

Sudan University of Science and Technology
College of Graduate Studies



Assessment of Design of Nuclear Medicine
Department design and
Radiation Safety

تقويم اقسام الطب النووى من حيث التصميم و السلامه
من الاشعاع

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

By:

Sahar Elsir Elsamani Mohamed

Supervisor:

Dr: Mohamed Mohamed omer Mohamed yousef

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بسم الله الرحمن الرحيم

(إنما يخشى الله من عباده العلماء إن الله

عزيز غفور)

صدق الله العظيم ،،،

فاطر 28

Dedication

*To my parents,
my teachers,
and friends*

For giving me never-endless gifts of encouragement, love and
patience

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*I would like to express my sincere gratitude to
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Abstract

The purpose of this study is to highlight the importance of radiation protection in nuclear medicine, to assess the level of application of Radiation safety measures programs in the nuclear medicine department.

This study was done in selected departments of nuclear medicine included the National Center for radiotherapy ,Alneilin , Fadil and Royal Care using questionnaire for workers for evaluation of radiation safety in the departments, in the period from January 2015 to may 2015

The results of this study showed that the level of radiation protection in the centers needs some attention and development, and based on that the development of proposals and recommendations which would help improve the level of radiation protection in the departments of nuclear medicine.

ملخص الدراسة

والغرض من هذه الدراسة هو تسليط الضوء على مجال الحماية من الإشعاع في الطب النووي ، لتقييم مستوى تطبيق برامج الوقاية من الإشعاع في قسم الطب النووي في ولاية الخرطوم.. أجريت هذه الدراسة في دوائر مختارة من الطب النووي شملت مركز القومي للعلاج بالإشعاع، النيلين ، فضيل ورويال كير باستخدام استبيان للعمال لتقييم السلامة من الإشعاع في الإدارات، في الفترة من يناير 2015 إلى مايو 2015 أظهرت نتائج هذه الدراسة أن مستوى الحماية من الإشعاع في المراكز يحتاج بعض الاهتمام والتطوير، وبناء على ذلك وضع مقترحات وتوصيات من شأنها أن تساعد على تحسين مستوى الحماية من الإشعاع في أقسام الطب النووي في الخرطوم..

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List of abbreviations

CT	Computed Tomography
NM	Nuclear medicine
PET	Positron Emission Tomography
RPA	Radiation Protection Adviser
MRI	Magnetic Resonance Imaging
DNA	deoxyribonucleic acid

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Chapter One

(Introduction)

Chapter one

1.1 Introduction:

Nuclear medicine is a medical specialty involving the application of radioactive substances in the diagnosis and treatment of disease. In nuclear medicine procedures, radionuclide's are combined with other elements to form chemical compounds, or else combined with existing pharmaceutical compounds, to form radiopharmaceuticals. [james et al,2003]

These radiopharmaceuticals, once administered to the patient, can localize to specific organs or cellular receptors. This property of radiopharmaceuticals allows nuclear medicine the ability to image the extent of a disease process in the body, based on the cellular function and physiology, rather than relying on physical changes in the tissue anatomy. In some diseases, nuclear medicine studies can identify medical problems at an earlier stage than other diagnostic tests. Nuclear medicine, in a sense, is "radiology done inside out", or "endo-radiology", because it records radiation emitting from within the body rather than radiation that is generated by external sources like X-rays. . [Simon et al 2003]

Treatment of diseased tissue, based on metabolism or uptake or binding of a particular legend, may also be accomplished, similar to other areas of pharmacology. However, the treatment effects of radiopharmaceuticals rely on the tissue-destructive power of short-range ionizing radiation. .[Simon et al ,2003]

In the future, nuclear medicine may provide added impetus to the field known as molecular medicine. As understanding of biological processes in the cells of living organisms expands, specific probes can be developed to allow visualization, characterization, and quantification of biologic processes at the cellular and sub cellular levels. Nuclear medicine is a possible specialty for adapting to the new discipline of molecular medicine because of its emphasis on function and its

utilization of imaging agents that are specific for a particular disease process.
.[Simon et al,2003]

February 1934, they reported the first artificial production of radioactive material in the journal *Nature*, after discovering radioactivity in aluminum foil that was irradiated with a polonium preparation. Their work built upon earlier discoveries by Wilhelm Conrad Roentgen for X-ray, Henri Becquerel for radioactive uranium salts, and Marie Curie (mother of Irene Curie) for radioactive thorium, polonium and coining the term "radioactivity." Taro Takemi studied the application of nuclear physics to medicine in the 1930s. The history of nuclear medicine will not be complete without mentioning these early pioneers. .[Simon et al,2003]

Nuclear medicine gained public recognition as a potential specialty on December 7, 1946 when an article was published in the Journal of the American Medical Association by Sam Seidlin. The article described a successful treatment of a patient with thyroid cancer metastases using radioiodine (I-131). This is considered by many historians as the most important article ever published in nuclear medicine.^[8] Although the earliest use of I-131 was devoted to therapy of thyroid cancer, its use was later expanded to include imaging of the thyroid gland, quantification of the thyroid function, and therapy for hyperthyroidism.[Simon et al,2003]

Widespread clinical use of nuclear medicine began in the early 1950s, as knowledge expanded about radionuclides, detection of radioactivity, and using certain radionuclides to trace biochemical processes. Pioneering works by Benedict Cassen in developing the first rectilinear scanner and Hal's scintillation camera (Anger camera) broadened the young discipline of nuclear medicine into a full-fledged medical imaging specialty.[Simon et al,2003]

In these years of nuclear medicine, the growth was phenomenal. The Society was formed in 1954 in Spokane, Washington, USA. In 1960, the Society began publication of the Journal of Nuclear Medicine, the premier scientific journal for the discipline in America. There was a flurry of research and development of new radionuclides and radiopharmaceuticals for use with the imaging devices and for in-vitro studies⁵. [Simon et al,2003]

Among many radionuclides that were discovered for medical-use, none were as important as the discovery and development of Technetium-99m. It was first discovered in 1937 by C. Perrier and E. Segre as an artificial element to fill space number 43 in the Periodic Table. The development of a generator system to produce Technetium-99m in the 1960s became a practical method for medical use. Today, Technetium-99m is the most utilized element in nuclear medicine and is employed in a wide variety of nuclear medicine imaging studies. [Simon et al,2003]

By the 1970s most organs of the body could be visualized using nuclear medicine procedures. In 1971, American Medical Association officially recognized nuclear medicine as a medical specialty.¹ In 1972, the American was established, and in 1974, the American was established, cementing nuclear medicine as a stand-alone medical specialty.[Simon et al,2003]

In the 1980s, radiopharmaceuticals were designed for use in diagnosis of heart disease. The development of single photon emission computed tomography (SPECT), around the same time, led to three-dimensional reconstruction of the heart and establishment of the field of nuclear cardiology.[Simon et al,2003]

More recent developments in nuclear medicine include the invention of the first positron emission tomography scanner (PET). The concept of emission and transmission tomography, later developed into single photon emission computed tomography (SPECT), was introduced by David E. Kohl and Roy Edwards in the

late 1950s their work led to the design and construction of several topographic instruments at the University of Pennsylvania. Topographic imaging techniques were further developed at the Washington University School of Medicine. These innovations led to fusion imaging with SPECT and CT by Bruce Hasegawa from University of California San Francisco (UCSF), and the first PET/CT prototype by D. W. Townsend from University of Pittsburgh in 1998 PET and PET/CT imaging experienced slower growth in its early years owing to the cost of the modality and the requirement for an on-site or nearby cyclotron. However, an administrative decision to approve medical reimbursement of limited PET and PET/CT applications in oncology has led to phenomenal growth and widespread acceptance over the last few years, which also was facilitated by establishing ^{18}F -labelled tracers for standard procedures, allowing work at non-cyclotron-equipped sites. PET/CT imaging is now an integral part of oncology for diagnosis, staging and treatment monitoring. A fully integrated MRI/PET scanner is on the market from early 2011.[Simon et al,2003]

1.2 The Problem:

A patient undergoing a nuclear medicine procedure will receive a radioactive material which may contaminate accessories in NM department and may give unnecessary radiation dose to staff co-patients and other under present international guidelines it is assumed that any radiation dose, however small, presents a risk. The unnecessary radiation doses delivered to a patient staff and co-patients in a nuclear medicine will be investigated.

1.3 objectives:

1.3.1 General Objective

The main objective of this study is to Assessment Nuclear Medicine Department design and Radiation Safety

1.3.2 Specific Objectives;

- To assess safety procedures followed in NM concerning administer of radioactive drugs.
- To assess safety measures followed with patient after having radioactive drugs
- To assess the procedure followed with residual of radioactive drugs and syringe and others material.

