Sudan University of Science and Technology
College of Graduate Studies.

Assessment of Building Design of Nuclear Medicine Department of Al-nilain Medical Diagnostic Center of Khartoum.

A thesis submitted for partial fulfillment of the requirements of M.Sc. degree in Medical Physics

تقويم تصميم مبنى قسم الطب النووي بمركز النيلين الطبي التشخيصي في الخرطوم .

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((إنّما يخشى الله من عباده العلماء إن الله عزيز غفور))

فاطر82

Dedication

To my parents, my teachers, and friends
for giving me ever-endless gifts of encouragement, love and Patience.

Acknowdgement.

First of all, I’m grateful to Allah the Almighty, for providing me with heath and strength to complete this work.
I would like to express my sincere gratitude to Dr. Awadh Abdalla Adlan who has given me great advice and help in the whole process of my research, and for his fruitful day to day supervision, guidance, endless help and encouragement that built confidence in my work for his valuable and continuous help, his patience through all the period that made this work possible and for giving this opportunity of study, and for unlimited support.

My thanks extend also to colleagues in Al-nilain Medical Diagnostic Centre, colleagues in the College of Medical Radiologic Sciences and all Library staff of the college for their contribution in the data collection. Thanks to my friends for their assistance in many social activities through the period of the study.

Thanks to all staff of the College of Medical Radiologic sciences for their endless moral support and encouragement.
I would like to thank everyone who assisted me in a way or another to bring this study to life.

Abstract.

The objective of this study was to make an assessment to the building design in the nuclear medicine department of Al-neilain medical diagnostic center at khartoum, and to show the level of conformity as compared to the international standards for an ideal building designs of a nuclear medicine department in aspect of radiation protection.

This study was done in Al- neilain medical diagnostic center of Khartoum, in the period from February to April 2017.

Measurements of scanning room dimensions, Patient injection room, hot lab, radionuclide storage area, and waste management area were performed. Data concerning N.M department location within the center , building design and layout, ceilings, doors, floors, floor covers and benches, location and design of scanning room, patient injection room, hot lab, radionuclide store, waste management room . Assess the doors, windows, ventilation requirements and design detailed checklist depends on the ideal design .All this data were gathered and analyzed using excel software program.

Data analysis showed that the department partially conforming the accredited standards by: 49.61% .

المستخلص .

تهدف هذه الدراسة إلى تقييم تصميم مبنى قسم الطب النووي بمركز النيلين الطبي التشخيصي بالخرطوم لمعرفة مدى مطابقتها للمعايير الدولية للتصميم المثالي لاقسام الطب النووي.

أجريت هذه الدراسة بمركز النيلين الطبي التشخيصي بالخرطوم فى الفترة من فبراير إلى أبريل 2017

قام الباحث بقياس كل من أبعاد غرفة التصوير بجهاز قاما كاميرا وغرفة حقن المرضى ومعمل تحضير المواد الصيدلانية المشعة وتخزينها وأرفف تحضير المادة المشعة ومخزن التخلص من النفايات المشعة,, وتقييم سمك الجدران لكل الغرف التابعة للقسم ,, تقييم النوافذ والأبواب و المخارج والمسافات بين الغرف ,, تم تصميم قوائم معيارية اعتمادا على التصميم المثالي المعتمد عالمياً ومحلياً.

تم جمع كل البيانات المتعلقة بموقع القسم بالمركز التشخيصي والتصميم العام للقسم,, أبعاد جميع غرف القسم و المسافات بين الأجهزة و امكانية الدخول إلى الغرف بمراعاة التعرض وسلامة المرضى والمعايير الدولية للوقاية من الإشعاع ,, كذلك السقوف والأرضيات وأغطيتها والأبواب و متطلبات التهوية والتبريد ومن ثم تحليل جميع البيانات باستخدام برنامج اكسيل.

أظهرت نتائج البحث أن القسم مطابق جزئياً للمعايير المعتمدة بنسبة تقدر ب : 49.61%

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List of abbreviations.

abbreviation.	meaning
CT	Computed Tomography
NM	Nuclear medicine
PET	Positron Emission Tomography
RPA	Radiation Protection Adviser
MRI	Magnetic Resonance Imaging
AAPM	The American Association of Physicists in Medicine
ACR	American College of Radiology
ALARA	As Low As Reasonably Achievable
HVL	Half Value Layer.
ICRP	International committee on radiological Protection.
MR\H	Mile Rontgen per hour
MSV	Mile sievert
PDA	Patient dose administration.
SPECT	Single Photon emission computed tomography
NCRP	National Council on Radiation protection.
RSO	Radiation Protection officer.
AEC	Atomic Energy Commission
AMP	authorized medical physicist
LAB	Laboratory
LC	Level of conformance.

Chapter One.

Introduction.

1.1 Introduction:

Nuclear medicine Unit provides facilities for the administration of radiopharmaceutical agents to patients and patient imaging for diagnostic purposes and for treatment. The Nuclear Medicine unit may be provided within the medical imaging unit or as a freestanding Unit. The unit may or may not include a radio pharmacy Laboratory. The size of a unit in terms of numbers and type of cameras will be determined by the service plan and clinical needs.

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. (NCRP, 2004. Structural Shielding Design for Medical X-ray Imaging Facilities, Report no. 147. Bethesda: National Council on Radiation Protection. NHS, 2001.)

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. (NHS Estates, London Stationery Office. NRPB, 1993. National Radiological Protection Board Statement on the 1990.)

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).

1.2. Problem of the study:

Protection against ionizing radiation in N.M practice can be provided using protection measure including the design of the building within which of the N.M facility is located an ideal building design contributes in the overall radiation protection in the N.M department .the department must asses because there is no quality department or auditing.

1.3. Objectives of the study:

1.3.1General objective:

The main objective of this study is to make an assessment to the design of the Nuclear Medicine Department of Al-neilain medical diagnostic center based on the ICRP recommendation in radiation protection aspect.

1.3.2 Specific objectives:

- To assess department location within the center.
- To check safety and protection building design and layout.
- To assess ceiling, doors, floors, floor covering and benches.
- To measure the dimensions of scanning room, patient injection room, hot lab, radionuclide storage, injected patient waiting room and waste management room
- To check safety and protection of patient injection room location, hot lab, radionuclide storage Area, injected patient waiting room, waste management room and ventilation requirements.

Chapter Two.

Literature Review

2.1: Theoretical Background.

Nuclear medicine is uses unsealed radioactive materials for treatment and diagnosis of 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 car 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. (NCRP, 2004. Structural Shielding Design for Medical X-ray Imaging Facilities, Report no. 147. Bethesda: National Council on Radiation Protection. NHS, 2001.

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 waste store 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. (NCRP, 2004. Structural Shielding Design for Medical X-ray Imaging Facilities, Report no. 147. Bethesda: National Council on Radiation Protection. NHS, 2001.

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 vapor 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.

Fig (2.1) : An Ideal department of nuclear medicine in Saudi Arabia.

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. (P. Hickman, Department of Health, UK, Medicines Management: Health Building Note 14-01: Pharmacy and Radio pharmacy facilities. London: The Stationery Office 2007).

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. (The Design of Diagnostic Medical Facilities where Ionizing Radiation _ Code of Practice issued by the Radiological Protection Institute of Ireland _June 2009).The Nuclear Medicine Unit will contain a combination of Standard Components and Non- Standard Components, according to the Level of Service.

2.1.1: Scanning Room:

PET: The shielding of PET and PET/CT facilities presents special challenges because of the high energy emissions involved. Barrier shielding required in ceilings, floors and walls must be specified by the RPA. The patient is the main source of radiation, and once injected consideration has to be given to their journey through the facility. Thus the areas in which the patient spends time post-administration, particularly the “uptake” waiting area and the scanning room, must be shielded. The design of the facility should minimize contact between staff and patient as far as possible without unduly compromising patient care. Floor markings indicating patient routes obviating the need for staff escorts can be useful in this regard. The dominant shielding requirements will be dictated by the PET radionuclides in the case of PET/CT, but the radiation protection issues related to CT must also be considered. The use of local shielding should be maximized in areas where radionuclide’s are stored, dispensed and injected (e.g. purpose-built dispensing stations, shielded dose calibrators, shielded waste containers, shielded injection systems). This will reduce room shielding requirements. The use of concrete nibs can be very effective in reducing shielding requirements particularly for barriers such as doors. The conflicting requirements of providing high level shielding and smooth mechanical operation in a heavy door are considerable, so the use of shadow shielding can be effective. (The Design of Diagnostic Medical Facilities where Ionizing Radiation _ Code of Practice issued by the Radiological Protection Institute of Ireland _June 2009).

2:1:1:a Description and function:

The SPECT and SPECT/CT Scanning rooms will be used for patient imaging procedures using a SPECT camera or combined SPECT/CT hybrid system. Installation of equipment should be in accordance with manufacturer's recommendations. Room size may vary according to the equipment selected.

2:1:1:b Location and Relationships:

Scanning rooms require ready access from dosing rooms and dosed patient waiting areas. Scanning rooms may be collocated with shared Control rooms to enable monitoring of two rooms simultaneously.

Fig (2.2) Scanning room .

