بسم الله الرحمن الرحيم

Sudan University of Science and Technology

College of Graduate Studies

Assessment of Radiation Protection in Nuclear Medicine Departments in Khartoum-Sudan

تقويم وضع الوقاية من الاشعاع في أقسام الطب النووي في السودان

A thesis submitted for partial fulfillment of the Requirements of Master degree in Medical Physics

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قال تعالي :

وَإِذَا أَنْعَمْنَا عَلَى الإِنسَانِ

أَعْرَضَ وَنَأَى بِجَانِبِهِ وَإِذَا مَسَّهُ

الشَّرُّ كَانَ يَؤُوسًا (83) قُلْ كُلٌّ

يَعْمَلُ عَلَى شَاكِلَتِهِ فَرَبُّكُمْ أَعْلَمُ

بِمَنْ هُوَ أَهْدَى سَبِيلاً (84)

وَيَسْأَلُونَكَ عَنِ الرُّوحِ قُلِ الرُّوحُ

مِنْ مْرَ رَبّ ِي وَمَـــا أ ُوتِ يتُم مّ ِـــن

الـْعِـلْمِ إِلاّ قَـلِـيـلاً (85))

صدق الله العظيم

الاسراء الايــة 82-85

Dedication

To

My father's soul.....

To

My mother and brothers for their help and support....

To

My teachers, friends and colleagues.....

I dedicate this work

A cknowledgments

My full thanks to God in every thing. My deep gratitude to my supervisor ***Dr. Salah Ali Fadlalla*** *for his invaluable guidance, fruitful discussions and comments throughout this work. My very special thanks to the staff of nuclear medicine departments in the three hospitals. Also my thanks are extended to my teachers, friends and colleagues.*

Abstract

The main objective of this study was to assess radiation protection situation in nuclear medicine departments in Sudan. This is attributed to the importance and

the noticeable inadequacy of the application of the available programs . The evaluated procedures followed in these departments were in accordance with the standards, international recommendations and code of practice for radiation protection in nuclear medicine , and included protection of the public and the working staff, as well as the radiation accidents , radiation waste management and the methods of departments design . Measurements were taken of the dose rate and radioactive contamination in some areas where there are radiation sources, workers and the public.

The results showed that the level of radiation protection in the departments under study was inadequate and needs additional attention and development.

The personal monitoring devices, the records , programs of staff training and emergency management plans were not available .The study proposed some recommendations which may be useful in updating the level of radiation protection in the nuclear medicine departments in Sudan. One of the most important recommendations included that the RPO must be given the full authority and the adequate time to enable him to do his duties effectively.

الخلاصه

الغرض من هذه الدراسة تقويم وضع الوقاية من الاشعاع في اقسام الطب النووي بالسودان .لما له من اهمية ولملاحظة الباحث للضعف الواضح في تطبيق برامج الوقاية من الاشعاع وعدم

الاهتمام بها من قبل المختصين بهذه المراكز .حيث تم تقييم اجراءات الوقاية من الاشعاع بما يتوافق مع التوصيات العالمية ذات الصلة بهذا المجال يتضمن حماية الجمهور والعاملين و الحوادث الاشعاعية والنفايات المشعة وطرق تصميم الاقسام. تم اخذ قياسات لمعدل الجرعة والتلوث الاشعاعي في بعض المناطق التي يوجد بها مصادر الاشعاع، العاملين والجمهور .

استنادا للنتائج المتحصل عليها وبعد مناقشتها وضح ان مستوي الوقاية من الاشعاع في المراكز قيد الدراسة تحتاج لبعض الاهتمام والتطوير وبالاخص في عدم وجود اجهزة القياس الشخصية وعدم توفر السجلات وكذلك برامج التدريب للعاملين وخطط لمواجهة الطوارئ في بعض المراكز .وتم وضع التوصيات والمقترحات التي من شانها ان تساعد في تحسين مستوي الوقاية من الاشعاع في اقسام الطب النووي .من اهم تلك التوصيات اعطاء ضابط الوقاية من الاشعاع (RPO) كامل الصلاحية والوقت الكافئ لاداء مهامه بفاعلية وعلي اكمل وجه .

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List of Abbreviations

ALARA	As low as reasonable achievable.
CT	Computed tomography.
RPO	Radiation Protection Officer
SPECT	Single Photon Emission Computed Tomography
QA	Quality Assurance
ICRP	International committee on radiological protection.
SNRRA	Sudanese Nuclear and Radiological Regulatory Authority
IAEA	International Atomic Energy Agency
SAEC	Sudan Atomic Energy Commission
SSDL	Secondary Standard Dosimetry Laboratory
QC	Quality Control
RP	Radiation Protection
Bq	Becquerel
NM	Nuclear Medicine

Chapter One

Introduction

Introduction

1.1General introduction:

Nuclear medicine is a branch of medicine that uses unsealed radioactive materials as either a diagnostic tool to image a patient s body or a treatment tool to destroy diseased cells. In diagnostic nuclear medicine, the aim is to reliably make the correct diagnosis while keeping the radiation dose to the patient to a minimum. In therapy, the aim is to cure a cancerous, or other, condition or to provide pain palliation and relieve the symptoms of a disease in order to improve the quality of life of a patient. It utilizes the nuclear properties of radioactive and stable nuclides to perform diagnostic evaluations and to provide therapy. A diagnostic technique in nuclear medicine uses radioactive tracers which emit gamma rays from within the body. These tracers are generally short-lived isotopes linked to chemical compounds which permit specific physiological processes to be scrutinized. The key benefit of Nuclear Medicine is its ability to identify metabolic functions. By observing the distribution of a radiopharmaceutical administered to the patient. Positioning of the radiation source within the body makes the fundamental difference between nuclear medicine imaging and other imaging techniques such as x-rays. Nuclear medicine imaging provides a view of the position and concentration of the radioisotope within the body. Organ malfunction can be indicated if the isotope is either partially taken up in the organ (cold spot), or taken up in excess (hot spot). If a series of images are taken over a period of time, an unusual pattern or rate of isotope movement could indicate malfunction in the organ. Since physiologic / pathophysiologic processes

are being monitored / measured, the patient must remain Photon Emission Computed Tomography (SPECT), and Positron Emission Tomography (PET) imaging. (Australia,2008).

1.2Image Modalities in Nuclear Medicine

There are different modalities in nuclear medicine that include Planar, Single Photon Emission Computed Tomography (SPECT) imaging, Positron Emission Tomography (PET), and Fusion Imaging. (Australia,2008).

1.2.1 Scintillation or Gamma Camera

This is a method of producing images using gamma or scintillation cameras that detect radiation from different parts of a patient ‟s body after administration of a radioactive tracer material. Nuclear imaging camera consisting of a collection crystal (head) and magnifiers that create images of a target physiologic process from the radiation being emitted from a patient following the administration of a radioactive uptake material (See Fig 1.1) (Australia,2008).