Chapter Two

(Literature Review)

Chapter two

Back ground and literature Review

2.1 Nuclear medicine:

Nuclear medicine specialists use safe, painless, and cost-effective techniques to image the body and treat disease. Nuclear medicine imaging is unique, because it provides doctors with information about both structure and function. It is a way to gather medical information that would otherwise be unavailable, require surgery, or necessitate more expensive diagnostic tests. Nuclear medicine imaging procedures often identify abnormalities very early in the progress of a disease—long before many medical problems are apparent with other diagnostic tests.

Nuclear medicine uses very small amounts of radioactive materials (radiopharmaceuticals) to diagnose and treats disease. In imaging, the radiopharmaceuticals are detected by special types of cameras that work with computers to provide very precise pictures about the area of the body being imaged. In treatment, the radiopharmaceuticals go directly to the organ being treated. The amount of radiation in a typical nuclear imaging procedure is comparable with that received during a diagnostic x-ray, and the amount received in a typical treatment procedure is kept within safe limits. Today, nuclear medicine offers procedures that are essential in many medical specialties, from pediatrics to cardiology to psychiatry. New and innovative nuclear medicine treatments that target and pinpoint molecular levels within the body are revolutionizing our understanding of and approach to arrange of diseases and conditions [The Society of Nuclear Medicine 50 th Anniversary task Force 1850].

2.1.1The History of Nuclear Medicine:

One of the earliest instances of nuclear medicine occurred in 1946 when radioactive iodine, via an” atomic cocktail,” was first used to treat thyroid cancer. The thyroid gland took up the radioactive iodine and the radiation eradicated the cancer cells, curing the patient. Widespread clinical use of nuclear medicine began in the early 1950s.[Simon,1980]

In addition to curing thyroid cancer, radioactive iodine, in much smaller doses, was used to measure the function of the thyroid and to diagnose thyroid disease. Physicians began to use “nuclear medicine” for the treatment of hyperthyroidism; a condition where the thyroid over-produces thyroid hormones. .[Simon,1980]

As more knowledge was gained about basic biochemical processes, using radioactive versions of certain elements to “trace” these metabolic processes led to dramatic breakthroughs in diagnostic medicine.(Unlike a diagnostic X-ray where radiation is passed through the body, nuclear medicine tracers are taken internally; external detectors measure the radiation that they emit. The amount of radiation that a patient is exposed to is about the same.) .[Simon,1980]

In the 1960s and the years that followed, the growth of nuclear medicine as a specialty discipline was phenomenal. Initially, techniques were developed to measure blood flow to the lungs and to identify cancer “hot spots.” By the 1970s most organs of the body could be visualized with nuclear medicine procedures, including liver and spleen scanning, brain tumor localization, and studies of the gastrointestinal tract. In 1971 the American Medical Association officially recognized nuclear medicine as a medical specialty. .[Simon,1980]

In the 1980s, radiopharmaceuticals were designed for such critical diagnoses as heart disease and cancer. Also in the 1980s compounds were developed, including

monoclonal antibodies and FDG, that carried radioactive elements directly and specifically to cancer cells. At small doses, these radiopharmaceuticals can be used to identify the existence and location of cancer cells long before they are visible using traditional imaging methods. At higher doses, radiolabeled monoclonal antibodies are used today to deliver a therapeutic dose of radiation directly to cancer cells. .[Simon,1980]

In 1989 the FDA approved the first positron radiopharmaceutical (Rubidium-82) for myocardial perfusion imaging. Special cameras can detect photons, not normally emitted by the body but produced in the blood stream by certain radiopharmaceuticals, and compute a map of the way that blood is being distributed to heart tissue. .[Simon,1980]

By the 1990s, PET (Positron Emission Tomography) was becoming an important diagnostic tool. PET also uses photos produced by positrons, but PET provide more detailed images. The history of PET has been one of continuous improvement in the resolution and sensitivity of the imaging devices. Despite advances in other imaging methods such as CT and MRI, the ability to image the metabolic abnormalities associated with disease has made PET one of the most significant diagnostic tools ever developed. .[Simon,1980]

The next generation in PET technology, PET/CT fusion imaging, has the ability to combine CT structural information with PET's metabolic information into a single set of images. This ability to detect the exact location of a metabolic "hot spot" by overlaying the PET and CT images provides priceless information for physicians in the treatment of cancer and other metabolic diseases. .[Simon,1980]

In the years to come, as more is learned about the fundamental processes of diseases and as new radiopharmaceuticals and analysis tools are developed, PET

and PET/CT scanning will prove to be an invaluable tool in the diagnosis and treatment of some of the most critical diseases challenging modern medicine. .[Simon,1980]

2.2 Radiation:

Is energy, It can come from unstable atoms or it can be produced by machines. Radiation travels from its source in the form of energy waves or energized particles. There are actually two kinds of radiation, and one is more energetic than the other. It has so much energy it can knock electrons out of atoms, a process known as ionization. [Canadas Nuclear Regulator,December 2012]

This ionizing radiation can affect the atoms in living things, so it poses a health risk by damaging tissue and DNA in genes. While there are other, less energetic, types of non-ionizing radiation (including radio waves, microwaves—and visible light), this booklet is about ionizing radiation. . [Canadas Nuclear Regulator,December 2012]

In the late 1800s, Marie and Pierre Curie were among the first to study certain elements that gave off radiation. They described these elements as radio-actif, the property that is now called “radioactivity.” As scientists studied radioactivity more closely, they discovered that radioactive atoms are naturally unstable. In order to become stable, radioactive atoms emit particles and/or energy waves. This process came to be known as radioactive decay. The major types of ionizing radiation emitted during radioactive decay are alpha particles, beta particles and gamma rays. Other types, such as x-rays, can occur naturally or be machine-produced. Scientists have also learned that radiation sources are naturally all around us. Radiation can come from as far away as outer space and from as near as the ground that you are standing on. Because it is naturally all around us, we cannot eliminate

radiation from our environment. We can, however, reduce our health risks by controlling our exposure to it. . [Canadas Nuclear Regulator,December 2012]

2.2.1 Types of Ionizing Radiation:

2.2.1.1 Alpha Particles: Some unstable atoms emit alpha particles (α). Alpha particles are positively charged and made up of two protons and two neutrons from the atom's nucleus, as shown in the illustration at the right. [Donald et al,1997]

Alpha particles come from the decay of the heaviest radioactive elements, such as uranium, radium and polonium. Even though alpha particles are very energetic, they are so heavy that they use up their energy over short distances and are unable to travel very far from the atom. [Donald et al,1997]

The health effect from exposure to alpha particles depends greatly on how a person is exposed. Alpha particles lack the energy to penetrate even the outer layer of skin, so exposure to the outside of the body is not a major concern. Inside the body, however, they can be very harmful. If alpha-emitters are inhaled, swallowed, or get into the body through a cut, the alpha particles can damage sensitive living tissue. The way these large, heavy particles cause damage makes them more dangerous than other types of radiation. The ionizations they cause are very close together--they can release all their energy in a few cells. This results in more severe damage to cells and DNA. [Donald et al,1997]

2.2.1.2 Beta Particles: Beta particles (β) are small, fast-moving particles with negative electrical charge that is emitted from an β atom's nucleus during radioactive decay. These particles are emitted by certain unstable atoms such as hydrogen-3 (tritium), carbon-14 and strontium-90. [Donald et al,1997]

Beta particles are more penetrating than alpha particles but are less damaging to living tissue and DNA because the ionizations they produce are more widely spaced. They travel farther in air than alpha particles, but can be stopped by a layer of clothing or by a thin layer of a substance such as aluminum. Some beta particles are capable of penetrating the skin and causing damage such as skin burns. However, as with alpha emitters, beta-emitters are most hazardous when they are inhaled or swallowed. [Donald et al,1997]

2.2.1.3 Gamma Rays: Gamma rays (γ) are weightless packets of energy called photons. Unlike alpha and beta particles, which have both energy and mass, gamma rays are pure energy. Gamma rays are similar to visible light, but have much higher energy. Gamma rays are often emitted along with alpha or beta particles during radioactive decay. [Donald et al,1997]