Considerations:

Floor structure should support the equipment weight. Uninterruptible power supply is required to the cameras and associated computer modules to prevent data loss and/or damage during power surges or loss of supply. Power to patient areas shall be body protected to protect against electric shock. Individual room temperature and humidity control is required. Lighting should be placed to avoid lights shining directly into the patient's eyes and should be dimmable. Radiation shielding will be required according to assessment by the Radiation Consultant. . (The Design of Diagnostic Medical Facilities where Ionizing Radiation _ Code of Practice issued by the Radiological Protection Institute of Ireland _June 2009).

Bed / trolley access is required to the room:

Fixtures, fittings and equipment within the room will include Collimator rack/s for a range of collimator sizes should be included; the collimator is a directional guide; the size and length of the collimator holes determine which gamma rays reach the detector in the camera; collimator racks vary according to the model / level of Gamma Camera.Patient ECG monitoring may be required in the room. CCTV camera may be included (optional in SPECT/CT room).Lead apron rack and aprons will be required in the room or immediately adjacent. hand basin - Type B with paper towel and soap fittings .Television, ceiling or wall mounted is optional. Bench and shelving for preparation and storage may be provided.

Services will include:

- Medical gases - oxygen, suction, medical air on service panel
- Nurse and emergency call system
- Power outlets for patient equipment on the medical services panel and additional power on all walls
- Computer data points on patient services panel, near gamma camera unit and in control areas.

2.1.2 Patient injection room:

The Nuclear medicine department should have a separated injection room. its area is 35m^2 and the location of injection room is very close to the hot lab and radionuclide storage area .the room should have separated ventilation system and air conditioning. and entrance for injection room very close to the radionuclide storage , hot lab and the waste store .the injection room must have an emergency light and warning signs . (The Society of Nuclear Medicine 50 th Anniversary task Force, for the nuclear medicine, 1850).

2.1.3 Hot lab/radio pharmacy:

The nuclear medicine department must be containing of a hot lab Cleaning and ordering. Hot lab area should be in 20 m^2 .The hot lab have a separated ventilation system, washing sink .The dry benches coverage available. (RPII, 2004, Guidance Notes on Radiation Risk Assessment. Dublin: Radiological Protection Institute of Ireland).

2.1.4: Radionuclide storage area:

A storage area is required for sealed and unsealed radioactive materials that will be used in the radio pharmacy and should be located a 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 m Its location and access arrangements should facilitate delivery of radioactive materials by suppliers, transport to the radio pharmacy 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 compartmentalized 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 28ºC 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 or the radio pharmacy [Radiological protection institute of Ireland, june2009]
Over and above the requirements for radionuclide's, adequate general storage and security should be provided for all the materials required for the operation of the radio pharmacy, and for quality control equipment (Radiological protection institute of Ireland,june20) .

2.1.5: Floors and ceilings:
Imaging facilities are frequently located on the ground floor of hospitals. Floor shielding is not necessary if there are no occupied basements or under floor service corridors, provided that the shielded wall extends the full way to the ground and does not end at a false floor level. Walls extending beneath false floors shall be appropriately shielded to protect the adjacent rooms. If there is occupancy or services beneath the X ray facility or if it is located on an upper level, floor shielding will normally be required. In addition, it is likely that the floor will be required to provide protection against the primary beam. Poured concrete is commonly used in floor or ceiling slabs. A thickness of 150 mm is needed for load bearing and this will provide sufficient protection for many ceilings and floors provided that it is solid throughout (Section 6.1). Waffle type slabs are widely used for floors and ceilings in buildings as illustrated in Photo 2.1.5

They typically have a maximum thickness of 150 mm that reduces to 75 mm at the thinnest part. Thus when waffle type construction is used in the floor or ceiling of an X ray room, additional shielding is generally necessary. This may be provided by lead plywood to the top or underside. The additional shielding must provide sufficient overlap with the waffle slab and perforations made during fixing must be protected (The Design of Diagnostic Medical Facilities Where Ionizing Radiation _ Code of Practice issued by the Radiological Protection Institute of Ireland _June 2009).

Lead paneling may be used in ceilings and, less commonly, on floors; it may be used on the underside of the ceiling or on the floor of the room above. Care must be taken to avoid damage or perforations by heavy loads or rough handling. Screed is a building product commonly used in ceilings of buildings, in addition to other materials. It is not suitable for shielding X ray room ceilings due to its low density and inconsistencies in its density. Thus if screed is present in a ceiling, its shielding properties are usually ignored in shielding calculations and additional shielding may therefore be required. The RPO must take account of the shielding required for areas adjacent to rooms where sources of ionizing radiation exist, including where maintenance/service staff may require access e.g. interstitial space above ceilings or a plant room on the roof. In the case of X-ray rooms located on the top of a building where other higher level buildings are in the vicinity, the possible need for additional shielding must be taken into account. Finally, conventional floor and ceiling construction generally provides.

Fig (2:3) : Waffle type ceiling

2.1.6: Doors:

As illustrated in picture, there may be several doors leading to an X ray room including the patient door, the staff door, and doors to changing cubicles or possibly to a patient toilet. The room should be designed so that the uninterrupted X ray beam will not normally be directed towards doors, windows, or the operator’s console. Even with this provision the door and doorframe must be shielded against scatter. The shielding must be uninterrupted between double doors, between the door and frame, and between the doorframe and the adjoining wall. Generally the minimum overlap is 1.5 cm. In the case of a concrete or brick wall, the shielding should overlap the doorframe and wall by a distance at least equivalent to the thickness of the concrete or brick in the wall (WHO, 1974). Sliding doors are attractive for saving space but can become difficult and tiring to move, which results in their not being closed properly. Patient doors should be wide enough to allow beds and trolleys to pass through. They should open into the controlled area to provide protection should a person enter the room inadvertently (NHS, 2001). Doors should be of solid construction with the lead bonded on both sides by wood or a suitable alternate protective material Fig (2.4). The doors should have Radiation warning lights and signs as shown in Fig (2.5). (The Design of Diagnostic Medical Facilities Where Ionizing Radiation _ Code of Practice issued by the Radiological Protection Institute of Ireland _June 2009).

The shielding must run the entire length and width of the door down to a few mm from the floor. The shielding in the window, window frame and door must be effectively uninterrupted and sufficiently overlapped as indicated in Appendix E. Doors in rooms such as shielded operating theatres may contain ventilation panels. These must also be appropriately protected. Doors and windows should be marked with their lead equivalent thicknesses. Hinges, handles and keyholes should not compromise the shielding and should be protected as outlined in Section 6.5. For general rooms, the lead equivalence of the door is typically 2 mm at 150 kV although doors of 3-4 mm lead equivalence at 150 kV or more may be required for angiography suites and multi-slice CT installations. It is essential that door hinges and sliding tracks are suitable for the weight involved. (The Design of Diagnostic Medical Facilities Where Ionizing Radiation _ Code of Practice issued by the Radiological Protection Institute of Ireland _June 2009).

Fig (2:4): Lead doors.

Fig (2:5): Radiation warning lights and signs

Access through doors must be controlled by the use of appropriate lights and signs, unless the entrance is locked during exposures (as may be the case with doors leading to/from changing cubicles or toilets).
Warning lights should preferably be located beside the door at eye level (MDGN, 2002). They should be two stage devices, with a yellow 'Controlled Area' warning light illuminating when power is supplied to the unit.

and a red 'Do Not Enter' warning illuminating on preparing the X ray tube for an exposure (Appendix F). Rooms using a single warning light must also have a sign indicating what action is to be taken when the light is illuminated.
Appropriate radiation warning signage should be put in place on each entrance door including doors leading from changing cubicles and toilets, stating that the area is controlled .The radiation trefoil symbol should be illustrated on the signage. Multilingual pictorial signage, advising female patients to bring a pregnancy or a suspected pregnancy to the attention of the radiographer before being X ray , should be positioned in all changing cubicles. Additional information on signage is available in the UK Medical and Dental Guidance Notes (MDGN, 2002).

2.1.7: Windows:
Unshielded windows at a height of greater than 2 m from the outside ground were previously considered to be acceptable. However this is often no longer the case, given the high density of modern developments, the increased workloads possible with new technology and the present dose constraints. The issue of shielding of X ray room windows must be referred to the RPA as the majority of these windows may require shielding. For general rooms, the lead equivalence of the window required may be 2 mm at 150 kV depending on the workload, the occupancy outside, and the distance to the nearest occupied area, although windows of 3-4 mm lead equivalence at 150 kV or more may be required for multi slice CT and angiographic installations. In all cases the actual amount of shielding required should be based on the RPA's advice. If windows are required in X ray rooms, they may be shielded by lead glass or lead acrylic. These should be provided in the form of double-glazing, with plate glass on the outside as lead glass and lead acrylic may be easily damaged and lead glass must be kept dry. Window frames must also be shielded with sufficient overlap provided between the window and window frame and between the window frame and wall. Windows should be marked with the lead equivalent thickness. Alternatively, windows may be shielded by lead blinds or shutters. A range of lead blinds is available including electronically operated vertical blinds. The blinds should also be marked with the lead equivalent thickness. The primary beam should not be routinely directed towards a window.

