Sudan University of Science and Technology

Faculty of graduate studies

Assessment of Radiation Protection Implementation Measures of Nuclear Medicine Departments in Sudan

تقييم تطبيق إجراءات الوقاية الإشعاعية في مراكز الطب النووي في السودان

The thesis submitted for partial fulfillment of the requirements of master Degree in medical physics

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الآية الكريمة

قال تعالى:

{قَالُوا سُبْحَانَكَ لَا عِلْمَ لَنَا إِلَّا مَا عَلَّمْتَنَا إِنَّكَ أَنتَ الْعَلِيمُ الْحَكِيمُ{32}

صدق الله العظيم

سورة البقرة الآية (32)

Dedication

To my parents who taught me what life,

To my sisters who gave me all types of supports

To my brothers whom continuous support for me,

To my teachers who taught and guided me through my education journey,

To any person met in this time of research and helped me

To all my lovely friends

Acknowledgment

Firstly and before anything I thank the almighty Allah

For helping me to complete this research and I would to express my gratitude and appreciation to me, supervision **Dr. Salah Ali Fadallalah**

I thank him for all the assistance and faithful advice my appreciation to extends to the medical physics department under study .

مستخلص

اجريت هذه الدراسة في عدد من مراكز الطب النووي في السودان في الفترة من (يناير 2020 – اكتوبر 2020م) بهدف تقييم تطبيق اجراءات الوقاية الإشعاعية في عدة جوانب، من حيث تصميم مبني المركز، تطبيق أجراءات الوقاية الإشعاعية للعاملين والمرضي، توفر الأجهزة والصيانة الدورية لها، تطبيق برامج ضبط الجودة.

تم إجراء هذه الدراسة في ثلاث مراكز ، اثنان في ولاية الخرطوم وأخر في ولاية نهر النيل.

خلص البحث الي التوصل الي النسب المئوية لتقييم تطبيق اجراءات الوقاية الإشعاعية في كل جانب، من حيث التصميم بنسبة (62.4%) ، تطبيق اجراءات الوقاية والامن (72,73%)، تعاون الإدارة مع العاملين لتطبيق اجراءات الوقاية (81,16%) ، توفر الأجهزة والصيانة الدورية لها (55,88%)، وضع الخطط والتأهب للطوارئ (83,33%) وتطبيق اجراءات التعرضات الطبية (78,21%).

خلص البحث إلى عدد من التوصيات، ضرورة الإهتمام بالبرامج التثقيفية لعامة الجمهور عن الوقاية الإشعاعية، ضرورة توفر أجهزة الرقابة الشخصية والمسحية في المراكز، زيادة الإهتمام بالأجهزة وتوفر الصيانة الدورية لها، ضرورة توفر التدريب العملي للطلاب التشجيع لإجراء بحوث علمية في برامج الحماية من الإشعاع.

Abstract

This study was done in number of nuclear medicine center in Sudan from January 2020 to October 2020, to assessment implementation of radiation safety measures in various aspects.

The designing for building, radiation safety measures for workers and patients, availability of devices, periodic maintenance and implementation of the quality programs.

The study was done in three center, two centers in Khartoum state and one in River Nile state.

The research concluded to reach percentage of assessment the implementation safety measure , the design of the building (62.04%), safety and security procedures (72.73%) management cooperation with workers (81.16%), availability of devices and maintenance (55.88%), emergency preparedness (83.33%) and implementation of medical exposure measures (78.21%).

The researcher concluded to these recommendation the interest cultural programs in radiation safety for general public, the necessity and availability of personal monitoring devices for workers and survey meter in the center, increase attention to the devices and provide periodic maintenance, necessity of providing training during the study and encourage students to will do practical research in radiation safety programs.

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List of abbreviation

Abbreviation	Meaning
NM	Nuclear medicine
DNA	Deoxy ribo nuclide acid
MDP	Methylendiphosphatnate
TC^{99}	Technetium -99
NAI	Sodium iodite
CSF	Cerebro spinal fluid
SPECT	Single Photon emission computed tomography
PET	Positron emission tomography
FDG	Fluro deoxy glucose
CT	Computed tomography
MCI	Millicuri (unit)
LET	Linear energy transfer
RNA	Ribonucleic Acid
RBE	Relative biological effectiveness
OER	Oxygen enhancement ratio
SER	Sensitization enhancement ratio
DRF	Dose reduction factor
ICRP	International commission on radiological protection
ICRU	International commission of radiological unit
ET	Extra thoracic
IOS	International Organization for Standard
ISL	Inverse square law

HVL	Half – value layer
TVL	Tenth value layer
BSS	Basic safety standard
MSV	Milli sisvert(unit)
TLDS	Thermoluminscent dosimeters
QA	Quality assurance
IAEA	International Atomic energy Agency
RPO	Radiation protection officer
RPA	Radiation protection adviser

Chapter one

Introduction

1.1 Introduction:

The nuclear medicine (NM) and also known as undid imaging is to application of radionuclide techniques to the diagnosis and treatment of disease. [Royp, Peter, David, 1984].

The nuclear medicine is the use of sealed or unseeded sources in one of these three fields diagnosis, therapy or biomedical research, and the materials used are called radiotracers or radio pharmaceutical. [Royp, Peter, David, 1984].

Techniques employ in under medicine were known from prior the second world war, when used radioiodine for the investigation of thyroid diseases, also implanted radium .

226 for the treatment of tumors [Royp, Peter, David, 1984].

Contemporary clinical radionudide methods where divided broadly into three groups, the largest division was described as diagnostic procedures such as organ imagining aradiouncide is a suitable chemical form is administered to the patient and the distribution of radioactivity in the boy is determined these techniques were produced simple image of an organ or the while body , also will been yield information on the function of some organ for example the thyroid gland or the kidneys.

