital (B)

Measurement location	Cross dose rate D(Bq/cm ²)			Average (Bq/cm ²)
	D1	D2	D3	
On the table of injection room	1.19	1.22	1.24	1.21
On the floor of injection room	2.12	2.10	2.13	2.11
On the floor hot lab	3.29	3.28	3.31	3.29
On the bench hot lab	16.2	16.1	16.4	16.2
On the shielded working surface	7.56	7.58	7.63	7.59

Figure: 4.4 Relation between the contamination and location in hospital (B)

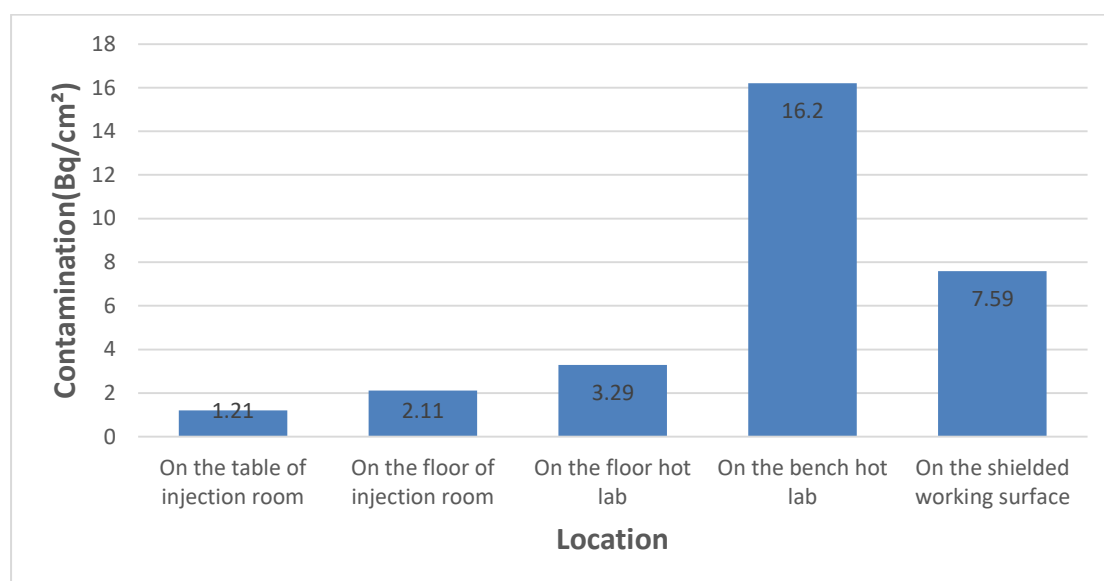


Table (4.6) shows Questionnaire

Chi-Square test (level of significance 5%)

Source: prepare by researcher from survey study using SPSS, 2018.

No	Hypothesis of Questions	Yes	No	Nature	Chi – square	P. value
1	Does management provide adequate equipment	16	4	0	7.2	.007
2	Does management provide adequate staffing levels	11	9	0	0.2	.655
3	Does management provide adequate resources for personal training (time and money)	8	12	0	0.8	.371
4	Has management invested the RPO with authority to stop unsafe operations	5	15	0	5	.025
5	Are management areas demarcated and there a locked/secured location with key control	7	13	0	1.8	.180
6	Is radioactive material storage (including waste) at physically defined locations	12	5	3	6.7	.035
7	Are an adequate number of lead containers, lead blocks, and portable or fixed shields available for shielding in storage and handling room	6	14	0	3.2	.074
8	Is remote handling equipment such as (tongs, forceps, etc.) available	12	8	0	0.8	.371
9	Is adequate provision for storage of wastes before disposal	11	3	6	4.9	.086
10	Do you think that the floor plans and arrangements of equipment as described in the application and appropriate considering any public areas adjacent to the installation	2	18	0	12.8	.000
11	Are visitors accompanied in controlled areas	10	10	0	0	1.000