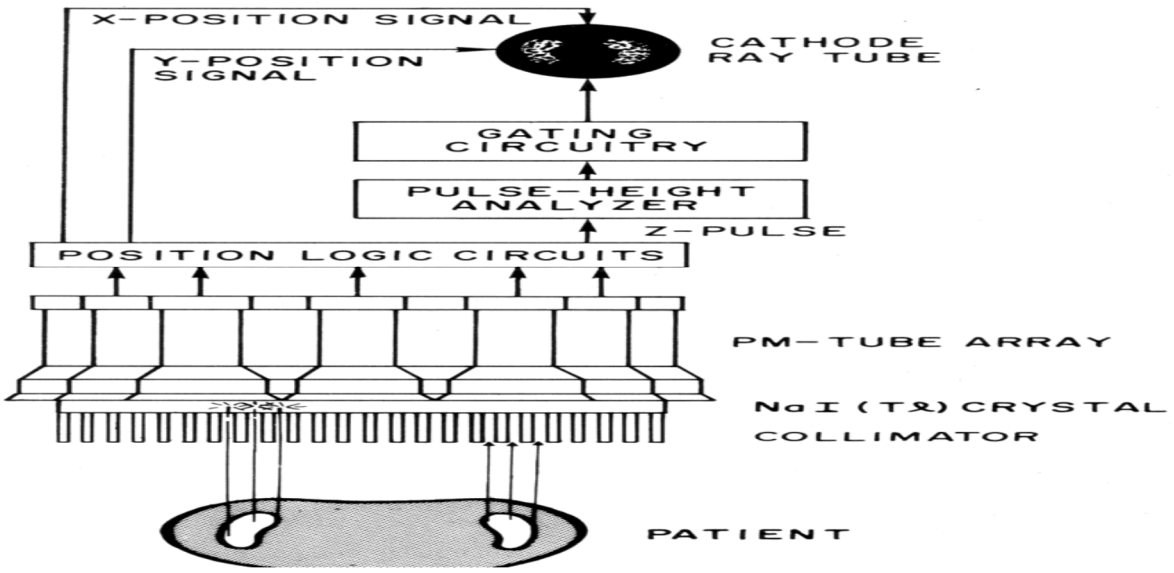


Fig 1.1 Schematic diagram of a γ camera

1.2.2. Single Photon Emission Computed Tomography (SPECT)

This is a diagnostic imaging modality that usually employs a rotating gamma camera and magnifiers to image the distribution of single photon emissions from the body. Cameras acquire multiple planar views of the radioactivity in an organ Detection is carried out using a gamma camera- a scintillation detector (NaI crystal) a collimator and a set of photomultiplier tubes. By rotating the gamma camera around the head, a three dimensional image of the distribution of the radiotracer can be obtained by employing filter back projection as shown in See Fig 1.2.

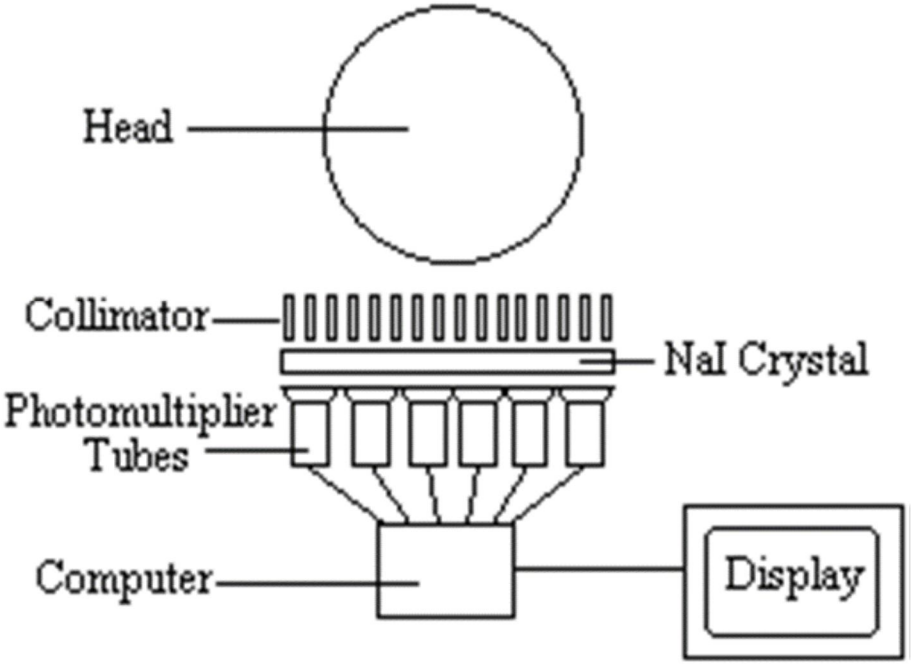


Fig 1.2 Schematic diagram of a gamma camera used in SPECT imaging.

The data are then processed mathematically to create cross-sectional views of the organ. SPECT utilizes the single photons emitted by gamma-emitting radionuclides such as Technetium-99m (99mTc), Gallium-67 (67Ga), Indium-111 (111In), Iodine 123I and 131I.(Peter et al 2005) .

1.3 Problem of the study

There is an inadequate radiation protection program, in nuclear medicine. This leads to unjustified exposure to radiation .and no code practice in nuclear medicine departments in Sudan.

1.4 Objectives of study:

1.4.1General Objectives

The aim of this study is to assess radiation protection situation in the Nuclear Medicine Departments in Khartoum- Sudan

1.4.2 Specific objectives:

To Study the current radiation protection programs in nuclear medicine department in Khartoum- Sudan.

To Compare the available radiation protection programs in Sudan with international programs.

To measure the radiation dose level in the NM departments in Khartoum state and to compare them with the international stables .

1.5 Importance of the study

The study will serve a guide in drawing up radiation protection program to comply with radiation safety requirements and safe design and to return the responsibility of management and personnel working in nuclear medicine.

It is ensure that doses to occupationally exposed persons and member of public are kept as low as reasonably achievable (ALARA) principle for optimization of radiation protection of workers and patients. Developing radiation protection program will reduce the probability of potential exposure and with less economic and social impact if they occur.

1.6 Outlines

The study was included in five Chapters:

Chapter one deals with Introduction and Chapter two Literature Review, chapter Three contain the Materials and methods, Chapter four include the Results and the last chapters contain the Discussion and conclusion, recommendation and references.

Chapter Two

Literature Review

Chapter Two

Literature Review

2.1 Theoretical background

2.1.1 Radiation protection in nuclear medicine Facilities:

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 concerning ventilation ,plumbing, materials used in walls, floors and workbenches. (Ireland June 2009).

2.1.1.1 Design Objectives :

The main objectives of adequate design of a nuclear medicine facility can be summarized in the following points:

Safety of sources, Optimize exposure of staff patient s , and general public, Prevent uncontrolled spread of contamination, Maintain low background where most needed and Fulfill requirements regarding pharmaceutical work . (Ireland June 2009).

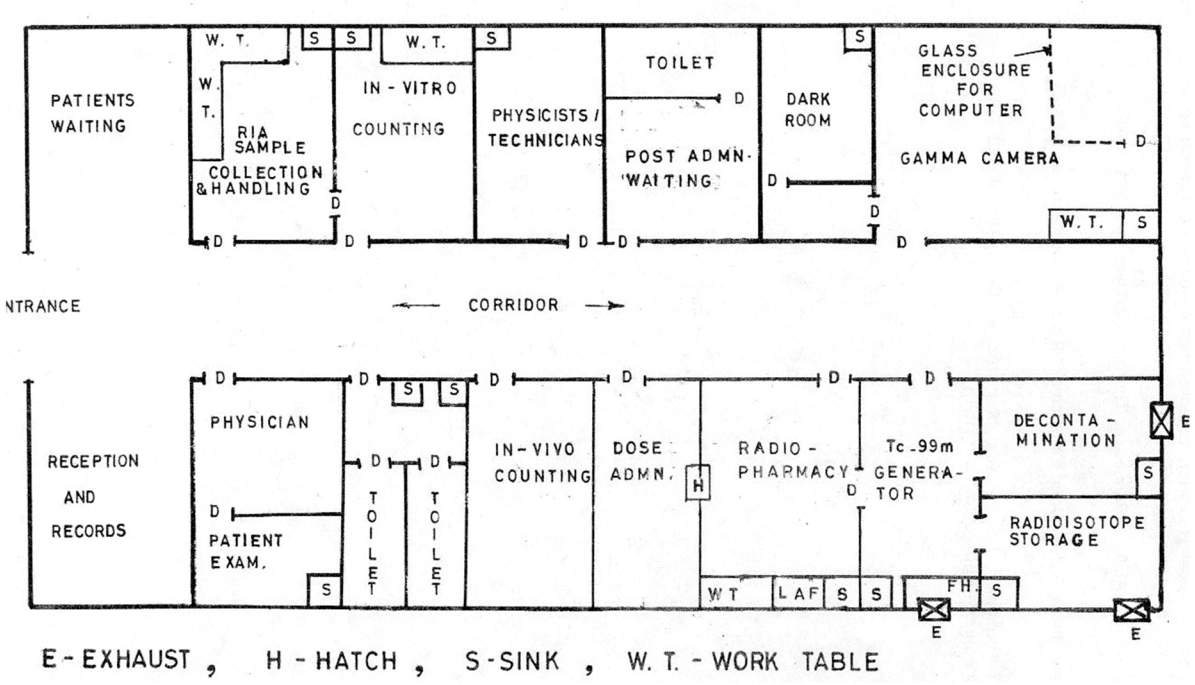


Figure 2.1 an example of optimum design of a nuclear medicine department

2.1.1.2Building requirements:

2.1.1.1Floors

The floors should be covered with one sheet of a material with the following properties :

Impervious material, Washable , Chemical –resistant , All joints sealed Glued to the floor.