Gamma rays are a radiation hazard for the entire body. They can easily penetrate barriers, such as skin and clothing that can stop alpha and beta particles. Gamma rays have so much penetrating power that several inches of a dense material like lead or even a few feet of concrete may be required to stop them. Gamma rays can pass completely through the human body easily; as they pass through, they can cause ionizations that damage tissue and DNA. Penetrating Powers of Alpha Particles, Beta Particles, Gamma Ray and X-ray. ALPHA Particles Stopped by a sheet of paper and cannot penetrate the outer dead layer of skin BETA Particles Stopped by a layer of clothier by a thin sheet of a substance such as aluminum gamma Rays and X-Rays Stopped by several feet of concrete or a few inches of lead. [Donald et al,1997]

2.2.2 Detectors for radiation protection

The following types of particle detector are widely used for radiation protection, and are commercially produced in large quantities for general use within the nuclear, medical and environmental fields. [Glenn.2000]

Gaseous ionization detectors, Geiger-Müller tube, Ionization chamber, Proportional counter, Scintillation counter, Semiconductor detectors, Dosimeters, Electroscopes. [Glenn.2000]

Commonly used detectors for particle and nuclear physics

Gaseous ionization detectors, Ionization chamber, Proportional counter, Multiwire Proportional Chamber, Drift chamber, Time projection chamber, Geiger-Müller tube, Spark chamber. [Glenn.2000]

Solid-state detectors, semiconductor detectors and variants including CCDs, solid-state track detectors, cherenkov detector, RICH (Ring Imaging Cherenkov Detector), scintillation counter and associated Photomultiplier or Photodiode / Avalanche photodiode, lucas cell, Time of flight detector, semiconductor detector, Silicon Vertex Detector, Transition radiation detector, calorimeters, microchannel plate detectors, Neutron detectors. [Glenn.2000]

2.3 Design of nuclear medicine department:

2.3.1 Introduction:

Diagnostic nuclear medicine uses chemical or pharmaceutical compounds labeled with a radioactive substance and administered to a patient via ingestion, inhalation or intravenous injection. The distribution of the radiopharmaceutical in the patient is later imaged either with a gamma camera, or another imaging or

measurement device. The radioactive isotope used to label the pharmaceutical is, in the majority of cases, ^{99m}Tc , and in Ireland the labeling generally takes place on site. This requires appropriate facilities to be provided. Therapeutic uses of radionuclides also occur in general hospitals, but less frequently and involving lower patient numbers. [Radiological protection institute of Ireland, june2009]

The design of a nuclear medicine department should take account of several issues including radiation protection, air quality and infection control. It is important to consult with the RPA, the radiopharmacist, medical physicist; the infections control officer and the radiologist or nuclear medicine physician throughout the design phase. Where no radiopharmacist is available, the advice of a pharmacist should be sought. A nuclear medicine facility must deal with all the problems of receiving, storing, handling, injecting, measuring and imaging, and waste disposal for radioactive materials in a hospital setting. [Radiological protection institute of Ireland, june2009]

2.3.2 Location and access:

The nuclear medicine department has close functional and operational relationships with the radiology/imaging service, with which it is frequently combined. However, many of its functions need to be self contained. Close proximity with general paediatric or obstetric imaging facilities should be avoided (this is particularly important for PET). Shielding and layout should be such that activities in adjoining areas, such as film storage or low level counting, are not affected by the presence or use of radioactive material. [Radiological protection institute of Ireland, june2009]

Access for both ambulatory and trolley patients are required. Some areas within nuclear medicine will be designated as controlled areas with access restricted to nuclear medicine staff. Entrance to controlled areas should be marked with a warning notice (at eye level) stating that the area is controlled. Other areas within the department may be designated as supervised areas and access to these will be regulated by appropriate signage and systems of work. [Radiological protection institute of Ireland,june2009]

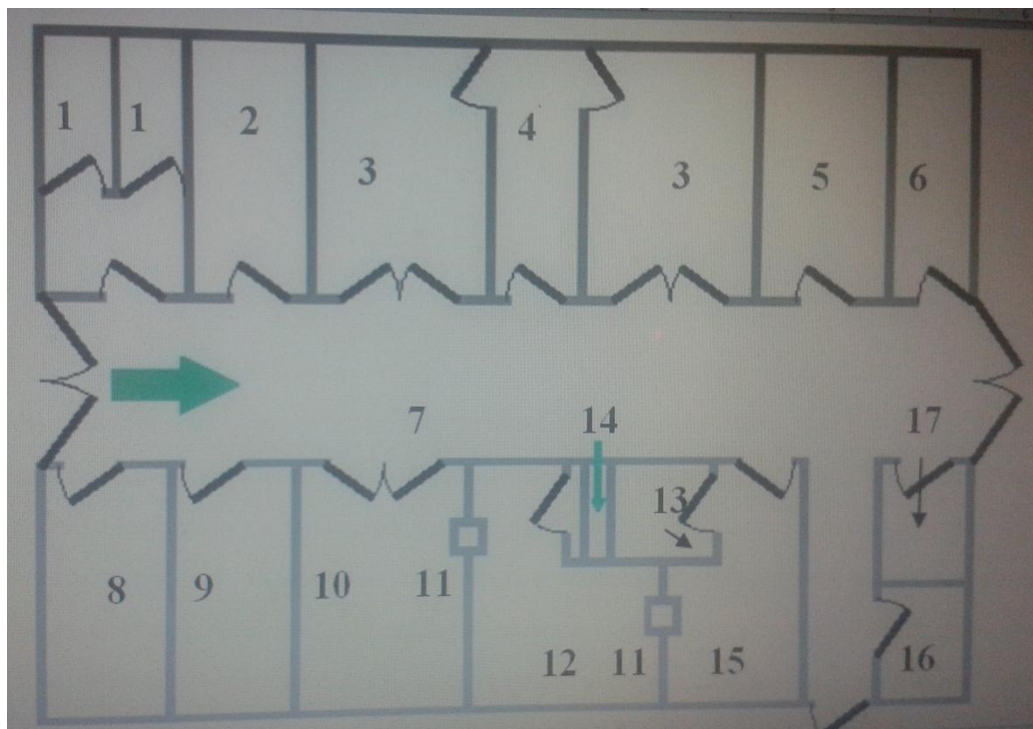
In determining location, ease of access for delivery of radioactive material and removal of waste must be considered. These activities may take place out of hours, so design and operational considerations are involved. Direct egress for patients without going through the busy public areas of the hospital is desirable, but not always possible. The requirements for appropriate access for cleaning staff should also be considered at the design stage. [Radiological protection institute of Ireland,june2009]

Ideally all the hospital's 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. Some clinical areas such as Endocrinology or Haematology may also use radioactive materials but, as far as possible, the handling of larger amounts of radioactivity should be centralized ,It is recognized worldwide that the security of radioactive materials is very important and that the design of facilities where these sources are used and stored must cater for the implementation of good security measures. Although the quantities used in diagnostic nuclear medicine are for the most part relatively low, the perceived threat that might arise should they be lost, damaged or stolen is more problematic than the hazard they present. Therefore, security of sealed and unsealed materials

and radioactive waste must be assured. To achieve this, the department should be designed with restricted access to all controlled areas using the system of access restriction employed by the hospital. These areas also require an appropriate level of fire and intruder alarms. Where appropriate, the design team should consider obtaining professional advice on these security issues. [Radiological protection institute of Ireland,june2009]

Figer of design 2.1

A possible layout of a nuclear medicine department



Patient toilet,in-vitro counting and uptake,gammcamera room, Operator console, Data processing, Staff toilet, Corridor, Waiting area, Cardiac stress test room, Injection room, Hatch, radiopharmacy /hot lab, Lopyy, step-over barrier, Radionuclide storage area, Storage area, Waste store. [Radiological protection institute of Ireland,june2009]

2.3.3 Overview of facilities and layout:

Within the nuclear medicine department, the following facilities must be provided: a radionuclide reception and storage area, a radiopharmacy, patient waiting area, injection area, gamma camera (scanning) room(s), patients WC and waste store. Other facilities that should be considered are a reception area, office/reporting facilities, cardiac stress, uptake assessment, in vitro sample counting and therapy administration areas. [Radiological protection institute of Ireland,june2009]

2.3.4 Storage areas: For general consumables and collimators will also be required. Premises should preferably be laid out in such a way as to facilitate workflow. Areas should be connected in the sequence of the operations and patient flow, and to allow the required level of cleanliness. Separating patient and staff areas will assist in creating a suitable environment for patients as well as helping reduce contamination hazards. Ensuring areas are adequately sized will not only provide a pleasant environment for both staff and patients, but will also contribute to dose reduction strategies and may reduce the need for shielding. [Radiological protection institute of Ireland,june2009]