12	Is adequate information provided to visitors entering controlled areas	5	15	0	5	0.025
13	Are there adequate controls over entries into supervised areas and appropriate postings	6	14	0	3.2	0.074
14	Have workers involved in implementing the plan received training	7	13	0	1.8	0.180
15	Have provisions been made for the plan to be rehearsed at suitable intervals in conjunctions with any designated emergency response authorities	5	12	3	6.7	0.035
16	Does the authorized organization provide dosimeters	12	8	0	0.8	0.371
17	Do you believe and trust in the personal monitoring service	9	11	0	0.2	0.655
18	Do you think that you are using it correctelly (worn it properly and exchange it at required frequency)	3	15	2	15.7	0.000
19	Are you get worry about your doses and asked about it each other period	12	8	0	0.8	.371
20	Does the RPO provide you with your periodic dose reading	14	6	0	3.2	0.074
21	Is no patient exposed unless the exposure is prescribed by a medical practitioner	13	5	2	9.7	0.008
22	Are there an adequate number of training medical and paramedical personnel to discharge assigned tasks	11	9	0	0.2	0.655
23	Are diagnostic medical and QA requirements fulfilled with the advice of a qualified expert in nuclear medicine physics	6	14	0	3.2	0.074
24	Are diagnostic medical exposures justified by taking into account the benefits and risks of alternative techniques that do not involve medical exposure	15	5	0	5	0.025

25	Do medical practitioners ensure that appropriate equipment is used that the exposure	17	3	0	9.8	0.002
26	For lactating mothers , is discontinuation of nursing recommended until the radiopharmaceutical is no longer secreted in an amount estimated	19	1	0	16.2	0.000
27	Are radiological examination causing exposure of women who are pregnant or likely to be pregnant avoided unless there are strong clinical reasons for such examinations	14	6	0	3.2	0.074

4.4.2 The reliability and validity:

Reliability: is the degree to which an assessment tool produces stable and consistent results.

Validity: refers to how well a test measures what it is purported to measure.

Table (4.7) shows the reliability and validity

coefficient of Reliability	Validity
0.98	0.99

Source: prepare by researcher from survey study using SPSS, 2018

From table (3.1) note that the reliability and validity nearest of the, this meaning the questionnaire is high validity and very good consistency.

Chapter Five

Discussion and Conclusion and Recommendations

Chapter Five

Discussion and Conclusion and Recommendations

5.1 Discussions:

In this study was conducted at two nuclear medicine department.

The evaluation of radiation Safety was carried out by conducting Measurement were taken from two different hospital (A) Alnelein Medical Diagnostic Center and (B) Khartoum Oncology Hospital (RICK) using the devices Survey meter and contamination monitor to the nuclear medicine departments and using a questionnaire that covers all areas of radiation protection, addition area radiation monitoring has been conducted around radioactive sources and their installations.

The results showed that all of the departments comply with the following issues indicated namely, security of the radioactive materials, prevention of unauthorized persons from entering controlled areas by keeping the door of the hot lab closed all the time and placing a warning signs on the door, The activity of the radiopharmaceutical is usually checked before administered, examination of pregnant women and children normally avoided unless there is a strong clinical reason and provisions have been made to transfer the Mo-Tc generators to an authorized waste disposal facility at the end of use. Also, OC tests of imaging equipment's are done regularly and results of such tests are recorded. Finally, all departments have adequate knowledge and expertise RPO who he/she has been given sufficient time and resources to do his job. The results of area radiation monitoring showed that the radiation levels were much less than the dose rate limit for workers and members of the public.

Discussion of *questionnaire*:

- The Value of Chi-Square for phrase No “1” equal (7.2) and the probability value is (0.007) and this value less than 5% level, this meaning is different significant in the answering of Respondents.
- The Value of Chi-Square for phrase No “2” equal (2.0) and the probability value is (0.655) and this value greater than 5% level, this meaning is not different significant in the answering of Respondents.
- The Value of Chi-Square for phrase No “3” equal (0.8) and probability value is (0.371) and this value greater than 5% level, this meaning is not different significant in the answering of Respondents.
- The Value of Chi-Square for phrase No “4” equal (5.0) and probability value is (0.03) and this value less than 5% level, this meaning is different significant in the answering of Respondents.
- The Value of Chi-Square for phrase No “5” equal (1.8) and probability value is (0.180) and this value greater than 5% level, this meaning is not different significant in the answering of Respondents.
- The Value of Chi-Square for phrase No “6” equal (6.7) and probability value is (0.04) and this value less than 5% level, this meaning is different significant in the answering of Respondents.
- The Value of Chi-Square for phrase No “7” equal (3.2) and probability value is (0.07) and this value greater than 5% level, this meaning is not different significant in the answering of Respondents.
- The Value of Chi-Square for phrase No “8” equal (0.8) and probability value is (0.371) and this value greater than 5% level, this meaning is not different significant in the answering of Respondents.
- The Value of Chi-Square for phrase No “9” equal (4.9) and probability value is (0.09) and this value greater than 5% level, this meaning is not different significant in the answering of Respondents.