Figure (2.2): A Room Floor in nuclear medicine

2.1.1.2Walls and ceiling :

Should be finished in a smooth and washable surface with joints being sealed , wherever practicable ,walls should be painted with washable ,non –porous paint (e .g gloss paint)(Ireland June 2009).

2.1.13Worktop surfaces :

Worktop surfaces must be finished in a smooth ,washable and chemical - resistant surfaces with all joints sealed .some laminates do not resist certain

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) should not be mounted on top of the bench ,but on walls or up stands ,Light fixtures should be easy to clean and of an enclosed type in order to minimize dust accumulation ,Structural reinforcement may be necessary ,since a considerable weight of lead shielding may be placed on counter tops ,Cover the surface with absorbing paper (Ireland June 2009).

2.1.1.4Ventilation:

Laboratories in which unsealed sources, especially radioactive aerosols or gases, may be produced or handled should have an appropriate ventilation system that includes a fume hood, laminar air flow cabinet or glove box.

The ventilation system should be designed such that the laboratory is at negative pressure relative to surrounding areas. the airflow should be from areas of minimal likelihood of airborne contamination to areas where such contamination is likely .all air from the laboratory should be vented through a fume hood and must no berecirculatedeither directly ,in combination with incoming fresh air in a mixing system ,or indirectly ,as a result of proximiy of the exhaust to a fresh air intake.(Ireland June 2009).

2.1.1.5Fume hood

The fume hood must be constructed of smooth , impervious ,washable and chemical-resistant material. 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 maybe required. The air –handling capacity of the fume hood should be such that the linear face velocity is between 0.5and 1.0meters/second with the sash in the normal working position .This should be checked regularly. (Ireland June 2009).

2.1.1.6Washing facilities:

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

2.1.1.7Patient 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 radioactive materials and minimize contamination. The facilities shall include a wash-up 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. (Ireland June 2009).

(Ireland June 2009).

2.1.1.3 Imaging room

The area of imaging room shall depends on the size of gamma camera and other associated equipment and accessories that may present in the room however typically the room area should about $25m^2$.

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 floor , walls and surface should comply with

2.1.1.4 Hot lab:

Hot Lab has been known to be anything from a facility handling large quantities of volatile radioisotopes, to as' "mall 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)

2.1.1.5 Isolation rooms

An inpatient treated with more than 400MBq of I-131 should be located in a single bedroom equipped with its own toilet and shower or bathroom.

The flooring should be smooth, continuous ,and non- absorbent .the walls and furniture should be covered with a non -absorbent 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(non-

radiotherapy)patient in the nearest neighboring bed for all the time a single therapy patient is present receives less than 0.3msv/procedure, Containers should be provided storage of used utensits and linen before they are checked for contamination**,** Drainpipes from bath room should be terminating in a delay tank ,Rooms should be equipped with movable shield for temporary.

2.1.2 Occupational Exposure:

2.1.2.1 Classification of Areas

Areas in nuclear medicine department should be clearly defined as part of the radiation protection plan (RPP)and their classification should result from safety assessment .two types of area may be defined controlled areas or supervised areas.

a. Controlled area:

The licensee and RPO shall classify any area needed to specific protective measures safety provisions or preventing spread of contamination and potential exposures as controlled area.

In particular ,an area should be designated as a controlled area when management considers that there is a need to adopt procedural controls to ensure an optimized level of protection and compliance with the relevant dose limits .Room for preparation of radiopharmaceuticals ,room for storage radionuclide ,room for storage of radioactive waste ,room for administration of

radiopharmaceuticals ,imaging rooms if or when administration is done and treatment room shall be a controlled area.(Peter F. Sharp, 2005)

b. Supervised area:

A supervised area is "any area not already designated as a controlled area but where occupational exposure conditions need to be kept under review even though specific protection measures and safety provisions are not normally needed". Supervised areas may include examination imaging rooms (with gamma cameras) and waiting rooms where there are patients who have been injected with radiopharmaceuticals .Radiation Protection Officer (RPO) and licensees shall, taking into account the nature and extent of radiation hazards in the supervised areas:

a. Delineate the supervised areas by appropriate means.

b. Display approved signs at appropriate access points to supervised areas.

c. Periodically review the conditions to determine any need for protective measures and safety provisions or changes to the boundaries of supervised areas. (Peter F. Sharp, 2005).

2.1.3 Individual monitoring:

Individual monitoring of individuals occupationally exposed to external ionizing radiation should be carried out in order to:

I. Control occupational exposure and to ensure safe and satisfactory working conditions

II. Demonstrate compliance with limits and the application of the principle of as low as reasonably achievable, economic and societal factors being taken into account‟ as part of legislative or regulatory systems;

III. Inform workers of their radiation exposure; where doses are low this may be for reassurance

IV. The controls should be supported by analyses of dose distributions and trends amongst and within groups of workers (Ireland June 2009).

2.1.4 Workplace monitoring

The nature and frequency of monitoring of workplaces shall be sufficient to enable:

Evaluation of the radiological conditions in all workplaces, Exposure assessment in controlled areas and supervised areas, Review of the classification of controlled and supervised areas, Depend on the levels of ambient dose equivalent and activity concentration, including their expected fluctuations and the likelihood and magnitude of potential exposures, Periodic monitoring with a survey meter and contamination monitor or by wipe tests should be conducted for controlled and supervised areas. Continuous monitoring with an area monitor should be

considered for source storage and handling areas. If a package containing radioactive sources is damaged upon arrival, a survey of removable contamination and the external radiation field should be carried out.

2.1.5 Medical Exposures:

To comply with radiation safety it is indispensable that licensees Establish to internal mechanism to ensure that medical exposure be prescribed by medical practitioner ,that the obligation for overall patient protection Be assigned to a nuclear medicine specialist or equivalent ,that medical and paramedical staff be available ,that advice of qualified experts in nuclear medicine physics be available ,and that only staff with the necessary training be in charge of exposure of patients for diagnosis and treatment (Ireland June 2009).

2.1.5.1 Justification:

Medical exposures should be justified by weighing the diagnostic or therapeutic benefits they produce against the radiation detriment they might cause ,taking into account the benefits and risks of available alternative techniques that do not involves medical exposure ,such as ultrasound or magnetic resonance imaging (MRI).

As children are at greater risk of incurring stochastic effects ,pediatric examinations should require special consideration in the justification process. thus the benefit of some high dose examinations should be carefully weighed against the increased risk.

The justification of examinations in pregnant women requires special consideration .due to the higher radiosensitivity of the fetus, the risk may be substantial ,so the licensee shall ascertain whether the female patient is pregnant before considering use of a radionuclides for diagnosis or for therapy.in these cases, the advice of a

medical physics expert should be required and a fetal dose and nominal fetal risk estimation performed before deciding whether the examination should be undertaken. As a rule ,a pregnant woman should not be treated with a radioactive substance unless the application is life –saving. Otherwise, the therapeutic application should be defer until after the pregnancy and after any period of breast feeding. (Ireland June 2009).

2.1.5.2Optimization:

a. Diagnostic procedures

The optimization process necessarily a balance between administered activity and patient radiation dose and image quality .the activity administered should be sufficient to produce good image quality .The following points apply to individual patients:

-There should be an affective system for correct identification of patients

-There should be a written protocol for each diagnostic procedure, designed to maximize the clinical information to be obtained from the study ,taking into consideration the appropriate guidance level for the procedure .

-Data acquisition conditions should be selected such that the exposure is the minimum necessary for a cheving the intended diagnostic objective .the choice of collimator ,energy window ,matrix size ,acquisition time ,angulations of collimator ,single photon emission computed tomography(SPECT) or PET parameters and zoom factor shall be set up to maximize quality image per administered activity .