Within nuclear medicine, clear demarcation between areas is required to confine the use and storage of radioactive material to certain areas within the department. The need for transport of materials within the department should be minimised by the use of hatches, where appropriate, and the design and layout of the department should be such that the movement of unsealed isotopes is minimized. Access for delivery of isotopes to a secure storage area within or adjacent to the radiopharmacy should be provided. In addition, it may be necessary to receive and

store radioactive waste from other areas within the hospital (e.g. theatre, laboratory, ward areas) and the route by which this will be achieved should be considered. [Radiological protection institute of Ireland,june2009]

The appropriate designation of areas such as the scanning room, injection room, patient WC, waiting area and the radiopharmacy (as controlled or supervised) should be determined by risk assessment and in consultation with the RPA. [Radiological protection institute of Ireland,june2009]

2.4 Nuclear medicine facilities:

This section provides a review of the facilities required for diagnostic nuclear medicine. It does not include those required for therapy or PET related activities, which are treated in Sections 4.4 and 4.6. In the areas frequented by patients, surfaces should generally be non-porous and easily cleaned. [Radiological protection institute of Ireland,june2009]

2.4.1 Scanning room:

A nuclear medicine imaging unit will have one or more scanning rooms. The scanning room will house the gamma camera and the operator console. The size of the room should be sufficient to accommodate the particular type of scanner envisaged and allow for patient trolley access and collimator exchange (typically 35-40 m²). Scanners with removable tables will need additional space for this facility. The room should be of a size that will accommodate the equipment in the preferred orientation. [Radiological protection institute of Ireland,june2009]

The operator console should be located at a sufficient distance from the patient table so that the patient can be observed while minimizing direct exposure to staff. The console area must have enough space for the gamma camera acquisition

terminal, and any other required equipment, terminals or workstations. If the gamma camera has an associated CT scanner, then a separate shielded operator console area will be required. [Radiological protection institute of Ireland,june2009]

As with interventional radiology and CT, a single operator room may be shared by a number of adjacent scanning rooms (see Fig 2.1). Where this is done, due regard must be given to the dose constraint used in planning .It should not be necessary to pass through the scanning room to enter a shared operator room. Shielding requirements for the room must be assessed by the RPA but 1-2mm lead is likely to be sufficient. The radiation involved is generally more penetrating than that used in the radiology department, but the intensity is lower. Shielding of walls, floor, ceiling, windows and doors must be considered. The walls and doors should be clearly marked to indicate the level of shielding provided. Consideration should be given to the exclusion of windows where meeting a dose constraint may present a problem now or in the future. The location and shielding of the room must ensure that radiation from sources external to the room, such as the operation of another scanning room close by, is reduced to a level which will not affect the performance of the gamma camera. If the gamma camera has an associated CT scanner, the use of the CT scanner must be taken into account in designing the room layout, shielding and operator area. The load bearing capacity of the building must be sufficient to take the weight of all equipment and shielding. [Radiological protection institute of Ireland,june2009]

Modern gamma cameras are used with a range of collimators; the storage, load bearing, and ergonomic requirements are considerable and must be taken into account during design. Radiopharmaceuticals are sometimes administered by

inhalation involving radioactive gases or aerosols. [Radiological protection institute of Ireland,june2009]

Adequate air extraction is required to minimize contamination risks. Ventilation systems should not re-circulate air and should be vented externally. Grills should be sited away from the gamma camera head(s). [Radiological protection institute of Ireland,june2009]

Temperature control should be provided so that conditions are suitable both for patient and staff comfort but also to ensure extremes that might be detrimental to system performance are avoided. Shielded sharps and waste containers, and a wash-hand basin with elbow or sensor operated taps, plumbed directly to the main drain, are required. Ceiling mounted services may offer advantages in terms of ergonomic design. [Radiological protection institute of Ireland,june2009]

2.4.2 Patient injection room:

The patient injection area should be adjacent to the radiopharmacy and should be sized to accommodate one or two bays for ambulatory patients. At least one of the bays should be able to accommodate wheelchair or trolley patients. Within the room, space should be provided for storage of consumables, shielded sharps and general waste bins, and an instrument trolley; a wash hand basin with elbow or sensor operated taps is also required. Some level of shielding is likely to be required in this area. The RPA must advise accordingly but 1 mm lead is often adequate. The walls should be clearly marked to indicate the level of shielding provided. [Radiological protection institute of Ireland,june2009]

Access to the area should be via a signed and shielded door. The injection area and the radiopharmacy should be connected by a shielded, airlocked pass through hatch

through which prepared radiopharmaceuticals can be transferred .An air extraction system must be provided if ventilation of patients is to take place in this room. [Radiological protection institute of Ireland,june2009]

2.4.3 Waiting area (pre & post administration):

Patient waiting areas are required within the nuclear medicine department. Some departments segregate patient's pre-and post-administration of radioactive materials. Advice should be sought from the RPA as to whether this is required. If a significant paediatric workload is envisaged, consideration should be given to a separate waiting area for children. Shielding requirements for the waiting area will depend on location and must be determined by the RPA. Typically, 1-2 mm lead equivalence is normally adequate. This also applies to any external windows included in the area. Seating in the waiting area should have non-absorbent, wipe clean finishes to minimize contamination risks. Fixed seating is preferred with a separation of 0.8 m centre to centre. A separate area for trolley patients (1 -2 trolleys) and accompanying staff will facilitate privacy and will help minimize exposure. Provision of good quality drinking water for patients is essential to assist clearance of unbound radionuclides. The area should be signed and access restricted to nuclear medicine patients, accompanying persons and staff. Consideration should be given to the installation of **CCTV** for supervision and observation of patients. [Radiological protection institute of Ireland,june2009]

2.4.4 WC facilities:

WCs for use by nuclear medicine patients only should be provided within the department close to the waiting area. The shielding requirements (if any) for this toilet area must be determined by the RPA. Signs limiting access to other persons should be prominently placed on the doors, as these toilets are likely to be

contaminated. The waste pipes should be plumbed directly to the external drain. The waste pipes from these toilets must be clearly marked indicating the presence of radioactive material. All surfaces should be non porous and easy to clean and decontaminate. Wheelchair access should be provided. It may be desirable to include a sluice to deal with bedpans from trolley patients. Consideration should be given to the provision of WC facilities for accompanying persons and staff either within the department or close by. [Radiological protection institute of Ireland,june2009]

Reception/office/reporting and consultation facilities: Office, reception, reporting or consultation facilities provided within the nuclear medicine department must comply with the design dose constraint of 0.3 mSv per year. This may be achieved by a combination of size, shielding and location. [Radiological protection institute of Ireland,june2009]

2.5 Radiopharmacy facilities

General requirements for the radiopharmacy suite :The radiopharmacy suite is an integral part of a nuclear medicine facility when on-site labelling and preparation takes place. A typical suite will consist of a lobby or changing area, a hot lab, and a number of other rooms. In practice an individual development may not require all of these facilities. Utilizations of therapeutic isotopes may alter the design and shielding requirements. Facilities using pre-labelled radiopharmaceuticals will not have such extensive requirements. [Radiological protection institute of Ireland,june2009]

There are no comprehensive statutory guidelines dealing with all of the issues in the previous paragraph. This Code will become the definitive guide on radiation protection issues for radiopharmacy design. The location of the radiopharmacy should facilitate easy delivery of radioisotopes by suppliers and allow a practical route for waste disposal. It should be adjacent to the injection rooms. The location should not create a new hazard to existing areas or personnel. It is also important that it is not immediately adjacent to areas where low level counting or imaging equipment is installed. The equipment selection and premises design should minimise the risk of errors, permit effective cleaning and maintenance, minimize the risk of cross-contamination , build up of dust and facilitate preparation of quality products. Lighting, temperature, humidity and ventilation should be appropriate and such that they do not adversely affect, directly or indirectly, either the medicinal products during their manufacture and storage, or the accurate functioning of equipment .Consideration must be given to the load bearing requirements of the workstations, where large quantities of lead shielding are required to protect the operator. [Radiological protection institute of Ireland,june2009]

Surfaces should be similar to those described for other areas in nuclear medicine. They should be non-absorbent, with the skirting overlapping the edges of the wall and every effort should be made to minimize fissures in the finish of the suite. Stainless steel finishes should not be used, as they absorb some types of radioisotopes and are difficult to decontaminate. The ceiling should be continuous and imperforate; the use of de-mountable tiles is not appropriate as it permits collection of dust and the associated infection risks within an essentially aseptic room. The walls should be easy to wash down in case of contamination or infection risks. Finishes may include specialist paints, as used in operating theatres and

elsewhere, or possibly laminate/plastic faced panelling systems with sealed joints. [Radiological protection institute of Ireland,june2009]