- The Value of Chi-Square for phrase No “10” equal (12.8) and probability value is (0.000) and this value less than 5% level, this meaning is different significant in the answering of Respondents.
- The Value of Chi-Square for phrase No “11” equal (0.0) and probability value is (1.0) and this value greater than 5% level, this meaning is not different significant in the answering of Respondents.
- The Value of Chi-Square for phrase No “12” equal (5.0) and probability value is (0.03) and this value less than 5% level, this meaning is different significant in the answering of Respondents.
- The Value of Chi-Square for phrase No “13” equal (3.2) and probability value is (0.07) and this value greater than 5% level, this meaning is not different significant in the answering of Respondents.
- The Value of Chi-Square for phrase No “14” equal (1.8) and probability value is (0.180) and this value greater than 5% level, this meaning is not different significant in the answering of Respondents.
- The Value of Chi-Square for phrase No “15” equal (6.7) and probability value is (0.04) and this value less than 5% level, this meaning is different significant in the answering of Respondents.
- The Value of Chi-Square for phrase No “16” equal (0.0) and probability value is (0.371) and this value greater than 5% level, this meaning is not different significant in the answering of Respondents.
- The Value of Chi-Square for phrase No “17” equal (0.2) and probability value is (0.655) and this value greater than 5% level, this meaning is not different significant in the answering of Respondents.
- The Value of Chi-Square for phrase No “18” equal (15.7) and probability value is (0.000) and this value less than 5% level, this meaning is different significant in the answering of Respondents.

- The Value of Chi-Square for phrase No “19” equal (0.8) and probability value is (0.371) and this value greater than 5% level, this meaning is not different significant in the answering of Respondents.
- The Value of Chi-Square for phrase No “20” equal (3.2) and probability value is (0.074) and this value greater than 5% level, this meaning is not different significant in the answering of Respondents.
- The Value of Chi-Square for phrase No “21” **equal** (9.7) and the probability value is (0.008) and this value less than 5% level, this meaning is different significant in the answering of Respondents.
- The Value of Chi-Square for phrase No “22” **equal** (0.2) and probability value is (0.655) and this value greater than 5% level, this meaning is not different significant in the answering of Respondents.
- The Value of Chi-Square for phrase No “23” **equal** (3.2) and probability value is (0.07) and this value greater than 5% level, this meaning is not different significant in the answering of Respondents.
- The Value of Chi-Square for phrase No “24” **equal** (5.0) and probability value is (0.03) and this value less than 5% level, this meaning is different significant in the answering of Respondents.
- The Value of Chi-Square for phrase No “25” **equal** (9.8) and the probability value is (0.002) and this value less than 5% level, this meaning is different significant in the answering of Respondents.
- The Value of Chi-Square for phrase No “26” **equal** (16.2) and probability value is (0.000) and this value less than 5% level, this meaning is different significant in the answering of Respondents.
- The Value of Chi-Square for phrase No “27” **equal** (3.2) and probability value is (0.074) and this value less than 5% level, this meaning is different significant in the answering of Responden

5.2 Conclusion:

This study was conducted at the nuclear medicine departments at Khartoum state in hospital (A) and hospital (B). The main objective was to evaluate radiation Safety in Nuclear Medicine Departments at Khartoum State.

And avoid the deterministic effects by keeping doses below the relevant threshold and to reduce the probability of stochastic effect as much as reasonably achievable.

The results showed that, the main problems found in the two center under this study included that the RPO have no full authorities and adequate time to enable them to do their duties effectively.

Evaluation is the worker questionnaire which was made out of the evaluation From result. Some questions are selected from the evaluation form, according to the physicist answer, and according to the type of question, that some question was presented to the workers to make comparison.

This done because we observed that there is a shortage in communication between the physicist and the technologists and this affecting the application of radiation safety. Result of the evaluation is very good, but some point need to be checked and reviewed periodically, and these are discussed in the last point.