2.1.8: Materials for fitting and furnishing nuclear medicine departments:

The selection of finishes and fittings in nuclear medicine should minimize the risk of radioactive contamination, prevent its spread and facilitate decontamination. Surfaces within controlled and supervised areas should be smooth, non-absorbent, non porous and easily cleaned and decontaminated. Non absorbent finishes such as conventional sheet vinyl flooring and skirting together with walls painted using gloss paint or similar easy to clean wall finishes are appropriate. To minimize residual contamination arising from spills particular care should be taken to avoid gaps in finishes and fixtures in which radioactive material could become lodged. All horizontal surfaces including the floor covering must be continuously sealed and impervious to spillage, and coved against the walls to provide in-situ skirting. (The Design of Diagnostic Medical Facilities Where Ionizing Radiation _ Code of Practice issued by the Radiological Protection Institute of Ireland _June 2009).

The choice of surface materials should take account of the type of solvents and cleaning materials likely to be used. Caution should be applied in the selection of surfaces that are reported to be cleanable. This can mean that they are capable of withstanding common cleaning agents rather than their suitability for decontamination. Bench surfaces in areas where unsealed radionuclide's or body fluids are handled should be coved against the walls and lipped at the edges to prevent radioactive substances becoming lodged in any cracks between the wall and bench or spilling onto the floor. It should be noted that the use of coving between walls and bench tops could mean that hatches at bench level may not be flush with the bench thus necessitating items, which are sometimes heavy or fragile, to be lifted through the hatch. Caution should be applied to the selection of laminate finishes which although satisfactory in many respects can be susceptible to damage and may not provide an optimal long-term solution. Durable materials should be used. Floors and benches must be strong enough to support the weight of shielding materials.

2.1.9 Shielding in nuclear medicine department:

Designing the department so that areas of high activity are grouped together, optimal use of shielding can be achieved. The provision of generously sized patient areas (in particular the scanning, injection and waiting areas) can help to reduce exposure rates at boundaries. Likewise, the use of local shielding in the immediate vicinity of sources is effective in controlling exposure rates and can help reduce overall shielding requirements. (The Design of Diagnostic Medical Facilities Where Ionizing Radiation _ Code of Practice issued by the Radiological Protection Institute of Ireland _June 2009).

2.1.10: Walls:

Walls surrounding high activity areas should be constructed from dense concrete with a minimum thickness of 22.5 mm. Depending on workload and occupancy of the surrounding areas, additional lead shielding may be specified by the RPA for walls, ceiling or floor. Wall and door shielding will differ from that used in conventional X ray rooms in that the source of radiation is the patient and other radioactive sources. The use of mobile shields can be helpful as a method of providing local additional shielding for particular situations. However, it should be noted that these shields are often between 0.5 and 1 mm lead equivalent. These will offer limited protection at the energies normally used in nuclear medicine.

2.1.11: Services, joints, openings and perforations:

During construction, many perforations will be required in the boundary walls, floors and ceiling of the room being shielded. These have obvious consequences for the integrity of shielding and measures must be taken to make good any breaches arising from perforation or other flaws in the shielding. Examples of perforations include those arising from:

- Nails and screws.
- Air conditioning ducts and ventilation grilles.
- Conduits, pipes and ducting.
- Electrical socket outlets.
- Light switches.
- Service outlets.
- Emergency cut-off and aid buttons.
- Plumbing and the installation of sinks, etc.
- Installation of storage cabinets and shelving, etc.
- Installation of light boxes, apron hangers and other wall mounted devices or fixtures.
- Medical gasses, vacuum and associated services.
- Particular services may be required in operating theatres.
- Where possible, these perforations should not be in the primary barrier. The perforations and all other breaches
- such as joints and outlets should be backed with additional lead shielding whose lead equivalence is the same as that of the boundary. The diagrams in Appendix E clearly illustrate effective approaches to this issue.

2.1.12: Store of Radioactive Waste:

Description and Function:

This room will store radioactive waste materials.

Location and Relationships:

Ready access to the Hot Laboratory is required.

Considerations:

Lead lining is required to ensure safe protection of radioactive materials. (The Design of Diagnostic Medical Facilities Where Ionizing Radiation _ Code of Practice issued by the Radiological Protection Institute of Ireland _June 2009).

2.1.13: The Ideal Layout:

The ideal layout submitted for 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.

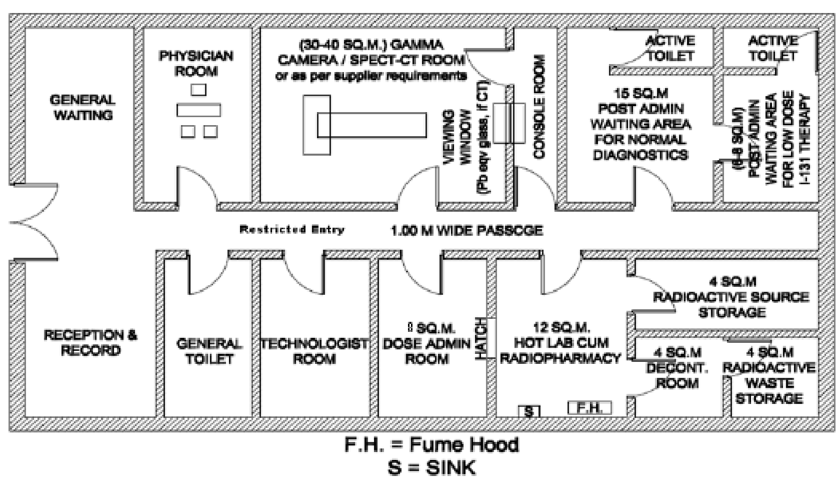

Fig: A TYPICAL LAYOUT OF A NUCLEAR MEDICINE LABORATORY FOR DIAGNOSTIC STUDIES (IN-VIVO) IMAGING) TOTAL AREA = 150-160 SQ. M.

Note: All the walls /partitions of the Nuclear Medicine laboratory should be made of 9" brick or 6" concrete. Fume Hood to be installed; if required
Decontamination Room is optional. The active toilet may be used for personnel decontamination by providing a shower and wash basin.

2.2. Previous studies:

S. E. Elsamani 2015 stated that future planning may consider the growing development of nuclear medicine, so radiation protection services would include designs of building and development of working procedures. The level of conformable to the accredited standards in all centers in Sudan is less than acceptable level. The waste store is the worst area in the department.

M.abdelmahmoud 2012 stated that the areas smaller than the accredited and conformable from the international health organization in 3% in the average of all centers in Khartoum .

M. jousefe 2016 stated that the scanning room of the center is conforming the ideal design but deafer from the dimensions in 0.18% that accredited as ideal area.

Chapter Three.

Materials and Methods.

Materials and methods.

3.1Materials:

Components of building design in AL-Neelain Diagnostic Center in Khartoum N M department design Including the imaging room, Scanning room, hot lab, Radionuclide storage area , Waste management area , and Patient injection room .

Plastic Meter used for measuring the dimensions of the rooms and different areas of the department .The records concerning the building design. The guides which used for designing checklists. The camera which used for taking photograph of the department.

3.2 Methods of data collection:

The data was collected by measuring the dimension, taking photograph, reviewing the documents, designing the checklist from the checklists guidelines designed by the researcher.

3.2.1 Measurement:

Reviewing the documents as the sketch layout , and measurements of areas dimensions using plastic mater .

3.2.2 Observation:

The researcher spent time in nuclear medicine department under study observed the design and take a clear sketch for the layout. Assess Department Location within the center, Building Design and layout, Ceiling, Door, Floor, floor cover and benches, Radionuclide storage area, Waste management area, and Ventilation requirements by Close Observation.

3.2.3 Checklist development:

The researcher designed a detailed checklists to asses all standards by calibrate it with the internationals guidelines which are used for optimizing the nuclear medicine department design.

3.2.4 Photographic Films:

The researcher imaged the all parts of the department, , Hot lab, scanning room, Radionuclide storage area, Waste management area, Patient injection room , and the injected patient waiting room.

Chapter Four.

Results.

Results.

4.1. Department location & access:

Table 4-1: Shows the results of the department location & access:

Item	L.C	percent
Control of access of public and visitors is in place.	3	12.5%
Scanning rooms have an access from dosing rooms and dosed patient waiting areas.	1	4.17%
Movement of nuclear substances is restricted.	4	16.67%
The Store separated and labeled areas are defined for the nuclear and non-nuclear work.	4	16.67%
Office and study space not located near radioactive work areas.	4	16.67%
There is an emergency exit in the department	1	4.17%
Total		70.85%