Calculation of the shielding required, which may be considerable, must be undertaken by the RPA. The approach frequently adopted is that of poured dense concrete or solid blocks to which additional shielding can be applied as required. The venting from the laminar airflow cabinets or isolators should be fire resistant, non-absorbent. Each cabinet/isolator should have its own individual exhaust system incorporating effective precautions against blow-back and providing safe dispersal to atmosphere. [Radiological protection institute of Ireland,june2009]

2.5.1 The lobby/changing area:

A separate gowning/lobby leading to the hot lab/radiopharmacy is required. The lobby will be used by staff to change into aseptic clothing, and will therefore need appropriate signage and an indication of when it is occupied. Access should be controlled by the system used by the hospital for secure areas (e.g. magnetic swipe or keypad). The finishes in the lobby should be similar to those described before. Shelving is required to store the appropriate aseptic clothing and a shielded bin should be available for used, and possibly contaminated, clothing. A permanent barrier/demarcation must clearly identify the entrance to the “clean” area. [Radiological protection institute of Ireland,june2009]

2.5.2 Hot lab/radiopharmacy

The hot lab accommodates the production functions of the radiopharmacy area and for a single workstation should not be less than 10 m² in area. A hot lab of approximately 20 m² should comfortably facilitate two cabinets or isolators. The work space must ensure a safe and comfortable operational environment to prevent

errors and cross-contamination of products. This is a controlled area and must be delineated by both signage and access arrangements. The shielding requirements for all the facilities in this area must be determined by the RPA. [Radiological protection institute of Ireland,june2009]

As described before the link to the injection room should be via an airlocked pass through hatch. For security purposes, it should only be possible to lock the hatch from the radiopharmacy side. [Radiological protection institute of Ireland,june2009]

The installation of bench top workspace should be kept to a minimum in the hot lab to prevent the accumulation of dust, but some may be required for operational purposes. Sinks should not be present in the production area. [Radiological protection institute of Ireland,june2009]

The preparation of radiopharmaceuticals generally takes place in a workstation such as a laminar airflow cabinet with HEPA-filtered Grade A air or a total containment workstation. The workstations should be in an environment conforming to at least Grade D. The requirements for the production of sterile materials are provided in the European Association of Nuclear Medicine Guidelines and the European Commission Guidelines. [Radiological protection institute of Ireland,june2009]

The workstation should be adequately shielded and incorporate lead glass windows for the protection of the operator. A minimum of 5 mm lead equivalent shielding should be present in the window. The ^{99m}Tc generator, which is usually integrated into the workstation, should be suitably shielded. Dose calibrator(s) integrated into the workstation should be also shielded from ambient activity, and to protect the staff using them. [Radiological protection institute of Ireland,june2009]

2.5.3 Radionuclide storage area:

A storage area is required for sealed and unsealed radioactive materials that will be used in the radiopharmacy and should be located adjacent to it. It may also serve as a central store for much, but not all, of the radioactive material used in the hospital. Typical dimensions for the storage room might be of the order of 10 m². Its location and access arrangements should facilitate delivery of radioactive materials by suppliers, transport to the radiopharmacy and elsewhere in the hospital, and removal of radioactive and non-radioactive materials for waste disposal. Consideration must be given to the requirement for security and the hazards that may arise in the event of a fire or flood. An appropriately worded warning sign should be prominently displayed on the door, and provision for control of access should be made. The shielding requirements for this area must be determined by the RPA and will depend on the level of the local shielding of each source or subgroup of sources. The suitability of the store room, and sub-storage arrangements must be subjected to a risk assessment prior to approving the design. The storage or sub-storage areas should be compartmentalised to allow segregation of high and low activity stock and also sealed and unsealed stock. Each compartment should be marked to permit easy identification. Gaseous or volatile radioactive materials or those which produce gaseous daughters should be stored in a facility which is vented directly to the outside or to the fume hood stack. Giga-Becquerel levels of radioactive materials may require more elaborate arrangements, which must be determined in consultation with the RPA. Storage areas must be designed to ensure ease of decontamination in the event of spillage. A temperature controlled and monitored refrigerator(s) for the storage of pharmaceuticals should be provided. Preparations that are stable at 2-8°C should be stored in a refrigerator until required. There may be a requirement

for shielding refrigerators .A wash hand basin with elbow or sensor operated taps should be located in close proximity to the storage area to allow staff wash their hands after handling radioactive substances. An additional sink or sluice for disposal of radioactive liquids should be installed in this area and should be marked appropriately. Both sinks should be plumbed directly to the outside drains as specified for the patient toilets. The finishes should be similar to those described for the radiopharmacy. [Radiological protection institute of Ireland,june2009]

Over and above the requirements for radionuclides, adequate general storage and security should be provided for all the materials required for the operation of the radiopharmacy, and for quality control equipment. [Radiological protection institute of Ireland,june2009]

2.5.4 Special considerations/areas:

Some departments will require additional facilities to those described in the preceding sections. This will be determined by the operational brief of the service to be provided. Provision or otherwise for these should be decided at the design stage, following consultation with the RPA and all other relevant parties. [Radiological protection institute of Ireland,june2009]

Radionuclides in the operating theatre: Radionuclides are increasingly being used in the operating theatres as part of planned procedures. They may also be present in patients who are scheduled for surgery or who arrive in the theatre as a result of an emergency having recently undergone a diagnostic nuclear medicine scan. Thus some thought needs to be given to the radiation protection issues involved. In at least one way, theatre design is compatible with the presence of radionuclides, as the surfaces and finishes used are designed with ease of decontamination in mind. The main issues that give rise to concern are storage and

removal of waste generated during the procedures and decontamination of the theatre in the event of a spill. Additional structural shielding is not generally required, and standard operating theatre procedures should protect the staff from contamination. Waste generated during the procedures will have to be segregated from non-radioactive waste. Provision must be made for storage of contaminated waste until it decays to background levels, or can be moved to a central waste storage facility within the operational guidelines. Finally, consideration must be given to the management of patients in the recovery area who have been administered radionuclides. [Radiological protection institute of Ireland,june2009]

Therapeutic use of unsealed radionuclides: Therapeutic administration of unsealed radionuclides often takes place in nuclear medicine departments, provided it can be managed on an out-patient basis. Radionuclide therapy, such as thyroid ablation using ^{131}I , requiring in-patient isolation arrangements is beyond the scope of this publication. The requirements depend on whether the isotope is administered as a capsule or liquid. Preparation and administration is generally possible with equipment and facilities used for diagnostic examinations. Administration should be carried out in a quiet, designated area and this may be either a separate small room or an area of the diagnostic department temporarily reserved for that purpose (for example the uptake room). However it should be such that, if there is a spill or the patient is incontinent or vomits, the impact of the contamination will not compromise the other functions of the department. The design of areas for radionuclide therapy should conform to the requirements for diagnostic nuclear medicine areas. Floors and other surfaces should be covered with smooth, continuous and non-absorbent surfaces that can easily be cleaned and decontaminated. Floor coverings should be coved against walls and removable if necessary. Walls should be finished with good hard gloss paint. The RPA must be

consulted on the appropriate designation of the area in which therapy administrations take place. It is likely that it will be considered as a controlled area. The additional shielding requirements, if any, will also be specified by the RPA. Separate facilities will be required for patients post administration if procedures do not require that they leave the hospital promptly. [Radiological protection institute of Ireland,june2009]

Uptake assessment area:A separate area for assessing quantitative uptake of radionuclides, as opposed to imaging, may be required within the nuclear medicine department. These measurements generally employ a dedicated uptake detector and stand (e.g. thyroid uptake). The area should be able to accommodate a patient chair and/or couch, the uptake probe and associated equipment. This room should be located away from high activity areas and/or it should be adequately shielded as the activities measured in it are generally low. A wash-hand basin with elbow or sensor operated taps should be provided. [Radiological protection institute of Ireland,june2009]

In-vitro measurement area:Several tests in nuclear medicine involve assessment of relatively low activity in vitrosamples. These include, for example, patient samples complementary to scanning, and radiopharmacy quality control materials. It may be possible to integrate this work into the uptake assessment area if both have relatively low workloads, although the possibility of contamination must be borne in mind. If the workload is large, additional facilities may be needed. The room should be located away from high activity areas and/or it should be adequately shielded. Laboratory bench areas will be essential for equipment, sample handling and record keeping. Surfaces should be non porous and easily cleaned and decontaminated. A dedicated sink connected direct to external drain

for disposal of liquids, and a wash-hand basin with elbow or sensor operated taps should be provided. [Radiological protection institute of Ireland,june2009]