Repeat examinations should be minimized .if a nuclear medicine procedure needs to be repeated ,this will result in increased exposure to both the patient and staff. (Ireland June 2009).

b. Therapeutic procedures :

The following provisions should be in place:

An effective system for identification of patients ,Procedures to find out ,before administration of the radiopharmaceutical whether patients are pregnant or breast feeding .Verbal and written instructions to patients to minimize exposure to family members and the Public, Special attention to preventing spread of contamination due to patient vomit and excreta, Observance of national regulations on release of patients after administration of therapeutic doses of radiopharmaceuticals (Ireland June 2009).

2.1.6 Public Exposure :

2.1.6.1Control of Access of Visitors:

Arrangements should be made to control access of visitors to patients undergoing Radionuclide therapy and to provide adequate information and instruction to these persons before they enter the patient s room so as to ensure appropriate protection. (Ireland June 2009).

2.1.7 Radioactive contamination:

Licensees shall ensure that for sources for which they are responsible ,measures optimized are taken ,as appropriate ,for restricting public exposure to contamination in areas accessible to the public . (Ireland June 2009).

2.1.8 Protection of the Embryo/Fetus :

2.1.8.1Biological Effects:

There are radiation related risks throughout pregnancy that are related to the stage of pregnancy and absorbed dose .radiation risk is most significant during organogenesis and in the early fetal period ,somewhat less in the 2nd trimester and last in the 3rd trimester .Malformation have a threshold of 100-200mgy or higher and are typically associated with central nervous system problems. fetal dose in exceeding 100mGy can result in some reduction of IQ (intelligent quotient).fetal dose in range of 1000Mgy can result in severe mental retardation and microcephaly .particularly during 8-15 weeks and to a lesser extent at 16-25 weeks .There is evidence of a slightly increased risk of induction of childhood cancer or leukemia for doses of more than 10mgy.

2.1.9 Confirming Absence of pregnancy:

In women of child –bearing age, the possibility of pregnancy and the justification of for examination should be considered .The recommendation precaution to prevent or minimize irradiation of an embryo or fetus includes the following :

The patient must be careful interviewed to assess likelihood of particular discretion is required to ascertain the possibility of pregnancy in an adolescent ,It is prudent to consider a pregnant any woman of reproductive age presenting for a nuclear medicine examination at a time when menstrual period is overdue or missed ,unless there is information that precludes pregnancy (e.g. hysterectomy).if the menstrual cycle is irregular , a pregnancy test me be indicated before proceeding .

In order to minimize the frequency of unintentional irradiation of the embryo or fetus advisory notices (in the local language) should be at several places within the nuclear medicine departments and particularly at its reception area tell the patient to inform the staff if she is pregnancy .An example of such a notice . ((NHMRC), Canberra, June 1995).

IF YOU THINK THAT YOU MIGHT BE PREGNANT . NOTIFY STAFF BEFORE TREATMENT

2.1.10 Pregnant patient:

Sometimes there may be good reasons to use ionizing radiation for diagnostic purposes in a pregnant patient in order to provide optimal care for the mother and, indirectly, potential benefit for the fetus. If a diagnostic radiation study is medically indicated the risk to the mother and fetus from not performing the study is usually greater than the risk from the radiation associated with the procedure. If a nuclear medicine study is justified and will be proceeded with, the administered activity should be as low as possible, provided it is sufficient to supply the required diagnostic information. Prior to the procedure the nuclear medicine specialist should assess the potential dose and communicate the risks to the mother in a meaningful manner. Individual fetal radiation dose estimates may require the services of a nuclear medicine physicist. ((NHMRC), Canberra, June 1995).

2.1.11Protection of an Infant:

The Infant of a breast feeding patient will receive external dose from close contact to patient and internal dose from ingested breast milk .Before commencing a

nuclear medicine procedure, every female patient of childbearing age should be asked by the administering person whether she is breast-feeding or caring for a young child. Steps can then be taken (if necessary) to minimize the external radiation dose to the child during periods of close contact with the patient, and the internal radiation dose from ingested breast milk.

In order to minimize the irradiation to the Infant advisory notices- in local languages should be posted within the nuclear medicine departments tell the patient to inform the staff if she is breast feeding . ((NHMRC), Canberra, June 1995)

IF YOU ARE BREAST FEEDING PLEASE NOTIFY THE STAFF.

2.1.12 Radioactive Sources and Waste :

2.1.12.1Receipt and Transfer of Radiation Sources :

When radioactive material is received in nuclear medicine facility, the following action will be taken:

-Radiation Protection Officer will check the package for damage or contamination.

- A radioactive material control number will be placed on each final source container.

- A radioactive material usage record will be prepared for each radioactive material control number assigned.

-The radioactive material labels on shipping containers will be defaced as appropriate.

- Do not transfer radioactive material, either on campus or to another institution, without prior approval by Radiation Protection Officer (RPO).

-If radioactive materials are inadvertently delivered to another location, please notify Radiation Protection Officer (RPO) immediately. ((NHMRC), Canberra, June 1995)

2.1.12.2Transport of Radioactive Sources:

Ideally all the hospital is activities involving radioactive material should be centralized into one location to avoid transport of radioactive materials between units. Exceptions to this include some laboratories within the pathology service and some research laboratories, A radioactive material to be transported beyond controlled areas must be stored in a suitable lead-lined receptacle, The receptacle should carry a radiation warning sign, Radioactive materials should be transported by, or under the supervision advice of a qualified radiographer or physicist, Care should be taken that radioactive materials are not moved inadvertently ,Package and vehicle used for transport should be properly labeled and marked. ((NHMRC), Canberra, June 1995).

2.1.12.3 Storage:

Source stores must: Provide protection against environmental conditions, Be only for radioactive materials ,Provide sufficient shielding, Be resistant to fire, Be secure.((NHMRC), Canberra, June 1995)

2.1.12.4 Security:

The objective of source security is to ensure continuity in the control and accountability of each source at all times. A multilayer (defense in depth) system of provisions for protection and safety commensurate with the magnitude and likelihood of the potential exposures involved should be applied to sources such that a failure at one layer is compensated for or corrected by subsequent layers, for the purposes of :

Preventing accidents that may cause exposure ,Mitigating the consequence of any such accident that does occur ,Restoring sources to safe conditions after any such accident .The licensee shall establish security systems to prevent theft, loss, unauthorized use , or damage to sources ,or entrance of unauthorized personal to the controlled areas .The licensee shall maintain an inventory of sources received by the practice and Develop procedures to ensure the safe movement of radioactive sources within the institution at all times from receipt to disposal. ((NHMRC), Canberra, June 1995)

2.1.13 Waste :

The use of unsealed sources in diagnosis and therapy will generate radioactive waste of different kinds during preparation, patient examination and care. Radioactive 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 sources, has

resulted in radiation exposure of members of the public or extensive contamination of equipment ,buildings or land . In some cases uncontrolled radiation exposure has been lethal. The Radioactive waste in hospitals comprises many different type of waste .It may be of high activity such as a technetium 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 .all these aspects must be accounted for in the planning of waste treatment in a hospital .