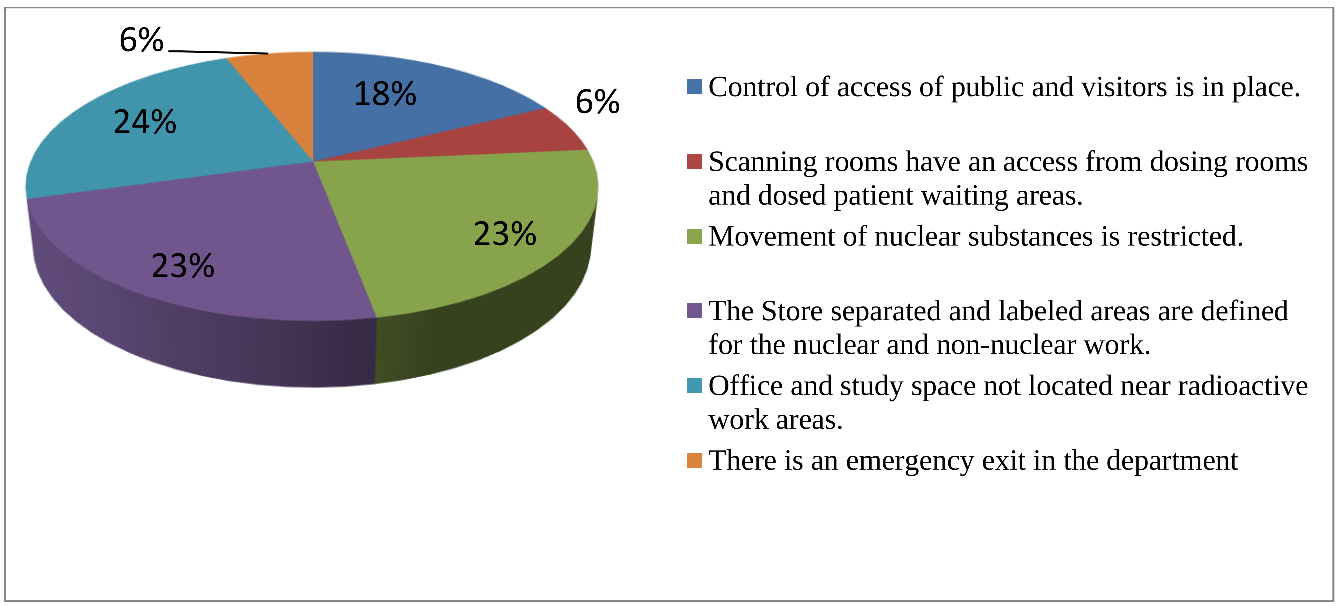

Figure (4-1) : shows the results of the department Location & Access.

4.2. The Department Scanning Room.

Table 4-2: shows the results of the department scanning room.

Item.	L.C	percent
Scanning room area.	4	12.5
Ventilation and air conditioning.	3	9.38
Location of control panel.	4	12.5
Scanning room entrance.	4	12.5
Gamma camera Location.	4	12.5
Patient areas shall be body protected to protect against electric shock.	4	12.5
Individual room temperature and humidity controlled.	4	12.5
Lighting should be placed to avoid lights shining directly into the patient’s eyes and should be dimmable.	4	12.5
Total.		96.88%

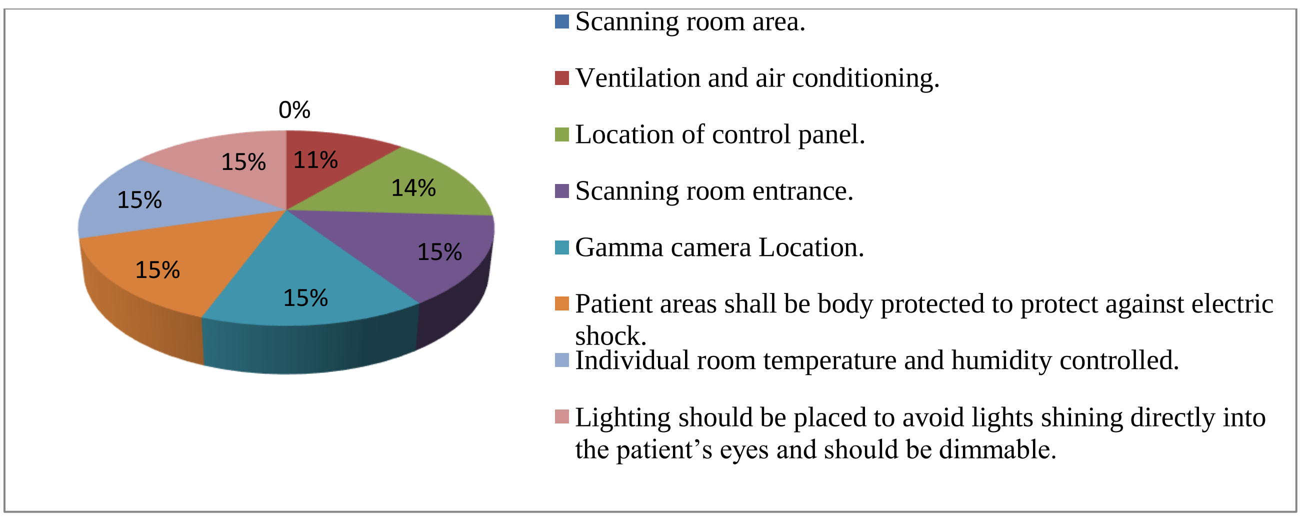

Figure 4-2 : shows the results of the scanning room data .

4.3 The Injection Room.

Table 4-3: shows the results of the Injection Room design.

Item.	L.C	Percent.
Injection room area.	2	10%
Separated Injection Room.	1	5%
Location of injection room.	4	20%
Ventilation and air conditioning.	3	15%
Injection room entrance.	4	20%
Total.		70%

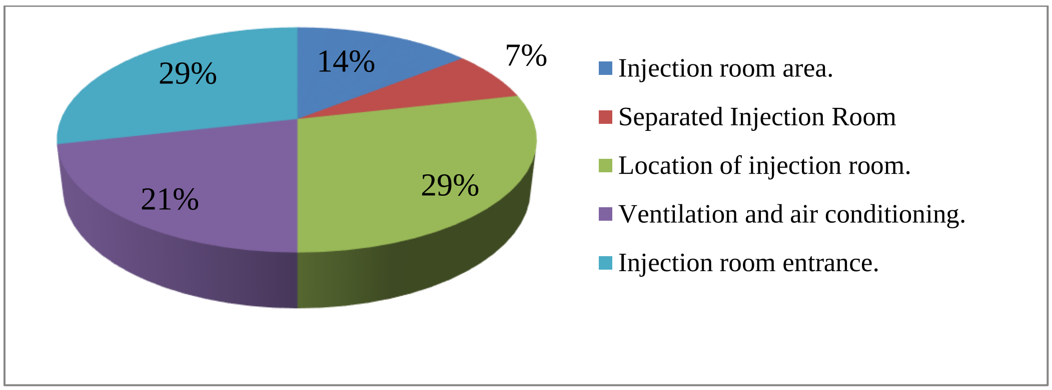

Figure 4-3 : shows the results of injection Room design.

4.4 The Radionuclide Storage.

Table 4-4: shows the data of Radionuclide Storage.

Item	L.C	Percent
Storage for radioactive materials is secured and shielded.	4	11.1%
The storage specified is for nuclear substances.	1	2.8%
The storage having adequate area.	1	2.8%
All storage cupboards for nuclear substances have smooth surfaces.	2	5.55 %
All store cupboards for nuclear substances have non absorbing surfaces.	4	11.1%
Washable surfaces of all storage cupboards.	4	11.1 %
All storage cupboards of nuclear substances have chemical-resistant surfaces.	1	2.8%
Location and movement of nuclear substances.	4	11.1%
Storage area.	1	2.8%
Total.		61.05%

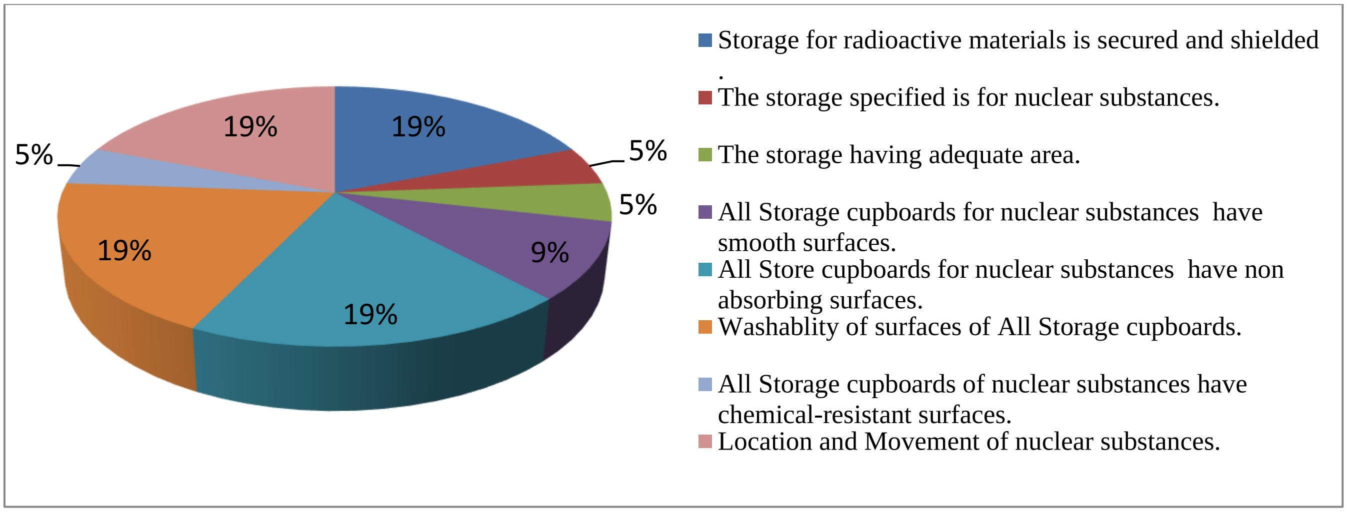

Figure 4-4: shows the data of Radionuclide Storage.

4.5 The Doors and Windows.

Table 4_5: shows the results of doors and windows.