5.3 Recommendations:

The following points are recommended:

- Management should provide all tools and equipment needs for radiation safety and it should be reviewed periodically to provide maintenance services. Suitable personal protective equipment ,the safety equipment provided to should include protective clothing, tools for remote handling of radioactive material, radiation monitor devices ,shields, containers for radioactive waste, decontamination and emergency kit
- It is important to increase the safety culture programs for the worker. This can be achieved by continuous education programs within the institute or through national and international radiation protection courses participating
- surveys for radiation and removable radioactive contamination must be performed after each use of radioactive materials
- A multilayer (defense in depth) system of provisions for protection and safety commensurate with the magnitude and likelihood of the potential exposures involved shall be applied to sources such that a failure at one layer is compensated for or corrected by subsequent layers
- Education programs for nuclear medicine should include intensive training and motivation, also The design of new nuclear medicine department should be reviewed by qualified expert to be compatible with the international standards regulation
- Proper (RPO) should be appointed to design and implement radiation safety program in nuclear medicine departments and must be given the full authority and adequate time to enable him to do his duties effectively .

- An external auditing should be performed at all nuclear medicine departments in Sudan to assess the efficiency of the approved radiation safety program and increase the level of radiation protection

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Appendices

Appendix 1

Values of annual limit of intake for some radionuclides in Becquerel

Radionuclides	Value(Bq)
Tc-99m	3×10^9
Mo-94	2×10^8
I-131	1×10^6
P-32	1×10^7
Sr-89	5×10^6
Y-90	2×10^7

Appendix 2

Suggested QC tests for SPECT

No	Test	Frequency of routine tests
1	Intrinsic uniformity	Semi annually
2	Intrinsic Energy resolution	Quarterly
3	Intrinsic spatial Resolution	Weekly
4	Extrinsic uniformity	Daily
5	Energy Spectrum	Daily
6	Centre of Rotation (COR-180)	Weekly
7	Sensitivity	Semi annually
8	collimator angulations	Semi annually
9	Shield leakage	Daily
10	Size of pixel check	Quarterly
11	Total performance check	Weekly
12	Reconstructed point-source	Quarterly

Appendix 3

Suggested QC tests for Dose Calibration

NO	Test	Frequency of routine tests
1	Constancy	Daily
2	Accuracy	Annually
3	Linearity	
4	Geometrical response	At Calibration acceptance and then for any change In sample geometry