The types of waste are:

- Solid waste: include cover papers ,gloves ,empty vials and syringes, radionuclides generators ,items used by hospitalized patients after radionuclides therapy, sealed sources used for calibration of instruments
- Liquid waste : residues of radionuclides .patient excreta .liquid scintillation solutions.
- Gaseous waste: Exhausted gas from patients in nuclear medicine

The registrant and the licensee shall develop and implement a program for safe disposal of radioactive waste or return of sources when their use is discontinued , as required by the regulation of management of radioactive waste issued by the RPTC in 1998. .((NHMRC), Canberra, June 1995)

2.1.13.1Waste collection and segregation and storage :

In order to simplify the waste management the selection of unsealed sources in a certain application should consider:

The half-life of the radionuclide ,which should be as short as is consistent with the application ,The type and energy of the radiation ,The activity ,which should be as low as is consistent with the application ,Selection of the materials that minimize the number of operations required to prepare them for the specific application. Containers to allow segregation of different types of radioactive waste should be available in areas where the waste is generated (mainly, the hot lab).The containers must be suitable for that purpose (volume , shielding ,leak proof, etc) Each type of waste should be kept in separate containers properly labeled to supply information about the radionuclides ,activity concentration etc. flammable good should be kept apart .A room for interim storage of

radioactive waste should be available in a nuclear medicine facility .the room should be locked ,properly marked and ventilated .((NHMRC), Canberra, June 1995)

2.1.14 Emergency plans:

2.1.14.1 Safety Assessment:

In nuclear medicine safety assessment deals with finding out ,what can go wrong ? at every step (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 therapy patients with high amounts of radioactivity ,and storage and handling 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 program .additional reviews shall be performed as necessary whenever:

Safety may be compromised as a result of modifications of the facilities or of the procedures , Operational experience or information on accidents or errors indicates that a review is necessary, Any significant changes to relevant guidelines or standards are envisaged or have been made . (www. iaea.org)

2.1.14.1Planning for accidents and Emergencies :

The employer shall prepare emergency procedures. The procedures should be clear, concise and unambiguous and shall be posted visibly in places where their need is anticipated.

2.1.15Types of Emergencies :

2.1.15.1 Lost Sources :

It is critical for this type of event that an up-to-date inventory exists so that it can be determined immediately which source(s) is (are) missing, what its type and activity are, when and where it was last known to be, and who last took possession of it. A proactive attitude is important for the case that sources are ordered and not received at the expected time. Making a check for the arrival of a source at the expected receipt time should be part of the procedures. The actions to be part of the contingency plans include:

Obtain assistance from the RPO, Conduct a local search, Check and ensure security and control of other sources, Check all possibilities in the hospital.

If still not found, call the company and inform them of the failure so that they can trace the shipment and find out where the radioactive material is, if not found report the loss of the material .

2.1.15.2Damage to Technetium-99m (99mTc) generators :

Generators contain a relatively large amount of radioactivity. In the event of a 99mTc generator being damaged, the measures to be taken are:

1. Evacuate the area immediately.
2. Inform the RPO, who should confirm the spillage and supervise the decontamination and monitoring procedures.
3. Record the event and make a report

2.1.16Quality Assurance:

The licensee shall establish a comprehensive QA program for radiation protection safety and image quality to ensure that all necessary procedures are develop and implement to comply with the regulations for radiation protection within the terms and conditions of the authorization of the facility. Experience has shown that the frequency of accidental exposures during in vivo application is directly related to the absence or inadequacy of an established quality assurance program in the department concerned.

Objectives of quality assurance program:

Improvement in the quality of the diagnostic information, Use of minimum amount of radionuclide activity to ensure the production of the desired diagnostic information, Effective use of available resources, The program should cover the entire process from the initial decision to adopt a particular procedure through to the interpretation and recording of results and should include ongoing auditing, both internal and external ,as a systematic control methodology. Quality assurance in nuclear medicine should cover as a minimum :

- Acceptance ,commissioning and QC of equipment and software
- QC of radiopharmaceuticals, radionuclide generators and other unsealed radionuclides
- Provide manuals and instructions for safe use and maintenance(www. .iaea.org)

2.1.17Qualified Expert:

The qualified expert is a medical physicist with suitable training and Experiences , usually in nuclear medicine physics and must be have license from RPTC. (www. .iaea.org)

2.2 previous studies:

the earlier code of practice regulate the work in nuclear medicine department in Sudan issued by Sudan Atomic Energy Commission on 1998 and the last code of practice regulate the work in nuclear medicine issued by the Sudanese Nuclear and Radiological Regulatory Authority(SNRRA) on 2009 after separated it from Sudan Atomic Energy Commission.

MOHAMMED IBRAHIM, 2010,(Code of Practice for Radiation Protection in Nuclear Medicine)The aim of this study was to develop a draft for a new code of practice for radiation protection in nuclear medicine that meets the current relevant international recommendations. The draft includes the following main fields: methods of radiation protection for workers, patients and public. Also, the principles of safe design of nuclear medicine department, quality assurance program, proper manipulation of radiation sources including radioactive waste and

emergency preparedness and response. The practical part of this study includes inspections of three nuclear medicine departments available in Sudan so as to assess the degree of compliance of those departments with what is stated in this code. The inspection missions have been conducted using a checklist that addresses all items that may affect radiation protection issues in addition to performing area radiation monitoring around the installation of the radioactive sources. The results of this study revealed that most of the departments do not have effective radiation protection program which in turn could lead to unnecessary exposure to patients, public and workers.

Finally, some recommendations are given that - if implemented - could improve the status of radiation protection in nuclear medicine department.

EZZELDEIN MOHAMMED,2015,GHANA, (Overview of Radiation Protection Program in Nuclear Medicine Facility for Diagnostic Procedures) This 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 this project is to keep dose to staff, patient and public as low as reasonably achievable (ALARA). The specific objectives were to review the Radiation Protection Program (RPP) in diagnostic nuclear medicine and to make some recommendation for improving the level of radiation protection in diagnostic

nuclear medicine that will help to control normal exposure and prevent or mitigate potential 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 if implemented could improve the level of radiation protection in nuclear medicine department. One of the most important recommendations is that a qualified Radiation Protection Officer (RPO) should be appointed to lay down and oversee a radiation protection in the nuclear medicine department. The RPO must be given the full authority and the adequate time to enable him to perform his duties effectively.

Chapter Three

MATERIALS AND METHODS

Chapter Three

MATERIALS AND METHODS

3.1 Materials :

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

Two types of survey meter were used to measure the dose rate

3.1.1 Survey meters

Survey Meter I Model 70934

Date of calibration 3/1/2016

Re- calibration due :2/1/2017

Figure (3.1): Survey Meter I Model 70934

Survey Meter:

Invasion Model 451P Pressurized Certificate No: SAEC/24/014.

Figure (3.2): Survey Meter Invasion Model 451P

3.1.2Contamination monitors:

CoMo170 contamination monitor

Serial Number: 0493CH

Manufacture: NUKLKAR-Medizintechnick Dresden (imbll

Detector size: 170 cm2

Result display: Bq /cm2

Figure 3.3 bellow shows the Co Mo 170 Contamination monitor

Figure 3.3 CoMo 170 Contamination monitor

FHT 111 Mcontamat contamination monitor:

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

Manufacture: Thermo Fisher Scientific Inc.

Model: FHT 111Thermo

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

Figure 3.4: CONTAMAT FHT111M at (CONTAMAT FHT 111 M Thermo

scientific α/β+Ɣ.)

3.2 Methods:

The study was conducted in Three nuclear medicine centers, one governmental and two private hospitals.

The measurements were taken from three different hospitals A, B,C using the devices mentioned in the previous section.

Two methods were used to evaluate the radiation protection level in nuclear medicine

Departments.

3.2.1 Data collection: Data were collected from text books, references, websites, and personal contact.

3.2.2Data analysis: Qualitative and Quantitative description. The data were processed using computer programs including excel.

3.2.3Direct measurement:

The dose rate and contamination level were measured in different locations within the nuclear medicine departments. The measurements were repeated and the averages were taken.

3.2.4 Checklist:

Radiation sources, Receipt and transfer of radiation sources, Quality Assurance (QA) and Quality Control, Area radiation surveys and contamination control, Area radiation monitoring

Personnel radiation monitoring, Radioactive waste management, Transport of radioactive sources, Warning signs and labeling, Training of workers, Responsibilities, Emergency, accident and incident.