Item.	L.C	percent
Doors Lead lined.	3	18.75%
Doors are Fully Safely lockable doors.	4	25%
Lead windows.	4	25%
Access through doors controlled by using appropriate lights and signs, Warning lights located beside the door at eye level	0	0
Total.		68.75%

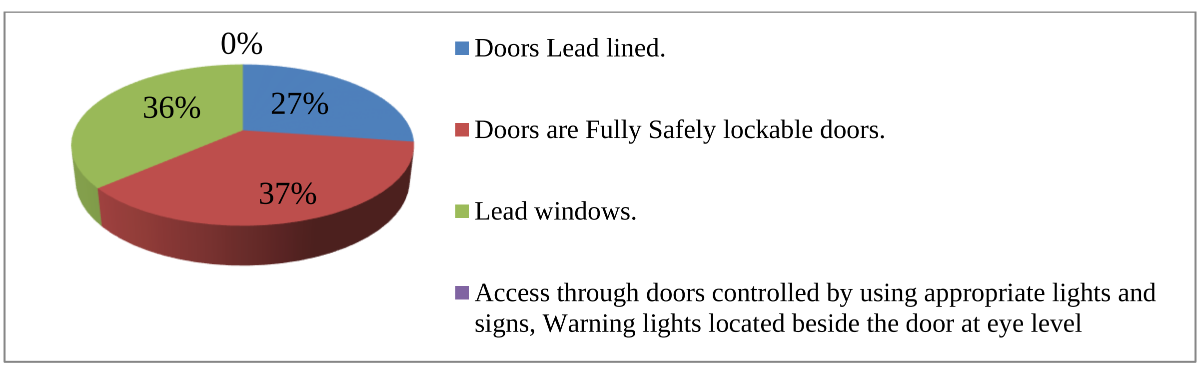

Figure 4_5: Shows the results of doors & windows.

4.6 The Floor Design .

Table 4_6: Shows the results of floor design.

Item	L.C	Percents.
Carpeting	2	8.3%
Flooring impermeability.	1	4.16%
Design of flooring (one-piece) .	1	4.16%
Washable surfaces.	4	16.67%
Chemical resistance.	1	4.16%
Covering.	0	0%
Total		37.5%

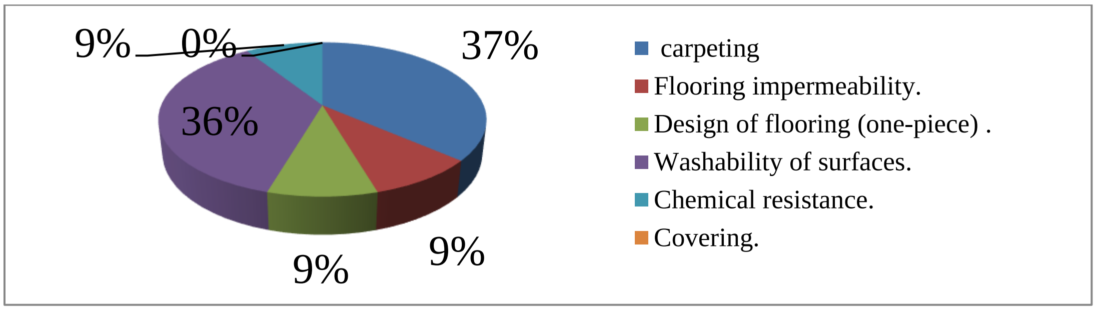

Figure 4_6: shows the results of the floor.

4.7 The Hot lab design.

Table 4_7: shows the results of the hot lab design.

Item.	L.C	Percents.
Cleaning and ordering.	4	20%
Hot lab area.	2	10%
Ventilation system.	4	20%
Washing sink	1	5%
The dry benches coverage.	1	5%
Total.		60%

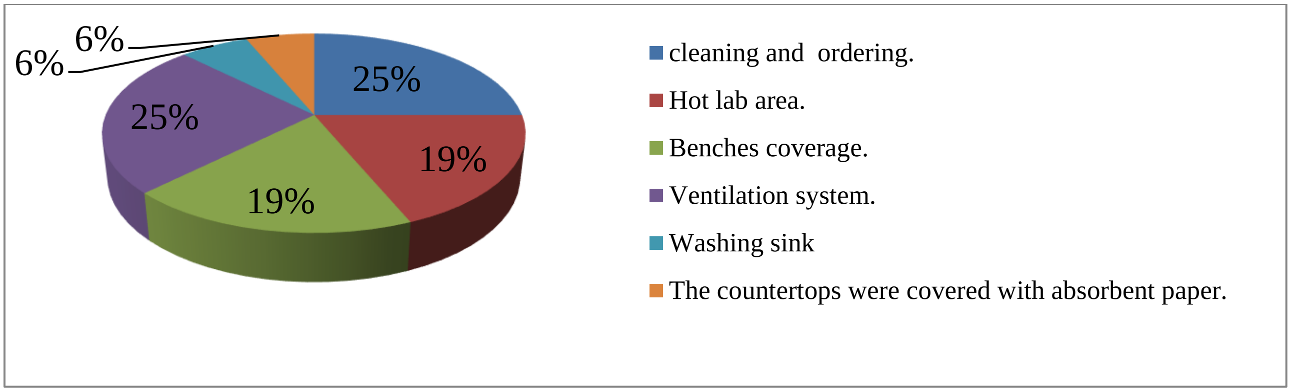

Figure 4_7: shows the results of the hot lab design.

4.8 Injected Patient Waiting Room :

Table (4_8) : shows the results of Injected patient waiting room.

Item.	L.C	Percent.
Injected patient waiting room area.	2	10%
Direct access to injection room.	3	15%
Separated washroom.	4	20%
Separated and controlled air condition and ventilation.	4	20%
Separate washing sink.	2	10%
Total		75%

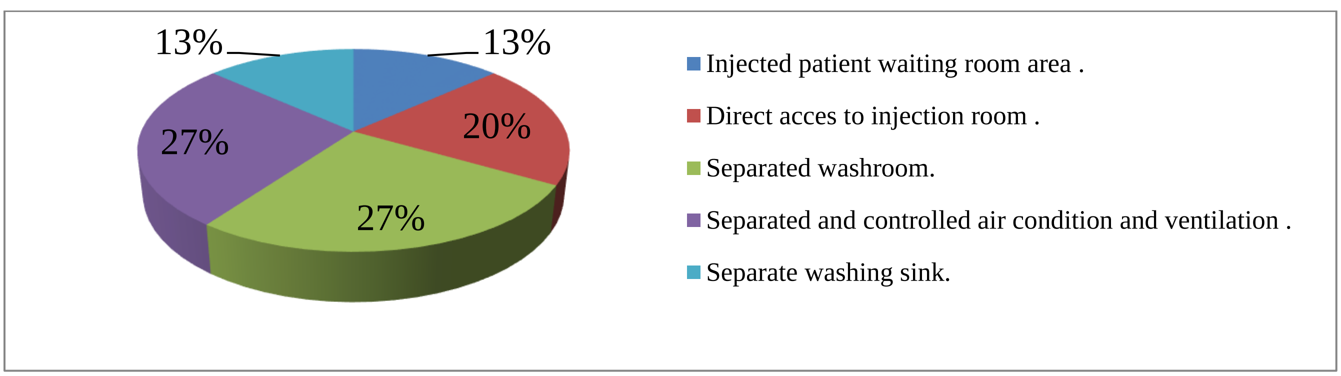

Figure (4_8) : shows the results of Injected patient waiting room.

4.9 Waste Disposal.

Table 4_9: shows the results of waste disposal.

Item.	L.C	percent
Storage for radioactive waste provided.	2	10%
Adequate space.	2	10%
Waste area ventilation	0	0
Separate washing sink	0	0
Ready access to the Hot Laboratory is required	0	0
Total.		20%

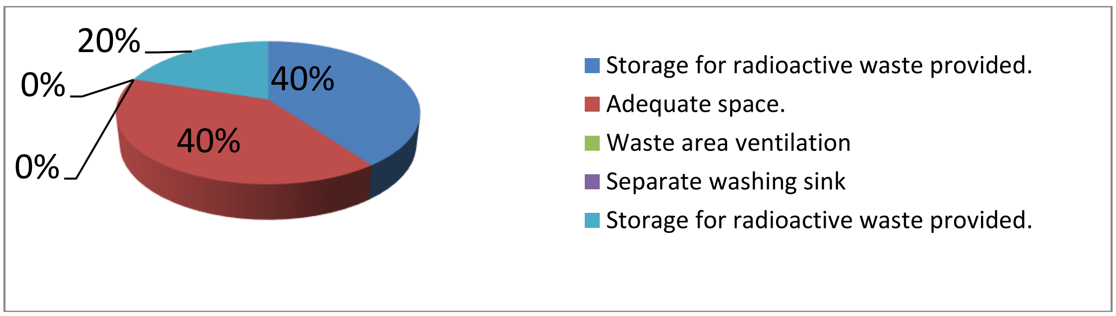

Figure (4_10) : shows the data of Waste disposal.

4.10 Department Washroom and plumbing:

Table 4_10: shows the results of the department washroom and Plumbing.