Appendix 4

Facility design

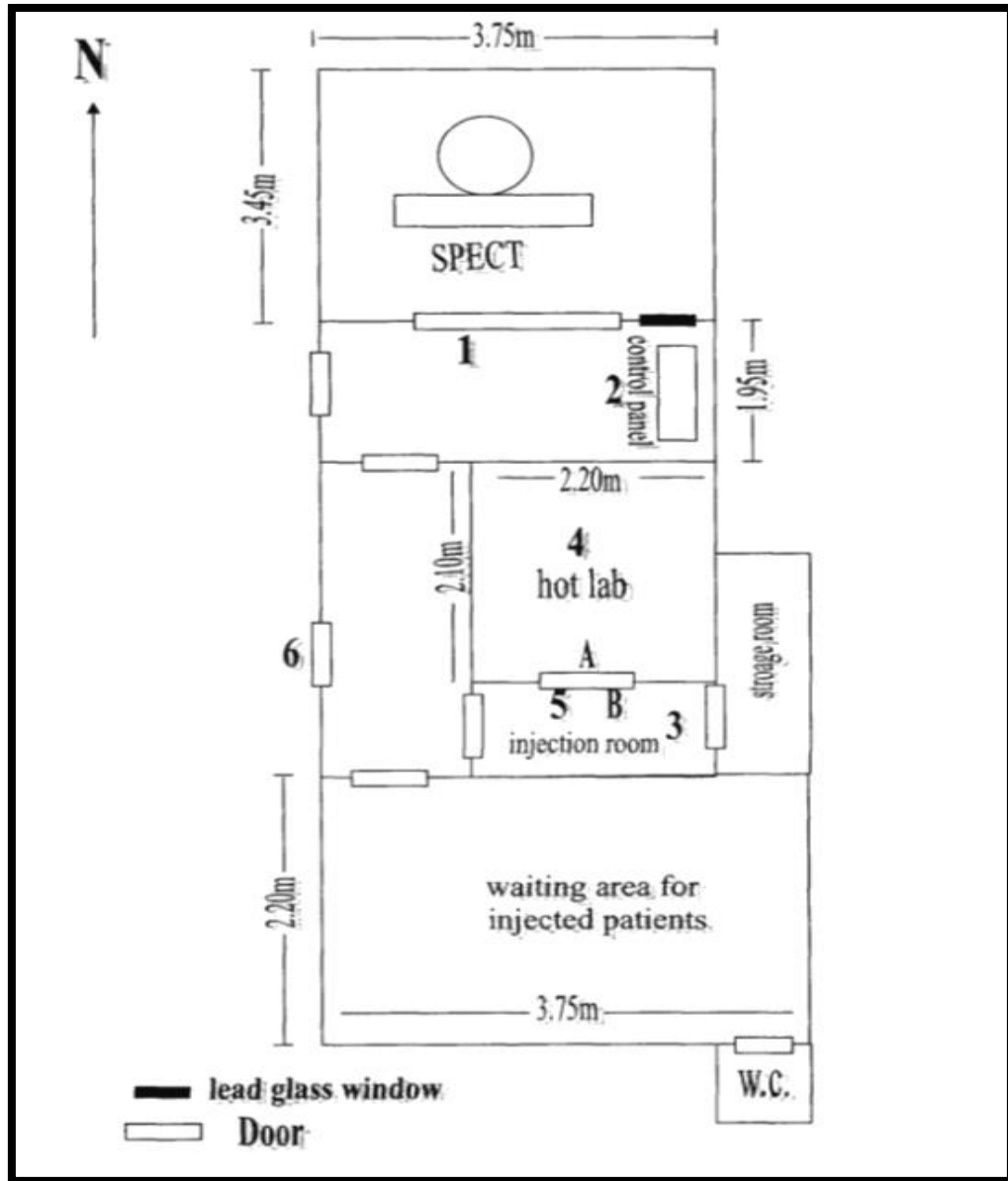


Fig (1) nuclear medicine department of hospital (A)