Other areas: There are a number of other areas where radionuclides may be used, both within the nuclear medicine unit and elsewhere throughout the hospital for example a cardiac stress test area. However, these areas are not considered in this Code as their design features do not draw heavily on radiation protection issues. [Radiological protection institute of Ireland,june2009]

Hospital laboratories using radionuclides:

Many hospitals will have laboratories that use radionuclides within the pathology service and/or research units. In these laboratories the radioactive material is generally more contained than in the nuclear medicine department and hence the design issues are more straightforward. [Radiological protection institute of Ireland,june2009]

The design of a laboratory for the use of unsealed radioactive substances depends on the radionuclides and activities to be handled, as well as the complexity of procedures being undertaken. Most hospital laboratories such as haematology or pathology use sources of low activity. However, it is important that the RPA and the laboratory end user are involved in the design. [Radiological protection institute of Ireland,june2009]

A radiation risk assessment will normally show that the structural shielding in good modern laboratory facilities need little or no upgrading to conform to the requirements for low-level radioactive work. A specific designated work-area within the laboratory may be required for the preparation and counting of radioactive samples. Surfaces should be easy to clean and decontaminate, be free

of joints and sharp corners should be avoided. [Radiological protection institute of Ireland,june2009]

A lockable storage facility, shielded if necessary, must be provided for the safe storage of radionuclides. This should be situated in proximity to the workbench. Radiation warning signs must be placed on the door of the storage facility, the designated work area, any sink designated for the disposal of low-level liquid waste and containers for solid waste. [Radiological protection institute of Ireland,june2009]

Local storage for short and medium term waste will be required within the laboratory. However, depending on space and operational policies, longer term waste storage may be available in the hospital radioactive waste management facilities. [Radiological protection institute of Ireland,june2009]

For work involving volatile radioactive materials (such as iodination), the active laboratory should include a workstation which may be a microbiological safety cabinet, an isolator, or a fume cupboard. Provision must be made for the safe discharge of all gases. Adequate shielding above and around the workstation should also be provided. [Radiological protection institute of Ireland,june2009]

2.6 Special considerations for PET:

2.6.1 General and facilities required:

Positron Emission Tomography (PET and PET/CT) is a diagnostic imaging procedure that provides both functional and anatomical information. PET imaging is similar to radionuclide imaging but differs significantly in both the technology and the radiation protection issues to be addressed. This is partly because it uses relatively high activities of radionuclides that emit radiation with

energy of 511 keV, almost four times as high as the most common energy used in nuclear medicine. This presents unprecedented radiation protection challenges in nuclear medicine and must be taken into account when constructing new facilities or adapting existing ones. The addition of CT to PET brings additional radiation protection and equipment issues. However, most facilities designed with shielding adequate for PET will require little modification for PET/CT. [Radiological protection institute of Ireland,june2009]

A PET imaging service will require the following facilities:

Patient waiting area, PET scanning room, control room/console area, uptake/injection areas, patient changing area, patient WC, isotope dispensing area, waste storage area. [Radiological protection institute of Ireland,june2009]

In addition an office area, reporting room, and consultation area may be required. Many of the requirements are similar in principle to those for general nuclear medicine, with important variations. [Radiological protection institute of Ireland,june2009]

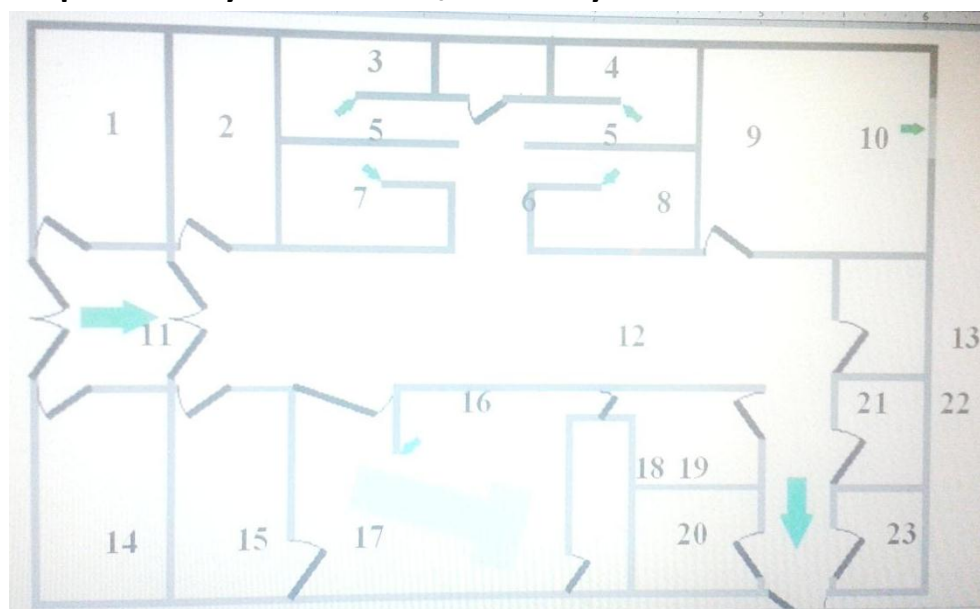
2.6.2 Location, layout and access:

Access to the department for both ambulatory and trolley patients is required. Some areas within the department will be designated as controlled areas with access restricted to authorized staff. Other areas within the department may be designated as supervised areas and access to these will be controlled by the use of appropriate signage and warning lights. Access to 'staff only' areas should be possible without passing through areas of high radioactivity. Patients should be able to enter and leave the department without passing through 'staff only' areas. The layout of the department should be such that it facilitates patient movement through the various steps involved. The exit route for patients post

scanning should be planned so that they leave the hospital promptly after their examination without passing through other departments or busy public areas, because of their residual radioactivity. [Radiological protection institute of Ireland,june2009]

If the PET scanner is to be located in or close to the nuclear medicine department, care must be taken to prevent radiation from PET patients after radionuclide administration interfering with other imaging equipment in the department. Care must also be taken to ensure that radiation from patients leaving the department following their scan does not interfere with sensitive equipment, including gamma cameras. An example of good layout is shown in Fig. 2.2. Grouping patient areas together reduces the need for shielding and reduces staff doses

Figur 2-2: A possible layout for a PET/CT facility



Waiting area reception, Staff WC, Uptake room 1, Uptake room, Concrete nib, corridor, Uptake room 2, Uptake room 4, radionuclide dispensing area, radionuclid delivery latch, entrance, corridor, Nurse/consultationroom,

Controlroom, Concrete nib, PET/CTscanner, Server, Patientchange back, Store, Patientexit, Dirtyutilityroom, Wastestoragehold

2.6.3 Patient facilities:

2.6.3.1 Interview room/office:

Thorough patient preparation is an important element of successful PET imaging. An interview room or office where this can be done prior to attendance for scanning is required. This should be located such that patients attending should not have to pass through high activity areas. [Radiological protection institute of Ireland,june2009]

2.6.3.2 Waiting room:

The waiting area requirements for a PET facility are relatively modest because of the pattern of workflow. The waiting area is for patients and any accompanying persons prior to administration of the radiopharmaceutical and so special shielding is not required. Access to a patient WC should be provided in this area. [Radiological protection institute of Ireland,june2009]

2.6.4 Uptake room:

The number of injection/uptake rooms required per scanner is in the range 4-6. Because of the high exposure rate from the patient post injection, these areas will require high levels of shielding. [Radiological protection institute of Ireland,june2009]

Each room should accommodate a reclining patient chair, instrument trolley and shielded waste and sharps bins. The patient may also change into a hospital gown in this area. At least one of the uptake rooms should be able to accommodate a patient trolley. A hand-wash basin with elbow or sensor operated taps should be

provided. Surfaces should be non-porous and easily cleaned and decontaminated. Privacy curtains, subdued lighting, and noise control should be provided (Anderson, 2004). Reliable climate control is essential both for patient comfort and to ensure optimal conditions for uptake. CCTV may be required for remote patient monitoring. [Radiological protection institute of Ireland,june2009]

The shielding requirements for uptake rooms are considerable and must be determined by the RPA. Use of concrete nibs can be effective in reducing the shielding requirements for the doors. A toilet dedicated for patient use should be provided nearby, so that the patient does not have to walk through the department to empty his/her bladder prior to scanning. [Radiological protection institute of Ireland,june2009]