Item.	L.C	
Injected patient's washrooms availability.	4	14.29%
Injected Patients washroom location.	4	14.29%
Washroom Drains.	4	14.29%
Staff Washroom availability.	0	0
Hand washing sink in the entrance of the department.	0	0
Hand washing sink in the injection room.	0	0
The instillation of the sinks in whole of the department.	1	3.75%
Total.		46.61%

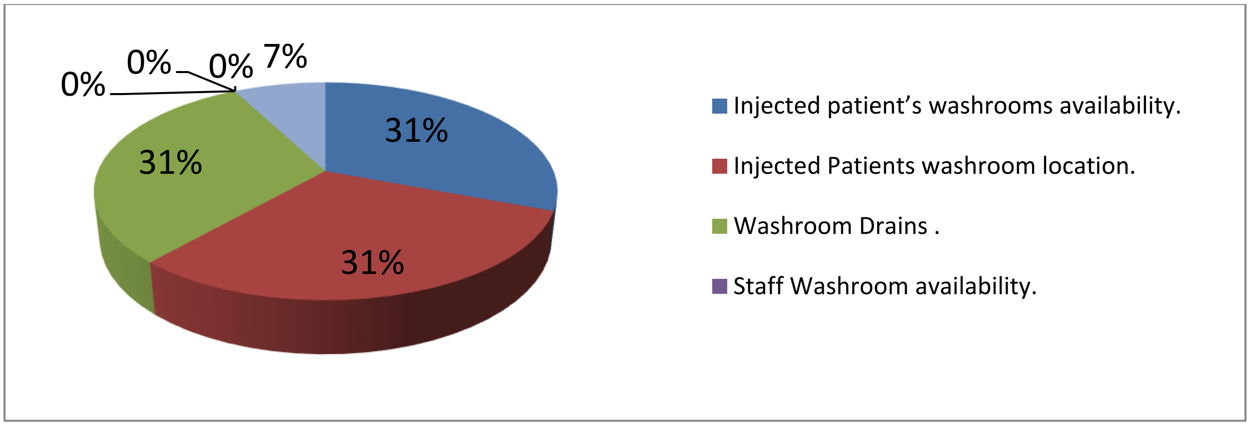

Figure (4_10) : Shows the results of the Washroom and Plumbing.

(L.C) Level of Conformance:
4 Documented and Conformable.
3 Documented and partially Conformable.
2 not Documented and partially Conformable.
1 Documented and doesn't Conformable.
0 not Documented and doesn't Conformable.

4.11 Dimension Rooms Measurements :

Table :4-11 Shows dimension of rooms Measurements for nuclear medicine department at Al-nilain center in (meter) .

Room	Dimensions			Area\ m^2	Standard\ m^2	Percent difference	Percent
	Length	Width	High				
Imaging Room	3.74	3.44	2.79	12.86	35	0.63%	9%
Control room	1.93	4.10	2.79	7,9	10	0.21%	3%
Storage room	1.7	2	-	3.4	10	0.66%	9.4%
Waiting area	3.9	4.73	-	18.4	19	0.03%	0.4%
Hot lab	2.21	2.1	-	4.6	20	0.77%	11%
Door	2.25	82.5	-	185.6	175	0.11%	1.6%
Lead Window	4.3	7.2	-	31	90	0.66%	9.4%
Total of difference percents.							43.8%

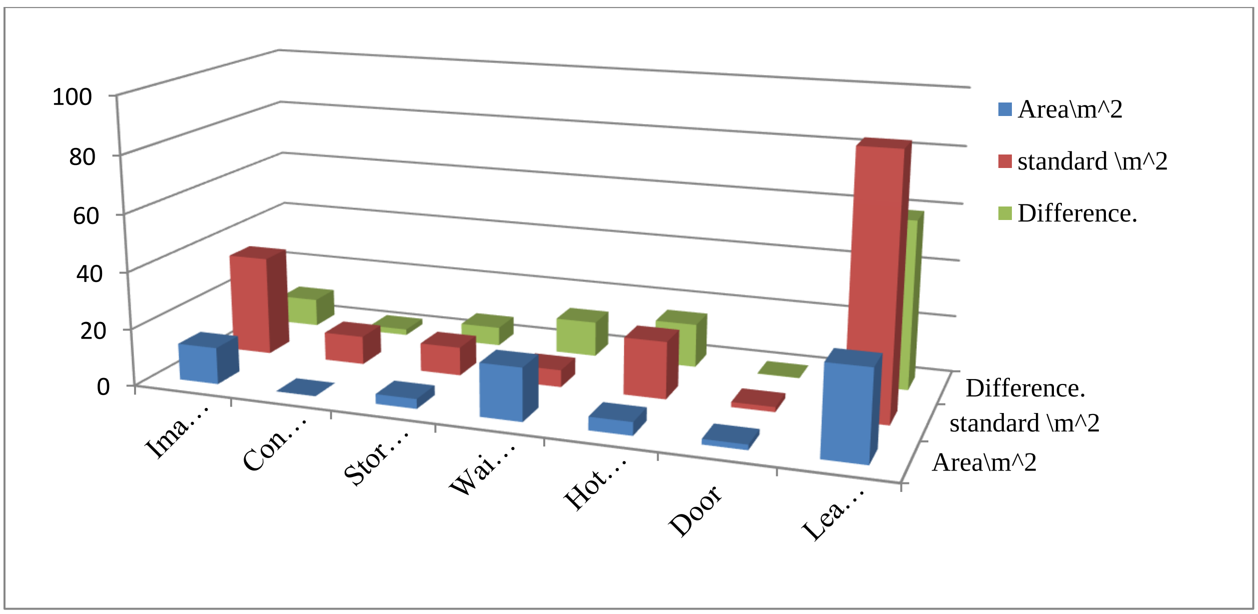

Figure: (4-11) : Shows dimension of rooms Measurements for nuclear medicine department at Al-nilain center in (meter).

4.12 The Thickness:

Table: 4-12 shows the thickness of rooms Measurements for nuclear medicine department at Al-nilain center in (meter).

Item.	thick	Standard	Difference range.	Difference percent
Wall thickness	0.28	0.22	0.06	0.18
Door thickness	0.05	0.11	0.06	0.18
Ceiling height of the imaging room.	0.28	< 0.3	0.03	0.09
Total				0.45%

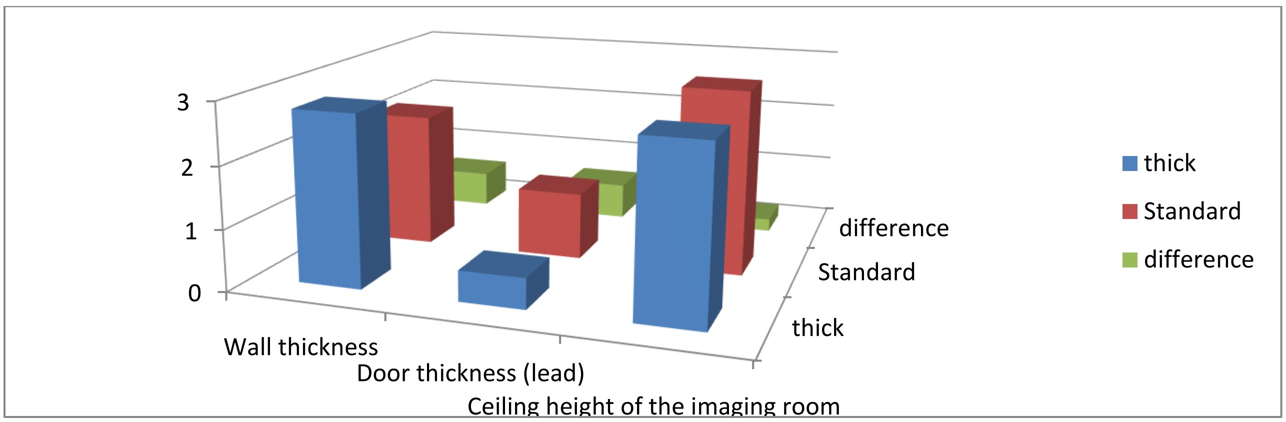

Figure: (4-12) : shows the thickness of rooms Measurements for nuclear medicine department at Al-nilain center in (meter).

4.13 Construction Materials:

Table (4_13): Shows the construction material of different areas of Nuclear medicine department.

Component	Material.	L.C	Percent.
Ceiling	Concrete.	2	20%
Window	Lead glass	2	20%
Door	Lead lined Thick solid core wooden door.	1	10%
Wall	Concrete and Ceramic.	2	20%
Floor	Ceramic.	1	10%
Total.			80%

Level of conformance in material:
2 Totally Conformable.
1 Partially conformable.
0 Unconformable.

4.14 Total Department :

Table (4_14) :The Results department which contain of six sections and seven aspects to assess the department:

Item	Item Percent.	Percent.
Scanning room.	96.88%	7.45%
Injection Room.	70%	5.39%
Radionuclide Storage.	61.05%	4.7%
Hot lab.	60%	4.62%
Injected patient waiting room.	75%	5.78%
Waste disposal	20%	1.5%
Location & access.	70.85%	5.5%
Doors & windows	68.75%	5.3%
Floor design	37.5%	2.9%
Washroom and Plumbing.	46.61%	3.6%
construction material	80%	6.2%
Total.		52.94%

Table (4_15) : Shows the difference in dimensions and thicknesses.

Item	Item Percent.	
Dimension	43.8%	3.3%
The thicknesses	0.45%	0.03%
Total of difference.		3.33%

Total percent of department : (52.94 _3.33) =49.61 %

The department is partially conformable by : 49.61%

Chapter Five.

Discussion, Conclusion and Recommendations.