Chapter Four

RESULTS

Chapter Four

RESULTS

4.1Results

Table (4.1.1) Background of dose rate for department hospital (A,B,C)

Background	Dose rate µSv/h
Background department hospital (A)	**0.1**
Background department hospital (B)	**0.2**
Background department hospital (C)	**0.12**

Table (4.1.2) dose rate measurement for department hospitals (A ,B,C)

Measurement location	Average(µSv/h**)** hospital (A)	Average(µSv/h**)** hospital (B)	Average(µSv/h**)** hospital (C)
1- out side the door of camera	0.03	0.1	0.10
2-inside the imaging room	0.1	0.16	0.156
3-in side the injection (room)	0.07	0.1	0.063
4- Inside the hot lab	1.03	0.5	1.316
5- outside the door of hot lab	0.1	0.3	0.063

6- outside the door of controlled area	0.06	0.1	3.66

- **The average was taken from three different readings .**

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

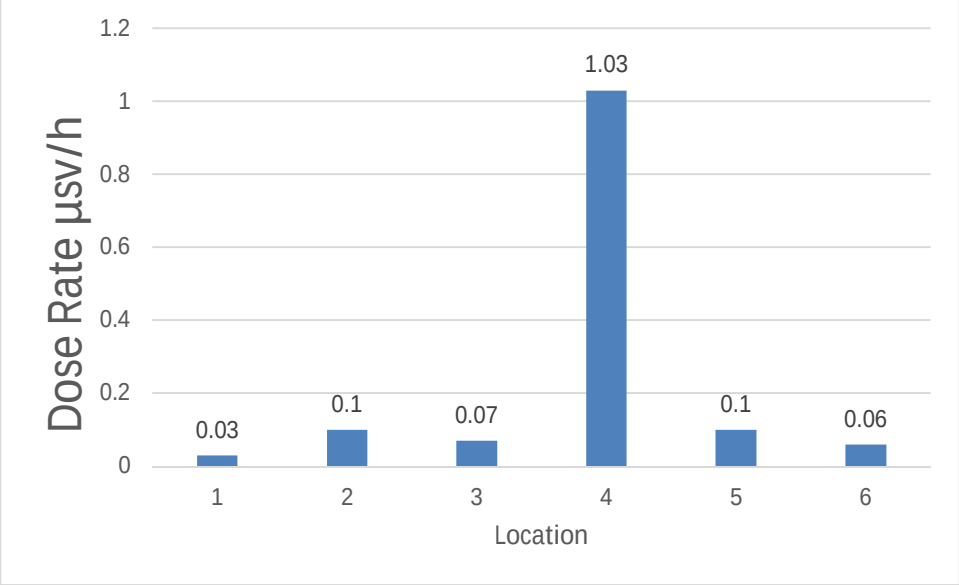


Figure: 4.2 Relation between the dose rate and location in hospital (B)

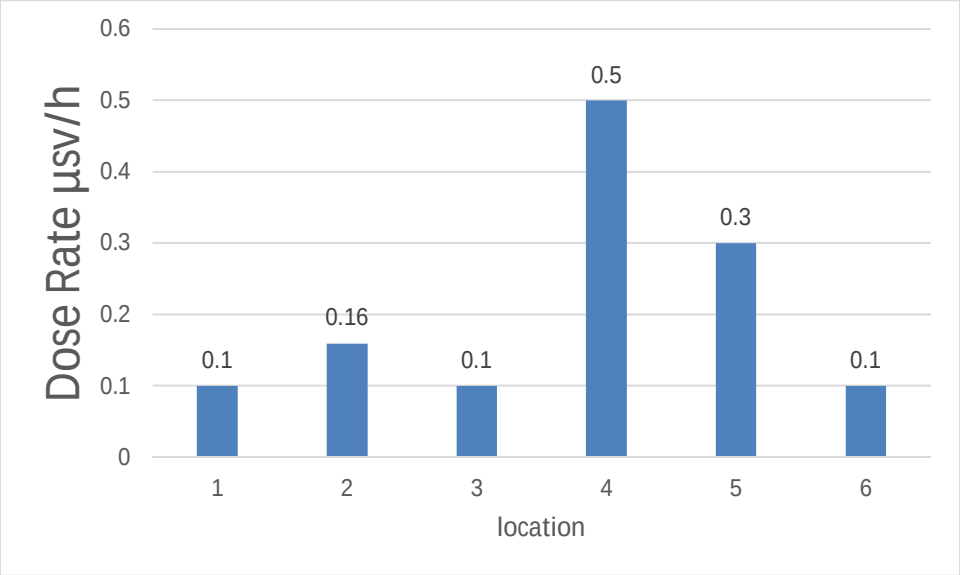


Figure: 4.3 Relation between the dose rate and location in hospital (C):

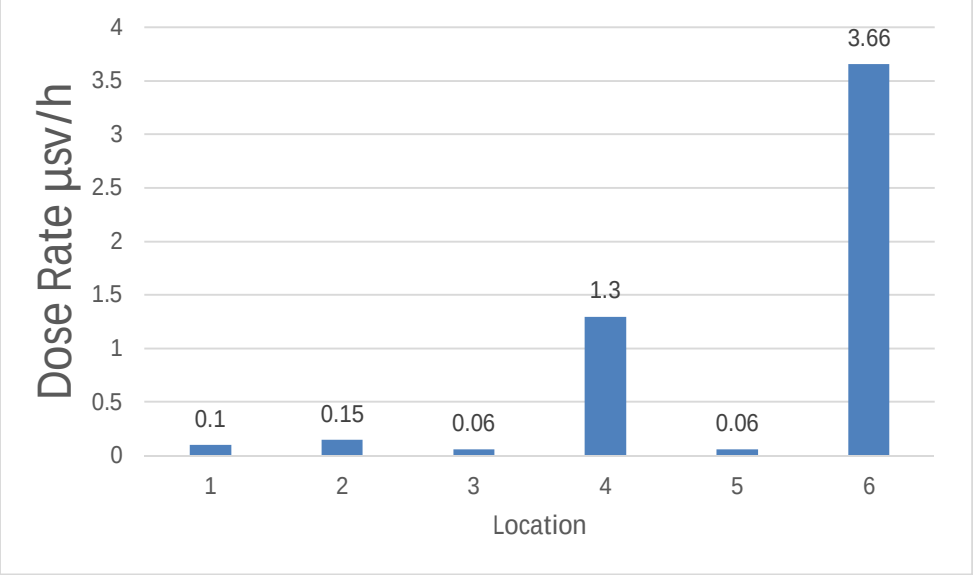


Table (4.1.3) Background radiation of Contamination level in hospitals (A ,B, C)

Background	Contamination level Bq/cm2
Background department hospital (A)	**3.352**
Background department hospital (B)	**2.4**
Background department hospital (C)	**2.7**

Table (4.1.4) Measurement of Contamination level in hospitals (A,B,C)

Measurement location	Average(Bq/cm^2**)** hospital (A)	Average(Bq/cm^2**)** hospital (B)	Average(Bq/cm^2**)** hospital (C)
On the table of injection room	1.17	1.0	41.46
On the floor of injection room	1.12	1.06	14.01
On the floor of hot lab	1.23	1.1	49.86
On the bench top	13.1	12.2	124.3
On the shield working surface	5.46	7.8	73.3

- **The average was taken from three different readings .**

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

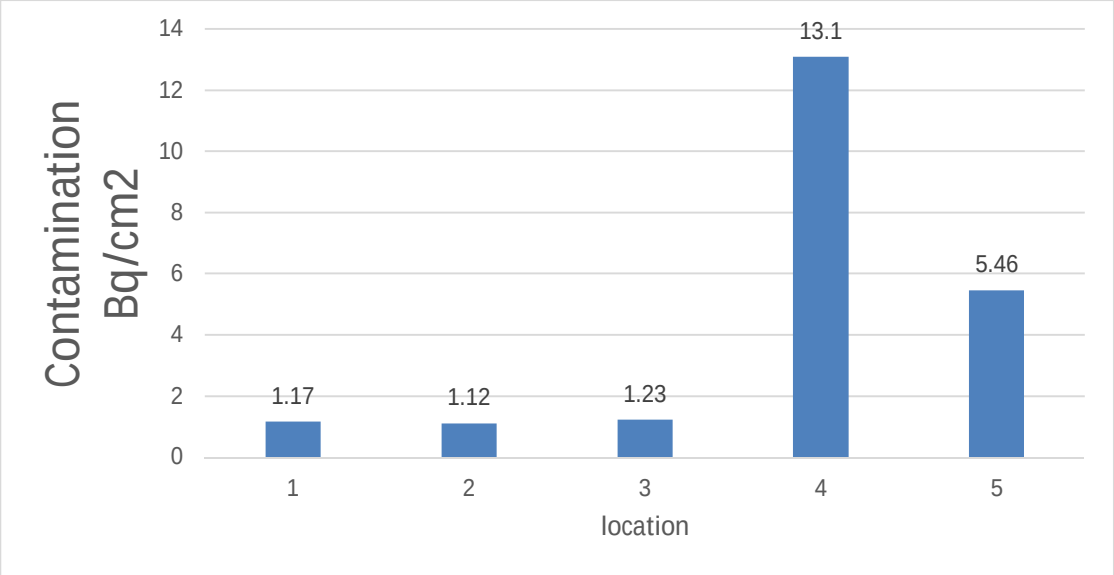


Figure: 4.5Relation between the contamination and location in hospital (B)