2.6.5 Scanning room:

The minimum requirements for space in the scanning rooms should be obtained from the equipment vendor's site planning documentation(Anderson, 2002). Typical dimensions are of the order of 30-35 m²with an additional 10-15 m²for the control room/console area. Extra space provided within the scanning room may reduce shielding requirements due to the decreased exposure at the boundaries. Means of observing the patient and maintaining aural communication with them must be provided. Provision for an automatic injector may be required for PET/CT examinations. There are strict requirements for environmental control in the scanning rooms because of the sensitivity of the PET scanner to temperature variation. The control/console room should provide direct access to the scanning room and be close to the dispensing and uptake rooms. The shielding of the control/console room must be specified by the RPA and will depend on whether the dose constraint to be applied is that for the public or designated radiation

workers. If access to the console area is limited to radiation workers, then the design dose constraint is 1 mSv per year. Where access cannot be restricted solely to radiation workers the design dose constraint of 0.3 mSv/year must be adhered to. In practice this will present design challenges particularly in cases where direct patient observation by the operator is required. Post scan patient changing room For PET/CT the patient will be scanned in a suitable gown. Changing facilities pre-scanning can be incorporated into the uptake rooms but after scanning it is convenient to have a changing area elsewhere so that maximum usage of the uptake rooms can be achieved. A single changing room should be adequate, as only one patient at a time will require it. This should be sited close to the scanning room in order to minimize movement of the patient through the facility. [Radiological protection institute of Ireland,june2009]

2.7 Dispensing and other facilities:

2.7.1 Dispensing area:

The dispensing area should be suitable for the handling of PET radiopharmaceuticals. It has few special requirement over and above those already mentioned for nuclear medicine. However the shielding requirements for 511 keV are substantial and must be specified by the RPA. Benches must be solidly built to cope with the weight of local shielding in the immediate vicinity of sources (Anderson, 2002). Good use of local shielding is helpful in reducing exposure rates within the area and at boundaries. Floor level storage must be provided for the carriers in which isotopes are delivered which are both heavy and bulky.Space for foot and hand monitors for staff should be provided at the exit from this and other high activity areas. [Radiological protection institute of Ireland,june2009]

2.7.2 Utility rooms: Scanners provided by some vendors require additional rooms or space for ventilation, cooling, heat exchange, or air conditioning systems. A separate room for the cabinets associated with the CT may also be required. [Radiological protection institute of Ireland, June 2009]

2.8 Waste management facilities:

Dedicated and secure storage facilities for radioactive waste will be required within the nuclear medicine department. Access to this area should be strictly controlled and limited to designated personnel. The store should be located adjacent to the radiopharmacy and injection areas. Access should not be through the clean area, offices, or scanning rooms, and should be such that disruption to services in the event of an accident in transit will be minimised. A warning sign should be placed on the door. The waste store included in Figures 4.1 and 4.4 should be of solid, non-combustible construction and should offer adequate protection from heat, cold, humidity, mechanical damage, vermin, fire and flood. Protective shielding (possibly up to 4 mm lead equivalent) will be required. This must be specified by the RPA so that protection is provided for all those outside the store and those who must transfer material to it or process materials within it. A shielded safe should be provided for small volumes of radioactive liquids which have high activity, and sources of small physical size, that must be kept secure for long periods. The ceiling, wall and floor finishes should be non porous and easy to clean and decontaminate. The store should be well lit and have sufficient space for the materials to be stored. Corrosive or explosive waste should not be stored in this facility. Waste stores should be adequately ventilated by mechanical means when radioactive gas, dust or vapour is liable to be present. Ventilation should be vented externally and at a height that ensures adequate dispersal. Filters are not usually required for the quantities used in hospitals. The type of waste likely to be stored will include spent generators, unused radionuclides (liquid and capsule),

contaminated needles, swabs, syringes, etc. Adequate space and shelving to allow segregation of waste should be provided. High specification shelving or a large floor area is required to store large numbers of self shielded items (e.g. spent generators which are heavy due to their protective shields). Low-level radioactive liquids may be disposed to drain via designated (and clearly marked) sinks in accordance with disposal limits specified in the license conditions. These sinks must be connected directly to the main outside drain and labelled to indicate their use for the disposal of radioactive material. The waste store should have a wash hand basin with elbow or sensor operated taps and fire and intruder alarms. For waste that cannot be otherwise disposed of there may be a requirement for a second, remote long-term storage facility. Design requirements are similar to those given above with access even more rigorously controlled, as it may not be under day-to-day surveillance. The signage may, on the advice of the RPA, be placed within the store immediately adjacent to the entrance instead of on the outside of the door. [Radiological protection institute of Ireland,june2009]

2.9 Ventilation requirements:

The specific ventilation requirements from a microbiological perspective detailing the pattern of airflow within the nuclear medicine department are beyond the scope of this publication but the design will have to take account of the potentially conflicting requirements for containment of radioactive material and protection of the product from environmental contamination. The ventilation system in the nuclear medicine department should be separated from other systems used by the hospital, and the exhaust duct should not be placed near windows or entrances. Air extracted from areas where radioactive products are handled must not be re-circulated. [Radiological protection institute of Ireland,june2009] .

Chapter Three

(Materials and Methods)

Chapter three

Material and method

3-1 Material:

3.1.1 Study sample:

4 Technician in private and governmental clinic in Khartoum state.

3-2 Method of data collection:

3-2-1 Questionnaire:

4 questionnaires distributed to 4 technicians (see appendix) all the questionnaires are receipted after had fallen by study sample.

3-2-2 observation:

The researcher spent a working day in nuclear medicine department under study observed process and action concerned radiation safety.

3-3 Study duration

The study samples collected from in February

Chapter Four

(Results)

CHAPTER FOUR

RESULTS

Table 4-1: shows the results of the data from all centers

	Yes	%	No	%
Flooring will have an impervious, chemical resistant, washable surface.	4	100	0	0
Carpeting will not be used.	4	100	0	0
The design of flooring one-piece.	4	100	0	0
Flooring will be coved up walls and cabinets to prevent spills from penetrating underneath them.	3	75	1	25
The countertop will include a lip to prevent run-off onto the floor. If the countertop abuts a wall, it will either be coved or have a back-splash against the wall.	3	75	1	25
All cupboards and shelving where nuclear substances may be stored will have				
i) smooth	3	75	1	25
ii) impervious	3	75	1	25
iii) washable	3	75	1	25
iv) chemical-resistant finish.	2	50	2	50
A separate hand washing sink and a wash-up/disposal sink will be Provided.	3	75	1	25
Hand washing sinks will be close to the room's entrance, to encourage hand washing on the way out of the room.	4	100	0	0
Emergency lighting will be provided within the room.	4	100	0	0
Facilities for storing outer garments and personal items will be provided outside the room.	4	100	0	0
Plumbing				
Drains that may carry radioactive material from the area will go directly to the facility's controlled active liquid waste system.	3	75	1	25
Security				
An access control system (key, keypad, key fob, other) will be in place to ensure that only authorized users can enter the restricted room.	4	100	0	0
The room will be equipped with lockable doors that	4	100	0	0

will remain closed and locked whenever nuclear substances and radiation devices are present in the room and the room is unoccupied.				
Any windows on the ground floor will be secured to prevent unauthorized access to the room.	4	100	0	0
If the room is to be shared with workers not authorized to use nuclear substances, a secondary lockable storage area (refrigerator, freezer, cupboard) will be provided within the room.	4	100	0	0
Miscellaneous				
Food and drink preparation, use, and storage areas will not be present in the room unless required as part of a nuclear medicine procedure. Only patients undergoing studies may consume food or drink in the nuclear medicine rooms.	4	100	0	0
Movement of nuclear substances will be minimized by locating in proximity those areas between which nuclear substances must be moved.	4	100	0	0
If the room or storage area is to be used for non-nuclear work as well, then separate labeled areas will be defined for the nuclear and non-nuclear work.	4	100	0	0
Nuclear medicine departments will have washrooms dedicated for use by nuclear medicine patients.	3	75	1	25
Adequate space will be available for radioactive wastes generated by work within the nuclear substance laboratories or nuclear medicine rooms. This space may be within the lab/room or in a separate area.	4	100	0	0
Office and study space will not be located near radioactive work areas.	2	50	2	50
Does the authorized organization provided personal dosimeters				
Are the dosimeter :				
i) Worn properly?	1	25	3	75
ii) Calibrated?	1	25	3	75
iii) Exchanged at required frequency?	1	25	3	75
Are personal exposure within limits	3	75	1	25

Are area and portable survey instrument :				
i)Appropriate?	3	75	1	25
ii) Calibrated?	3	75	1	25
iii) Operational?	3	75	1	25
iv) Checked before use?	3	75	1	25
Taking into account the principle of ALARA worker in dose to the examination.	4	100	0	0
The building is designed for imaging radiation	4	100	0	0
The workstation is adequately shielded and 5mm equivalent shielding lead glass in windows	4	100	0	0

Chapter Five

**(Discussion, Conclusion and
Recommendations)**

CHAPTER FIVE

DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1 Discussion:

From the previous mention results of the evaluation methods used in this research we can detect the main problems of radiation protection application in our country, where we took .the main points need to high- lighted are as followed:

The flooring is one-piece, impervious, chemical resistant, washable surface and easier clean-up if contaminated by percentage 100%.