5.1 Discussion:

From the results of the assessment methods used in this research we can detect the main problems in building design, the main points need to high- lighted are as followed:
The building future planning may consider the growing development of nuclear medicine, so radiation protection services would include designs of building and development of working procedures. The N.M department is partially conforming the international standards and this agrees with the previous study.

The results in (4_1) table Department location & access .The departmental location and access came very close to the accredited international standards in movement of nuclear substances. The separated and labeled areas are defined for the nuclear and non-nuclear work. Office and study space not located near radioactive work areas. And there is good Control of access of public and visitors is in place but all co-patients should enter via the same way with the Patient and at the front of the hot lab door which didn't conforming the applicable standards. There isn't any emergency exit in the department. So the access and location of the department confirms the standard in 70.85 %.

The Results in table (4_3) for the injection room .Injection room area is less than the international standard of the injection room and it is separated but is very close to the radionuclide store. There is a partition separating it from the hot lab. And it is confirm the standards in percent70%.

Results in (4_4) for radionuclide store reveals that : Security and shielding of radioactive materials were available. All Store cupboards where nuclear substances stored in have non-absorbing surfaces. All Store cupboards have washable surfaces. Location and Movement of nuclear substances come very close to the international standards. The storage is not specified for nuclear substances. And the area is not adequate. All Storage cupboards where nuclear substances stored have no smooth surfaces and are not chemical resistant. It is confirm the standards in percent 61.05%
Results in table (4_5) for doors and windows .The doors are lead lined but the lead thickness is less than the recommended standards but they are fully safe and lockable. The lead glass windows are designed according to the accredited guidelines. The department doors and windows confirm the standards in 68.75%
Results in table (4_6) of the floor design. Carpeting is not appropriate for N.M department but it's used there. Flooring not fully impermeable it is ceramic flooring. The design of flooring is not one-piece and not chemical resistance, and doesn't meet the

standards, although it is washable. Covering is not conformable to the international standards. The floor in general conforming the standards by37.5%

Results in table (4_7) of the hot lab design .Cleaning and ordering hot lab have appropriate ventilation and air conditioning system .Hot lab area isn't conformable the international standards. But the Washing sink didn't conforming the ideal design and didn't have separated drain system .The countertops haven't covered usually by absorbent paper. Hot lab confirming the accredited standards by 60%
And results of table (4_8) for injected patient waiting room .Injected patient waiting room area is not separated .There is a close access to injection room but it does not directly way. There is a good controlled air condition and ventilation and separated washroom. Separate washing sink instillation is not conformable the standards. Injected patient waiting room is confirm the standards in 75%
Result in table (4_9) of waste disposal .Storage for radioactive waste provided but there is not Adequate space, Waste area ventilation and no Separate washing sink it's confirm standards in 20%

Result in table (4_10) of washroom and plumbing. There is a high conformable in Injected patients' washrooms availability, and location, and separated Washroom Drains But there is no separated hand washing sinks in the entrance of the department and in the injection room. The instillation of the sinks in whole of the department is not conformable. Confirming the standards in 46.61%
Results in table (4_11) for the department dimension. The dimension of N.M department rooms is conforming the standards is Control room in 0.21%, in waiting area by 0.03% , and by 0.11% in doors But the rooms defers from the standards by Imaging Room in 0.63% , Storage room in 0.66%,and lead window in 0.66% witch mean its Partially conformable. The department uncomforting the standards in the hot lab the percent of difference is 0.77

Results in table (4_12) about thicknesses. Says that the thicknesses differ from standards by 0.06 m for wall and doors but the ceiling height less than the 0.03 m.

Result in table (4_13) of material reveals that . The ceiling, door, wall and window conforming the standards. But the floor is unconformable. Is not chemical resistance, carpeting used, flooring impermeability because design of flooring is not one-piece, and the cover does not meet the standards.

5.2Conclusion:

The researcher assumed the accredited standards. Design detailed check list containing of all items which concerning the building design. Then measuring the dimensions of all the department sections scanning room, injection room, hot lab, and injected patients waiting room. Evaluate all standards as thickness of building, the standards of areas. And the results can to summarize it as that:

The building design is partially conforming the international and local standards

The results shown in tables from (4_1) to (4_13) and figure from (4_1) to (4_13) :

The Results department which contain of six sections and seven asceps to assess the department conforming the standards by following percents:

The scanning room conformable the standards by 96.88%

Injection Room conformable the standards by 70%

Radionuclide Storage conformable the standards by 61.05%

Hot lab conformable the standards by 60%

Injected patient waiting room conformable the standards by 75%

Waste disposal conformable the standards by 20%

Location & access conformable the standards by 70.85%

Doors & windows conformable the standards by 68.75%

Floor design conformable the standards by 37.5%

Washroom and Plumbing conformable the standards by 46.61%

Construction material conformable the standards by 80%

Dimension and thicknesses differs from the standards by 3.33%

The department is partially conformable by: 49.61%

5.3 Recommendations:

The Ideal Design form and radiation protection program must be fully applied in the areas of scanning room and hot lab.

Scanning rooms' future design must have an access from dosing rooms and injected patient waiting areas.

Emergency exit in the department should build.

The storage must specifies for nuclear substances and separate it from the waste store, by adequate area.

All Storage cupboards for nuclear substances should have smooth surfaces, chemical-resistant surfaces.
Doors should line with lead in standards thick.

Carpeting should stopped, and check flooring impermeability, design of flooring (one-piece) ,chemical resistance , covering as standards recommended.

The hot lab area must be extinction; the benches should cover with absorbent paper.
The radionuclide store needs to have adequate space.

Instill Separate washing sink in the entrance of the department.
Hand washing of patient washroom sinks location must change.
Routine survey to the nuclear medicine department especially the hot lab should be done to prevent the side effect.