Appendix 5

Facility design

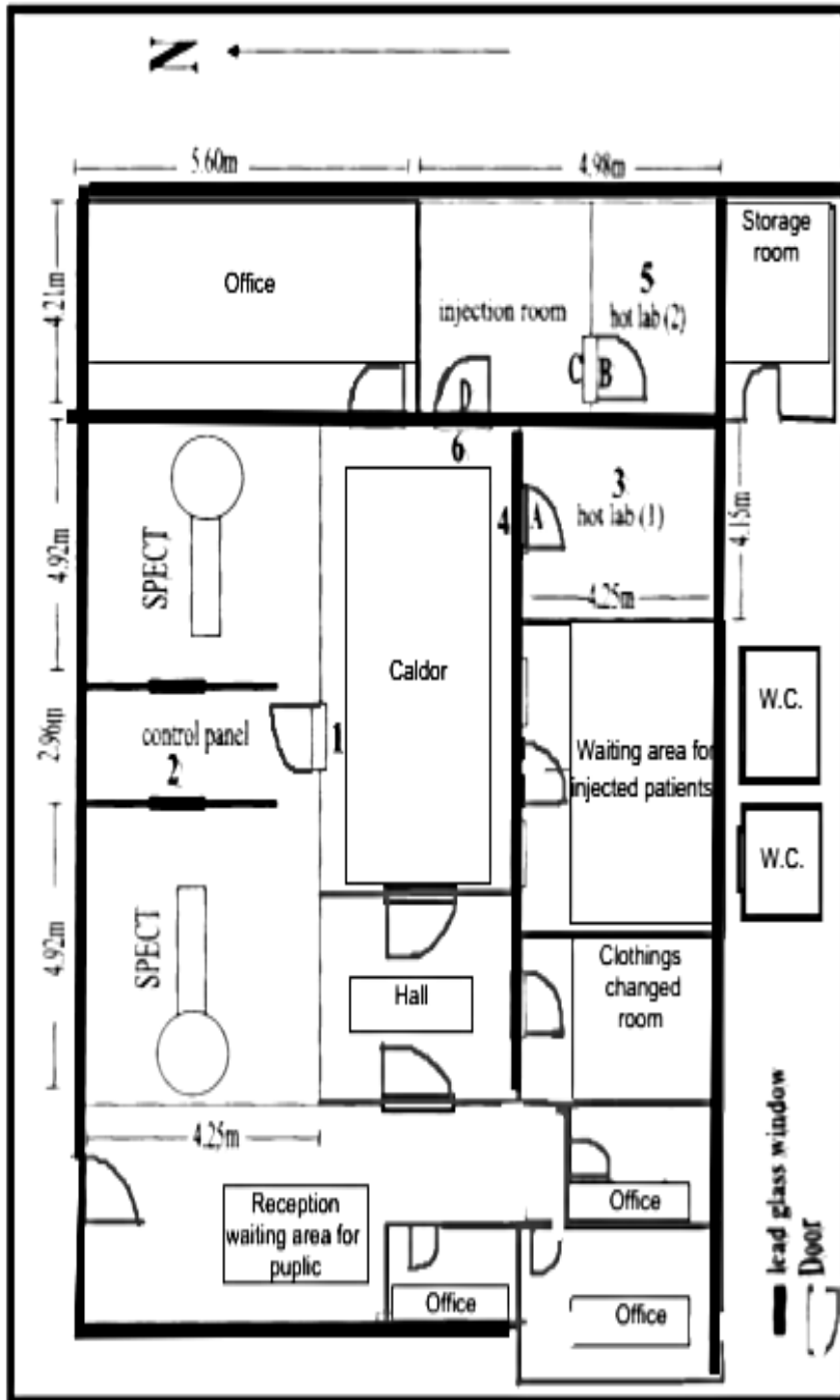


Fig (2) nuclear medicine department of hospital (B)

Appendix 6

Suitable warning Notice for the entry to an area where Radiation sources are in use



Appendix 7

Identifying Information

Describe any differences or modifications from those approved by the Regulatory Authority and/or considered in the safety assessment (e.g. shielding design, building materials, floor plan):		

a) Was a safety assessment by a qualified expert performed prior to any modifications?	Yes	
b) Is the thickness and type of shielding appropriate for the types and intensity of radiation produced by radioisotopes in use?	Yes	

Safety control and equipment design

a) Are an adequate number of lead containers, lead blocks, and portable or fixed shields available for shielding in storage and handling rooms?	Provided?		No
	Used?		No
b) Is remote handling equipment such as (tongs, forceps, etc.) available?	Provided?	Yes	
	Used?	Yes	
c) Are ventilated fume hoods for handling large doses of ^{131}I and for carrying out MEK (methyl ethyl ketone (2-butanone)) extraction of $^{99\text{m}}\text{Tc}$ available?	Provided?		No
	Used?		No
d) Are the drainage ducts in the laboratory (sinks, wash basins, toilets, etc.) connected directly to the sanitary sewage system?		Yes	

Safety operations –management

a) Is management familiar with the certificate of authorization and its restrictions and requirements?	Yes	
b) Does management provide adequate staffing levels?	Yes	
c) Has management invested the RPO with authority to stop unsafe operations?	Yes	
d) Does management provide adequate resources for personnel training (time and money)?	Yes	
e) Does management provide adequate equipment?		No
f) Does management provide for periodic programme reviews and recommendations?	Scheduled? Performed?	No No
i) Date of the last programme review:		
ii) Status of recommendations:	<hr/> <hr/>	

Safety operations — technical

a) Does the RPO have adequate knowledge and expertise?	Yes	
b) Does the RPO have qualified experts available?	Yes	
c) Is the RPO familiar with the requirements of the Regulatory Authority and the provisions of the certificate of authorization?	Yes	
d) Is the RPO given sufficient time and resources to do the job (e.g. not kept too busy with other assignments or not given sufficient technical and secretarial help)?		No
e) Is the RPO kept informed of activities of workers using radiation sources?		No
f) Does the RPO conduct initial and periodic training of workers?		No
g) Does the RPO maintain adequate records to demonstrate worker and public protection?	Yes	
h) Are there provisions for inventory of sources and accountability?	Procedures? Performed?	Yes Yes
i) Are there provisions for audits and reviews of radiation safety programme:	Procedures? Performed?	No No