The countertop include a lip to prevent run-off on to floor, the cupboards and shelving, smooth, impervious, washable (75%) and chemical resistant(50%).

Some hospital is the drains carry radioactive material from the area directly to the facility controlled active liquid waste system about (50%) and other move to main building sewer that is increase the dose to public . washing sink is close to the rooms entrance and wash-up disposal separate.

The security is 100% is found control system and just authorized allowed inter to room and the radioactive material in the storage area.

Some department building near to study space.

The personal monitoring service is applied in some department but not cover the entire worker in department.About 25% from all hospital used personal monitoring.

5.2 Conclusion:

Nuclear medicine is department used unsealed radioactive material to treatment and diagnostic diseases. In diagnostic the radioactive material emitting gamma rays from patient and detected by gamma camera.

Radiation exposure may rise to worker and general public from the radiation emitted by radionuclides in patient, by accidental contamination of skin with radioactive materials, or by accidental ingestion of these materials.

The main objective of radiation protection programs is avoiding the deterministic effect as much as reasonably achievable.

The principles of radiation protection are justification of practice and optimization and dose limitation.

The radioactive patients consider being the main source of radiation for the worker and public, so a care should be taken in reviewing the contact between the patient and the other. The activities administered for diagnostic purposes are moderate, and the patient does not normally need to be hospitalized. For almost all diagnostic procedures the maximum dose that could be received by another person due to external exposure from the patient is fraction of the annual public dose limit and it should not normally be necessary to issue any special radiation protection advice to the patient's family.

Surveys for radiation and removable radioactive contamination must be performed after each of radioactive material.

The purpose of this survey is to identify any contamination present and to prevent its spread. All spills of radioactive material must be cleaned promptly following general procedures for decontamination. The general layout of nuclear medicine department should take into account a possible separation of work areas. In general for purpose of radiation protection, the nuclear medicine department should be design that the activity concentration increase while we get inside the department.

The evaluation form is formed yes/no question, with all ways the (yes) answer is the positive indicator and the (no) are negative ones. The evaluation form includes 31 questions. The most of answer are (yes).

The design of floor as one piece that is mean easy removable from contamination if is done, decrease probability of radioactive material under the floor and easy clear also the cupboards must be chemical resistance.

Sewer of the patient after injection must be with the waiting room because the patient in this case as radioactive material that is mean increases the dose to the co-patient and the worker and the drains carry radioactive material to the facility's controlled active liquid waste system.

Dedicated and secure storage facilities for radioactive waste will be required within the nuclear medicine department. Access to this area should be strictly controlled and limited to designated personnel.

The store should be located adjacent to the radiopharmacy and injection areas. Access should not be through the clean area, offices, or scanning rooms, and should be such that disruption to services in the event of an accident in transit will be minimised. A warning sign should be placed on the door.

The waste store included in Figures 2.1 and 2.2 should be of solid, non - combustible construction and should offer adequate protection from heat, cold, humidity, mechanical damage, vermin, fire and flood. Protective shielding (possibly up to 4 mm lead equivalent) will be required. This must be specified by the RPA so that protection is provided for all those outside the store and those who must transfer material to it or process materials within it. A shielded safe should be provided for small volumes of radioactive liquids which have high activity, and sources of small physical size, that must be kept secure for long periods.

The ceiling, wall and floor finishes should be non porous and easy to clean and decontaminate. The store should be well lit and have sufficient space for the materials to be stored. Corrosive or explosive waste should not be stored in this facility. Waste stores should be adequately ventilated by mechanical means when radioactive gas, dust or vapour is liable to be present. Ventilation should be vented

externally and at a height that ensures adequate dispersal. Filters are not usually required for the quantities used in hospitals.

The type of waste likely to be stored will include spent generators, unused radionuclides (liquid and capsule), contaminated needles, swabs, syringes, etc.

Adequate space and shelving to allow segregation of waste should be provided. High specification shelving or a large floor area is required to store large numbers of self shielded items (e.g. spent generators which are heavy due to their protective shields). Low-level radioactive liquids may be disposed to drain via designated (and clearly marked) sinks in accordance with disposal limits specified in the license conditions. These sinks must be connected directly to the main outside drain and labeled to indicate their use for the disposal of radioactive material. The waste store should have a wash hand basin with elbow or sensor operated taps and fire and intruder alarms.

For waste that cannot be otherwise disposed of there may be a requirement for a second, remote long-term storage facility. Design requirements are similar to those given above with access even more rigorously controlled, as it may not be under day-to-day surveillance. The signage may, on the advice of the RPA, be placed within the store immediately adjacent to the entrance instead of on the outside of the door.

5.3 Recommendation

The radiation protection program is not applied in all hospital. According to evaluation to the evaluation results, the following are recommended:

Because evaluation of dose is an essential part of the radiation program, person monitoring service should be provided for all radiation workers at these departments, it is important that workers return dosimeters on time for processing. Delays in the evaluation of a dosimeter can result in the loss of the stored information. Licensees should make every effort to recover any

missing dosimeters, and the workers should be informed by the correct using of its. It is better to provide the worker with their doses, and to make them believe on it, and at same time understand the effects of the radiation protection in their doses.

Surveys for radiation and removable radioactive contamination must be performed after each use of radioactive materials.

Future planning may consider the growing development of nuclear medicine, so radiation protection services would include designs of building and development of working procedures

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Appendices

Sudan University of science and technology

Faculty of Graduate Studies

MS.c medical physics

Evaluation of Radiation Safety in Nuclear Medicine Department

(Khartoum State)

DATA COLLECTION SHEET

Flooring will have an impervious, chemical resistant, washable surface. Carpeting will not be used.	
Flooring will be coved up walls and cabinets to prevent spills from penetrating underneath them.	
The countertop will include a lip to prevent run-off onto the floor. If the countertop abuts a wall, it will either be coved or have a back-splash against the wall.	
All cupboards and shelving where nuclear substances may be stored will have a smooth, impervious, washable, and chemical-resistant finish.	
A separate hand washing sink and a wash-up/disposal sink will be provided.	
Hand washing sinks will be close to the room's entrance, to encourage hand washing on the way out of the room.	
Emergency lighting will be provided within the room.	
Facilities for storing outer garments and personal items will be provided outside the room.	
Plumbing	
Drains that may carry radioactive material from the area will go directly to the main building sewer or to the facility's controlled active liquid waste system. Drains from the room will be identified on plans supplied	

to maintenance personnel.	
Drains from the room will be identified on plans supplied to maintenance personnel.	
Security	
An access control system (key, keypad, key fob, other) will be in place to ensure that only authorized users can enter the restricted room.	
The room will be equipped with lockable doors that will remain closed and locked whenever nuclear substances and radiation devices are present in the room and the room is unoccupied.	
Any windows on the ground floor will be secured to prevent unauthorized access to the room.	
If the room is to be shared with workers not authorized to use nuclear substances, a secondary lockable storage area (refrigerator, freezer, cupboard) will be provided within the room.	
Miscellaneous	
Food and drink preparation, use, and storage areas will not be present in the room unless required as part of a nuclear medicine procedure. Only patients undergoing studies may consume food or drink in the nuclear medicine rooms.	
Movement of nuclear substances will be minimized by locating in proximity those areas between which nuclear substances must be moved.	
If the room or storage area is to be used for non-nuclear work as well, then separate labeled areas will be defined for the nuclear and non-nuclear work.	
Nuclear medicine departments will have washrooms dedicated for use by nuclear medicine patients.	
Adequate space will be available for radioactive wastes generated by work within the nuclear substance laboratories or nuclear medicine rooms. This space may	

be within the lab/room or in a separate area.	
Office and study space will not be located near radioactive work areas.	
Does the authorized organization provided personal dosimeters	
Are the dosimeter :	
i) Worn properly?	
ii) Calibrated?	
iii) Exchanged at required frequency?	
Are personal exposure within limits	
Are area and portable survey instrument :	
i)Appropriate?	
ii) Calibrated?	
iii) Operational?	
iv) Checked before use?	
Taking into account the principle of ALARA worker in dose to the examination.	
The building is designed for imaging radiation	
The workstation is adequately shielded and 5mm equivalent shielding lead glass in windows	