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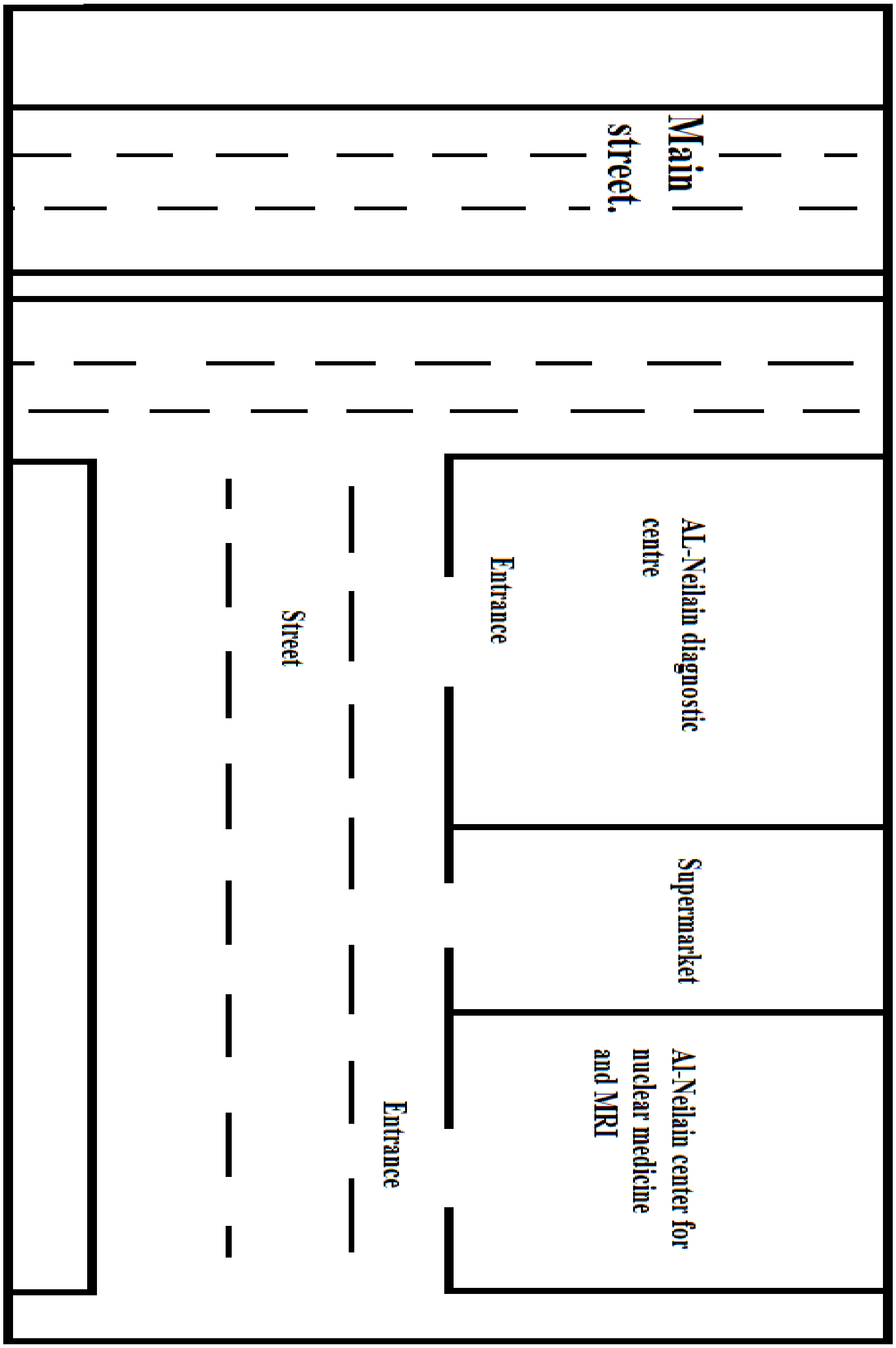
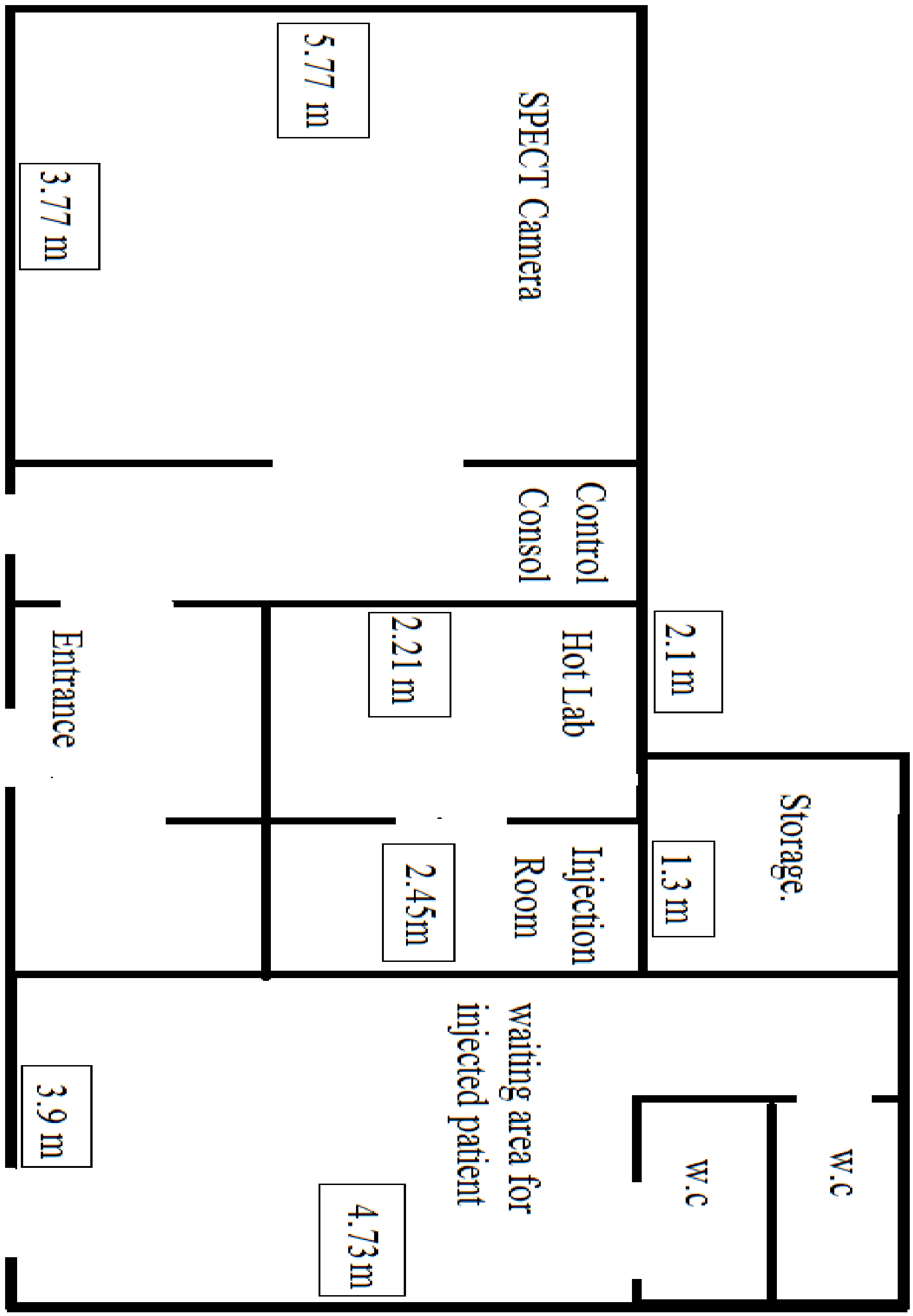
Appendices.

Appendix (1) : Al-neilain Medical diagnostic Center Location .

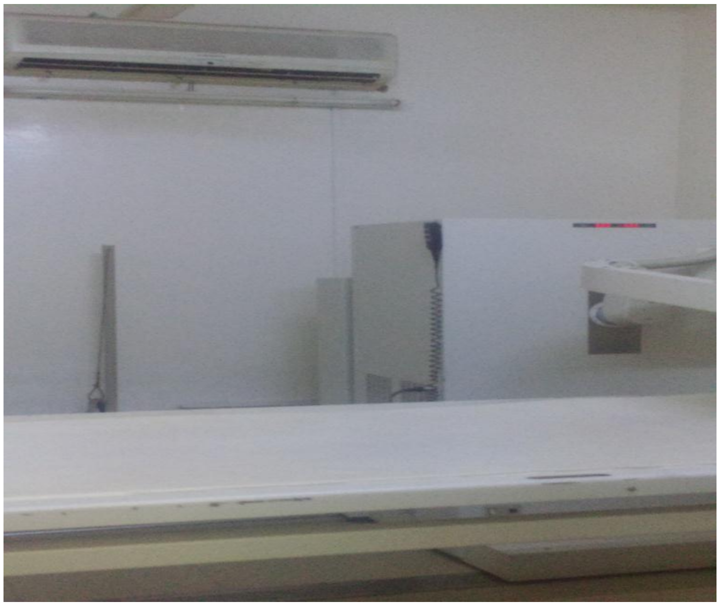


Appendix (2) : Building Design , layout and dimension of Al-neilain department of nuclear medicine .



Photographs.

Appendices (3) : The Gamma camera location in the scanning room .

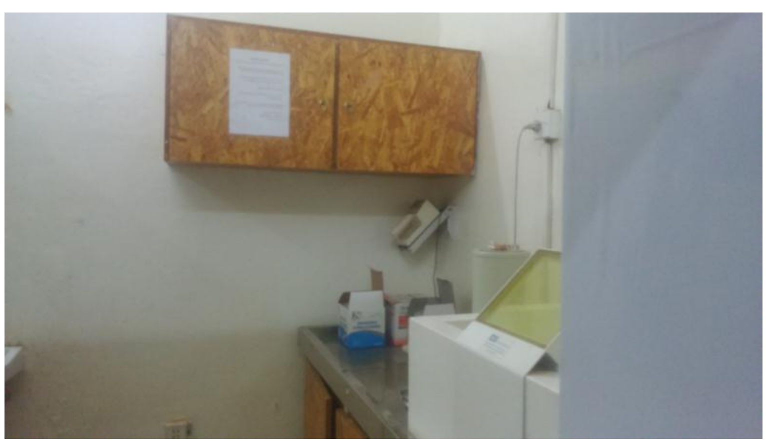


Appendix (4) : Scanning room seperated air condition system .

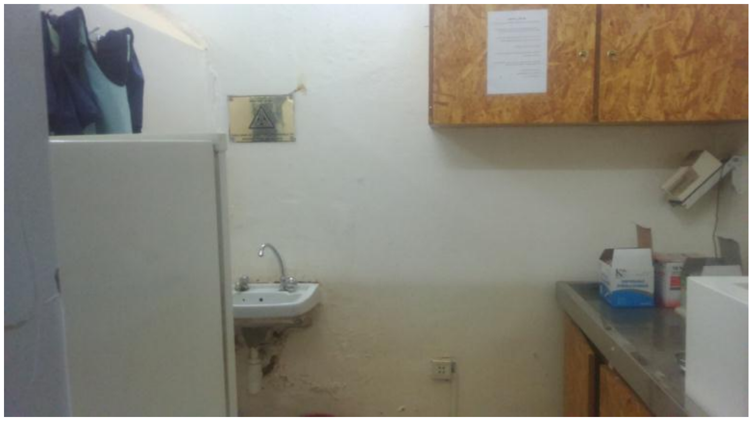
Appendix (5) : The location of control panel in scanning room.

Appendix (6) : The Hot lab benche .

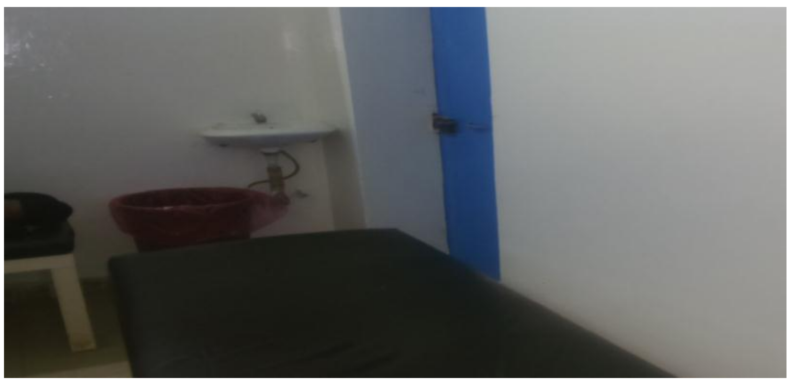
Appendix (7) : The Hot lab area and cupboards.



Appendix (8) :The Hot lab hand washing sink drains.



Appendix (9) : The injected patient waiting area and hand washing sink .



Appendix (10) : The radionuclide store and waste management store.


الحمد لله