Investigation and QA

a) Were there any incidents or accidents?		Yes	
b) If so, were incident and accident investigation reports prepared?		Yes	
c) Were safety assessments reviewed or made on the basis of lessons learned from any accident or accidents at similar facilities?		Yes	
d) Is there a written QA programme?	Procedures? Performed?		No No
e) Is maintenance and repair work (measuring equipment, imaging devices, ventilation systems, etc.) in accordance with manufacturer's recommendations?	Scheduled? Performed?	Yes Yes	
f) Are repair/maintenance procedures	Developed? Followed?	Yes Yes	

Verification of Worker Protection

Classification of areas

a) Are controlled areas demarcated?		Yes	
b) Are approved signs at access points	Provided? Legible? in local Language?		No No No
c) Is radioactive material storage (including waste) at physically defined locations?			No
i) Is there a locked/secured location with key control?		Yes	
ii) Are radiation warning notices	Provided? Legible? local Language?	Yes Yes Yes	
iii) Is there proper shielding (e.g. individual containers, enclosures)?		Yes	
iv) Are the storage locations reserved only for radioactive material?			No
d) Are supervised areas demarcated?		Yes	
e) Are approved signs at access points	Needed? Provided? Legible? in local Language?	Yes Yes Yes Yes	

Local rules and supervision

a) Are rules established in writing, in a local language?	Yes	
b) Do rules include investigation levels and authorized levels and the procedure to be followed when a level is exceeded?	Yes	
c) Are workers instructed in the implementing procedures?		No
d) Do workers have adequate supervision to ensure rules, procedures, protective measures and safety provisions are followed?		No
e) Specifically, are operating and working procedures for:		
i) nurses attending patients	Provided?	No
	Adequate?	No
	Followed?	No
ii) diagnostic examination	Provided?	Yes
	Adequate?	Yes
	Followed?	Yes
iii) therapy administration	Provided?	Yes
	Adequate?	Yes
	Followed?	Yes
iv) repairing and maintaining safety systems	Provided?	Yes
	Adequate?	Yes
	Followed?	Yes
v) making surveys	Provided?	Yes
	Adequate?	Yes
	Followed?	Yes

Monitoring

a) Does the authorized organization provide personal dosimeters?	Yes	
b) Are the dosimeters:		
i) Worn properly?		No

ii) Calibrated?	Yes	
iii) Exchanged at required frequency?		No
c) Are personnel exposures within limits?	Yes	
d) Are area and portable survey instruments:		
i) Appropriate?	Yes	
ii) Calibrated?	Yes	
iii) Operational?	Yes	
iv) Checked before use?	Yes	
v) Supplied with spare batteries?	Yes	
e) Do the authorized organization's surveys indicate that the shielding is adequate and the dose rates around storage and patient treatment rooms meet authorized radiation levels?	Yes	
f) Does the authorized organization make periodic tests for leakage of radioactive materials from any sealed sources (e.g. calibration sources)?		No
g) Is the instrumentation:		
i) Appropriate?	Yes	
ii) Calibrated?	Yes	
iii) Operational?	Yes	
Record independent measurements made during the inspection:		

Type/model no. of survey meter:		
Date last calibrated:		
Do the inspector's independent surveys confirm the survey results of the authorized organization?	Yes	
Document any significant differences and any agreed upon plan to resolve the discrepancies:		

3.9 Verification of Public Protection

Control of visitors

a) Are visitors accompanied in controlled areas?	Yes	
b) Is adequate information provided to visitors entering controlled areas?	Yes	
c) Are there adequate controls over entries into supervised areas and appropriate postings?		No

Sources of exposure

a) Are the shielding and other protective measures optimized for restricting public exposure to external sources of radiation?	Yes	
b) Are the floor plans and arrangement of equipment as described in the application and appropriate considering any public areas adjacent to the installation?		No

Radioactive waste and discharges

a) Have provisions been made to transfer waste to an authorized waste disposal facility at the end of use?	Yes	
b) If any sealed sources are no longer in use and being stored, does the authorized organization have a plan for timely transfer or disposal of the sources?		No
c) Are there provisions for control of discharges to the environment in the event of contamination?		No