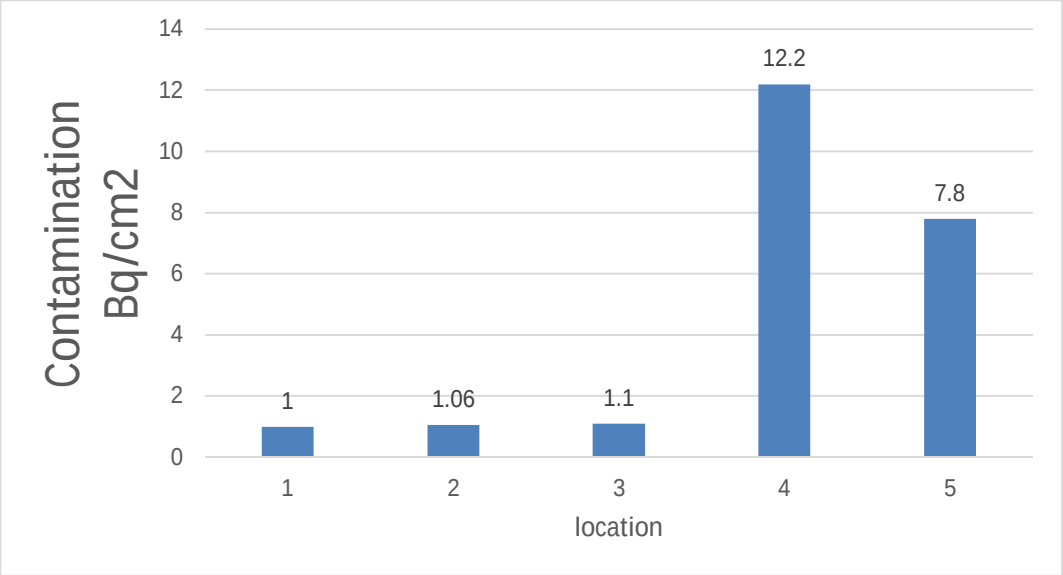
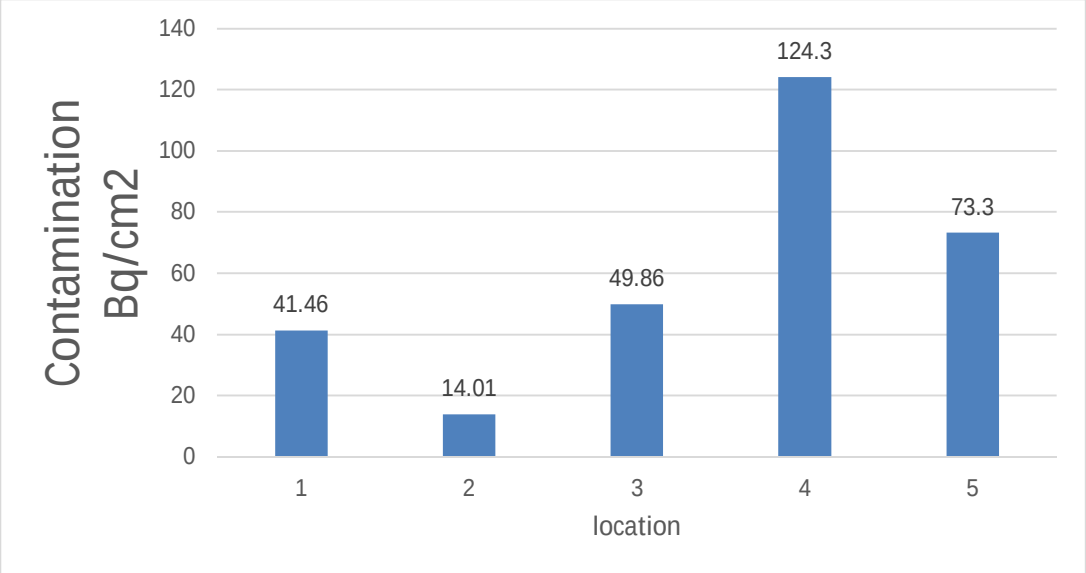


Figure: 4.9Relation between the contamination and location in hospital (C)



4.2 Check lists

The following check lists were performed for the three hospitals A, B, C. the list were about the evaluation of the radiation protection level.

Table 4.2.1 Check for radiation sources

Evaluated Items	**Evaluation Criteria (YES(1)OR NO(0)**		
	Hospital		
	A	B	C
License of using "Mo/^Tc generator?	1	1	1
Records of Leakage tests and inventory maintained?	0	1	1

Table 4.2.2 Check for receipt and transfer of radiation sources

Evaluated Items	**Evaluation Criteria (YES(1)OR NO(0)**		
	Hospital		
	A	B	C
Radioactive package opening procedures established	1	1	1

and followed?			
Record of packaging surveys, source receipt and transfer maintained?	0	0	0
Incoming radioactive packages surveyed for damage, dose rates and potential radioactive contamination before opening ?	0	0	0

Table 4.2.3Check for personnel radiation monitoring

Evaluated Items	**Evaluation Criteria (YES(1)OR NO(0)**		
	Hospital		
	A	B	C
Licensee provides personal dosimeter to all radiation workers?	0	1	0
Dosimeters are exchanged at the prescribed period?	0	1	0
Dosimetry reports are promptly reviewed by the RPO?	0	1	1
Does the licensee apply ALARA to occupational exposure?	0	0	0

Table 4.2.4Check for area radiation surveys and contamination control

Evaluated Items	**Evaluation Criteria (YES(1)OR NO(0)**		
	Hospital		
	A	B	C
Daily contamination surveys performed?	0	1	0
Weekly surveys of labs and storage areas ?	0	1	0
Survey meter calibrations are checked ?	1	1	1

Table 4.2.5Check for area radiation monitoring

Evaluated Items	**Evaluation Criteria (YES(1)OR NO(0)**		
	Hospital		
	A	B	C
Area exposure rate surveys are performed by an approved facility?	1	1	1
Survey for removable contamination conducted as required?	1	1	1

Records of calibrations, contamination surveys maintained?	1	1	1

Table 4.2.6Check for transport of radioactive source

Evaluated Items	**Evaluation Criteria (YES(1)OR NO(0)**		
	Hospital		
	A	B	C
Authorized package used?	1	1	1
Licensee's vehicles if used for transport, comply with regulations?	1	1	1
Package properly labeled and marked?	1	1	1

Table 4.2.7Check for warning signs and labeling

Evaluated Items	**Evaluation Criteria (YES(1)OR NO(0)**		
	Hospital		
	A	B	C

Controlled areas have appropriate warning signs (in local language)?	1	1	1
Containers of radioactive material are proper labeled?	1	1	1
Notices to workers are displayed as required?	1	1	1
Radiopharmaceuticals syringes, vials, storage areas labeled as appropriate?	1	1	1

Table 4.2.8 Check for radioactive waste management

Evaluated Items	**Evaluation Criteria (YES(1)OR NO(0)**		
	Hospital		
	A	B	C
Security and fire safety satisfactory?	1	1	1
A storage facility for radioactive sources complies with regulations?	1	1	1
Warning and notification signs (in local language) satisfactory?	1	1	1

Table 4.2.9Check for responsibilities:

Evaluated Items	**Evaluation Criteria (YES(1)OR NO(0)**		
	Hospital		
	A	B	C
Procedures are authorized by appropriately qualified practitioners?	1	1	1
Dose the practitioners ensure that procedure are justified?	0	0	1
Are satisfactory procedures in place to properly identify patients before procedures?	1	1	1
Are satisfactory procedures in place to identify potentially pregnant patient and if clinically appropriate, to defer or modify procedure?	1	1	1

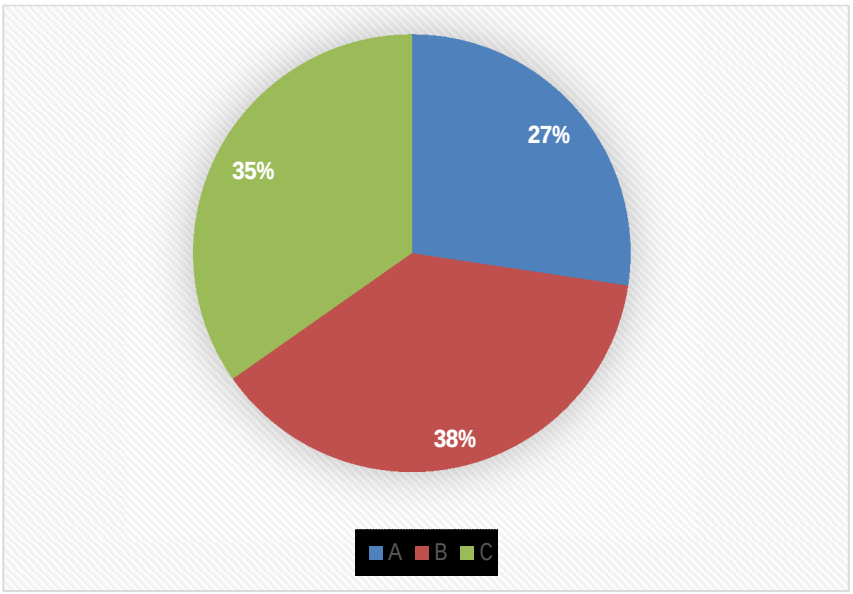
Table 4.2.10 Check for training of workers

Evaluated Items	**Evaluation Criteria (YES(1)OR NO(0)**		
	Hospital		
	A	B	C
All persons working with radiation have prescribed qualifications and /or training?	1	1	1
All occupationally exposed personnel are provided with initial safety training?	0	1	1
Adequate supervision of workers (technologists) by medical practitioners?	0	1	1

Table 4.2.11 Check for emergency, accident and incident:

Evaluated Items	**Evaluation Criteria (YES(1)OR NO(0)**		
	Hospital		
	A	B	C
Does the facility have appropriate equipment to deal with emergencies (spills)?	0	1	1

Are the facility procedures for dealing with accidents and incidents appropriate?	0	1	1
Personnel appropriately trained with regard to dealing with emergencies and with the requirements for notifying accidents / incidents?	1	1	1


27%
35%
38%
A
B
C

Chapter Five

Discussion and Conclusion and

Recommendations

Chapter Five

Discussion and Conclusion and Recommendations

5.1 Discussion :

This study was conducted at three nuclear medicine departments, two private and one governmental . All of those departments possess the required capability for conducting diagnostic procedure with only one has also capabilities for therapy procedures. There are six departments of nuclear medicine in Sudan.

The evaluation of radiation protection was carried out by conducting two methods to the nuclear medicine departments one of them was the use a checklists that covered 11 areas and the other was the use of direct measurements of dose rate and contamination in NM departments. The results showed that all departments of Diagnostic and therapy in NM meet the national regulations in some procedures and suffer in to other regulations.

In direct measurements it was found that radiation levels were much less than the acceptable limits. For The evaluation of radiation protection in nuclear medicine departments using check list, the result showed that for radiation sources three hospitals had license to use radioactive records sources . Records of survey were maintained except at hospital (A). According to tables(4.2.2). All hospitals established procedure and followed it for opening radioactive package. Two of hospitals (B, C) had QA program, and working rules. Three hospital followed QC program for imaging equipment and dose calibrators specified by the manufacturer. For radiation surveys and contamination controls all hospitals conduct surveys . Daily contamination and survey were performed in hospital B . Weekly surveys of lab and storage areas were performed in hospital (B) . All instruments for survey were current calibrated and calibration performed by SAEC at Secondary Standard Dosimetry Laboratory (SSDL). Radiation monitoring for all hospitals

(A,B,C) was performed by an approved facility, and all hospitals(A,B,C) had record for survey as for personal monitoring ,one departments(B) provided personal dosimeters to all radiation workers which were changed at the prescribed period. As For radioactive waste management ,all hospitals releasing and storage facilities comply with regulation, Security, fire safety, warning, notification were satisfactory and store contents were checked at acceptable intervals in all hospitals. For transportation of radioactive sources authorized, labeled and marked package were used. Vehicles used for transport comply with regulations. Controlled areas, storage areas., vials, syringes, and radioactive containers were properly labeled in all hospitals. Notices to workers were displayed as required in all hospitals . All radiation workers had prescribed qualifications and training. There was an adequate supervision of workers by medical practitioners except for hospital (A).All hospitals used satisfactory procedures to identify patient and pregnant patients before procedure. All hospitals procedures were authorized by medical practitioners.

All NM departments had waste storage facilities. There were waiting areas for injected and non injected patients . Floor in hospital (B) was constructed using easily decontaminated materials. For emergency, accidents and all incidents, hospitals had appropriate equipment to deal with emergencies except hospital (A). Personnel in all NM departments were trained with regard to dealing with emergencies and requirements for notifying accidents and incidents.

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 .The maximum dose rate was found inside the hot lab in all hospitals.

5.2 Conclusion:

This study was conducted at the nuclear medicine departments – in Khartoum namely Nuclear medicine department hospital (A),Nuclear medicine department hospital (B)and Nuclear medicine department hospital (C).

The main objective was to Assess Radiation Protection situation in Nuclear Medicine Departments in Khartoum- Sudan.

The results showed that , the two main problems found in the three Centers under this study included that the RPO"s have no full authorities and adequate time to enable them to do their duties effectively. The second problem was that design of nuclear medicine departments were not compatible with the international standards and regulations. All departments have to do a lot of work, to improve the level of radiation protection so as to comply with the code of practice and the international regulations. The current status of radiation program in all departments is not satisfactory that may lead to unjustified exposure to radiation.

5.3 Recommendations:

There are some recommendations that if implemented could improve radiation protection in nuclear medicine departments.

Application of a quality assurance programs (QA) that include quality control test for imaging instruments, waste management, survey of radiation, and radiation protection program to decrease the radiation risk to patients and staff.

The RPO must be given the full authority and the adequate time to be able to do their duties effectively.

The design of a new nuclear medicine department should be reviewed by qualified expert to be compatible with the international standards regulations.

Proper radiation protection officers (RPO) should be appointed to design and implement a radiation protection program in nuclear medicine departments .

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

Establishing and enhancing the available capacity regarding education and training of radiation workers on radiation protection is highly recommended.

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Appendixs

Appendix 1

Dose limits

Dose limit	Effective dose	Equivalent dose
Occupational dose limit	20 msv/year averaged over five constructed years but not more than 50 msv in each single year	150msv/year to lens of the eye.
		500mcv/year to the extremities (skin, hands and feel)
Student and apprentices	6 msv/year	50 msv/year to the lens of the eye
		150msv/year to the extremities
public	1msv/year averaged over five years	15msv/year to the lens of the eye
		50msv/year to the skin
Fetus or embryo	1msv per period of pregnancy	
Comforter of patient	< 5mcv during the period of patient diagnostic examination	

Appendix 2

QUALITY CONTROL PROGRAM FOR SPECT (QC)

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 resolution	Quarterly

Appendix 3

The door nuclear medicine department in hospital (B)

Appendix 4 (washing facility in hot lab in hospital (B))

Appendix 5 (Store)

Appendix 6 (ventilation system)

Appendix 7

The door Nuclear medicine department in hospital (C)

Appendix 8

The door Nuclear medicine department in hospital (A)