Monitoring of public exposure

a) Are routine periodic measurements of exposure rates in public areas adjacent to areas used for diagnostic examination, therapy treatment or radioactive materials made by the staff or qualified expert?	Yes	
b) Do surveys show that the room shielding is adequate and the dose rates outside the areas meet authorized radiation levels?	Yes	
c) Record independent measurements made during the inspection: _____		
Type/model no. of survey meter:		
Date last calibrated:		
Are the inspector's independent measurements in agreement with the organization's routine measurements?	Yes	
Document any significant differences and any agreed upon plan to resolve the different results		

Emergency Preparedness

Emergency plan

a) Is there a written plan?		No
b) Is the plan periodically reviewed and updated?		No
c) Does the plan take into account lessons learned from operating experience and accidents at similar facilities?		No

Training and exercises

a) Have workers involved in implementing the plan received training?		No
b) Have provisions been made for the plan to be rehearsed at suitable intervals in conjunction with any designated emergency response authorities?		No
c) Date of the last rehearsal:		

3.10 Medical Exposure

Responsibilities

a) Is no patient treated unless the exposure is prescribed by a medical practitioner?	Procedures?	Yes	
	Followed?	Yes	
b) Are there an adequate number of trained medical and paramedical personnel to discharge assigned tasks?		Yes	
c) Are diagnostic imaging and QA requirements fulfilled with the advice of a qualified expert in nuclear medicine physics?		Yes	

Justification

a) Are diagnostic medical exposures justified by taking into account the benefits and risks of alternative techniques that do not involve medical exposure?		Yes	
b) Are there procedures to ensure that exposure of humans for medical research is in accordance with the Helsinki Declaration and follows the guidelines for its application prepared by the Council for International Organizations of Medical Sciences and the World Health Organization?		N/A	

c) Is each exposure of humans for medical research subject to the advice of an ethical review committee or other similar institutional body?	N/A	
d) Are standards available and followed for radiological examinations for screening of large populations or for occupational, legal, or health insurance purposes?		No

Optimization

a) Do medical practitioners ensure that appropriate equipment is used, that the exposure of patients is the minimum necessary to achieve the diagnostic objective, and that relevant information from previous examinations is taken into account to avoid unnecessary additional examinations?	Yes	
b) Do the medical practitioners, the technologists or other imaging staff endeavour to achieve the minimum patient exposure consistent with acceptable image quality by:	Yes	
i) Appropriate selection of the radiopharmaceutical and its activity, noting special requirements for children and for patients with impaired organ function?	Yes	
ii) Use of methods for blocking the uptake in organs not under study and for accelerated excretion when applicable?	Yes	
iii) Appropriate image acquisition and processing?	Yes	
c) Are radiological examinations causing exposure of women who are pregnant or likely to be pregnant avoided unless there are strong clinical reasons for such examinations?	Yes	
d) For lactating mothers, is discontinuation of nursing recommended until the radiopharmaceutical is no longer secreted in an amount estimated to give an unacceptable dose to the nursing child?	Yes	
e) Is the administration of radionuclides to children for diagnostic procedures carried out only if there are strong clinical indications, and the amount of radioactivity is reduced according to body weight, body surface area or other appropriate criteria?	Yes	

Calibration

a) Is the calibration of sources used for medical exposure traceable to a standards dosimetry laboratory?	Yes	
b) Are unsealed sources calibrated in terms of the activity of the radiopharmaceutical to be administered, with the activity being determined and recorded at the time of administration?	Yes	

Clinical dosimetry

Are representative absorbed doses determined and documented?	Yes	
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Quality Assurance

Does the medical QA programme include:

a) Measurements and verification of physical parameters at the time of commissioning and periodically thereafter?	Procedures? Followed?	Yes Yes	
b) Written records of relevant procedures and results?	Procedures? Followed?	Yes Yes	
c) Verification of the appropriate calibration and conditions of operation of dosimetry and monitoring equipment?	Procedures? Followed?	Yes Yes	
d) Verification of patient identity?	Procedures? Followed?	Yes Yes	
e) Regular and independent quality audit reviews?	Procedures? Followed?		No No

Dose constraints

a) Does an ethical review committee or other institutional body specify dose constraints to be applied on a case-by-case basis in the optimization of protection for persons exposed for medical research purposes if such medical exposure does not produce direct benefit to the exposed individual?		No
b) Have dose constraints been established for individuals knowingly exposed while voluntarily helping in the care or comfort of patients undergoing medical diagnosis?		No