The radiopharmacetuicals used in diagnostic has short – half lives, a round six hours to eight days and emit gamma rays, so it isn't remain in the patient body after examination long period. (Roy P – Peter David, 1984].

The second division of nuclear medicine, is the therapeutic procedures, it was used sealed sources and a certain forms of radionuclide.

The nature and amount of the radio nuclides employed for therapeutic use present a more significant radiation hazard than those used in diagnostic procedures.[Royp, Peter, David, 1984].

The third division of nuclear medicine, it used in biomedical research to investigation from DNA sequencing, protein labeling and detection, the most radionuclides for research have much long half-lives than ones it used in diagnostic procedures. [Royp, Peter, David, 1984].

The radio pharmaceutical introduce into the body typically injected into the blood stream in haled or swallowed, it after that undergoes to decay and generate gamma rays, which are detected by special camera outside the body and computer to create images of happen in the body. [Gopal B.Saha. 2003].

The development of equipment and computer power has led to an increasing use of tomographic techniques, single photon emission tomography (SPECT) imaging using conventional radio nuclides like TC^{99m} is less expensive than positron emission tomography (PET). [K.miles, p.Dawson, M.Blomley, 1997].

The position emission tomography (PET) was provided quantitative, locational, functional, and biomedical information that would be difficult to obtain by other modalities. Recently sprouted other modalities of imaging have been able to anatomical and functional information in one examination, such as double-headed gamma camera and CT or PET camera and CT. [Gopal. B Saha, 2003) .

Also The development of radiopharmaceuticals such as labeled monoclonal antibodies and peptides is continuing to expand the range of application of nuclear medicine and to extend its role in diagnosis and therapy. [Gopal. B Saha, 2003) .

1.2 problem of study:

Protection procedures in nuclear medicine departments in Sudan are inadequate, and most protective procedures are not consistent with international standards, and there is little literature in this topic in Sudan, to the best of the researcher's knowledge.

(1-3) objective of the study:

(1.3.1) General objective

The main objectives of the study is to assessment radiation protection status in the number medicine departments in Sudan.

(1.3.2) the specific objectives:

1. Assessment of designing centers.
2. Assessment of monitoring
3. Assessment of safety operation management .
4. Assessment of quality assurance.
5. Assessment of quality assurance.
6. Assessment of emergency preparedness
7. Assessment of medical exposure.

(1-4) Place and duration of the study:

This Study was conducted at three nuclear medicine departments in Sudan, namely Radiation and Isotopes Center Khartoum (RICK).

El-MAK NIMR UNIVERSITY HOSPITAL AND NLEIN MEDICAL DIAGNSTIC CENTER during the period from January 2020 to October 2020.

Chapter two

Literature Review

2-1 Introduction:-

2-1-1The radiation:-

The radiation is an emission or transmission of energy in the form of waves or particles through space or through a material medium.

The radiation is classified into two types, ionizing radiation and non-ionizing radiation.

The ionizing radiation has sufficient energy to produce ions in mater at the molecular level, because it has higher energy and short wavelength while the non-ionizing radiation dose not has sufficient energy to remove electrons from atoms and molecules, because it is longer wavelength and lower frequency.

Ionizing radiation is produced by unstable atoms, it has not enough binding energy to hold the nucleus together permanently and this is called radioactive atom which it is arise from unbalance of proton and neutrons in a nucleus these are unstable atoms reach to stable atoms by losing the excess of energy may be it forms alpha, beta particles or gamma rays. [Health physic Society, 2016]

2-1-2 Radioisotopes:

The atom of an element always has the same number of protons but different in the number of neutrons.

Radioactive isotopes or radioisotopes are isotopes of an element having an unstable nucleus that decays (emitting alpha, beta or gamma rays) until Stability is reached, the stable end product is a non-radioactive isotope of another element. [Health physic Society, 2016].

Radioactive isotopes have many useful applications, in medicine uses cobalt 60 is extensively employed as a radiation source to arrest the development of cancer, other radioactive isotopes are used as tracers for diagnostic purpose as well in research on metabolic processes.[Angela N.H. creager,2014]

2-2 The biological effects of radiation:-

2-2-1 the effect of radiation on cells at atomic level:-

Ionizing radiation impinges on biological systems; energy is transferred into the system according to fundamental physical principles.

The energy deposited results in ionization or excitation.

The ionization occurs when alpha or beta particles or gamma photons transfer sufficient energy to remove one of the electrons from the target atom.

Each ionization event produces an ion pair consisting of free electron and the positively charged remainder of the atom.

The ionization is the basic mechanism to trigger the events that cause radiation damage to living tissues, and this mechanism either direct or indirect action. [Daniel,Grosch,1979].

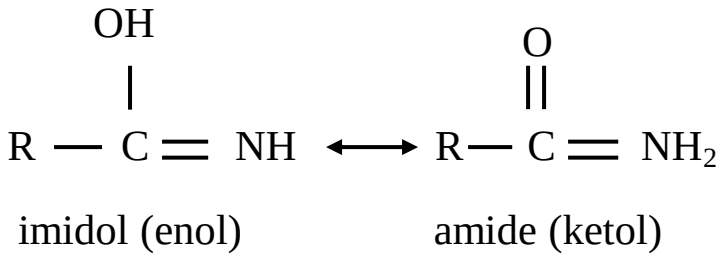
2-2-1-1The direct action:-

The direct action damage occurs as a result of ionization of atoms in key molecules in the biological system, and this causes inactivation or functional alteration of the molecule, and the Absorption of energy sufficient to remove an electron can result in bond breaks.

$$\text{ionizing radiation} + Rh^{-} \longrightarrow R + H^{+}$$

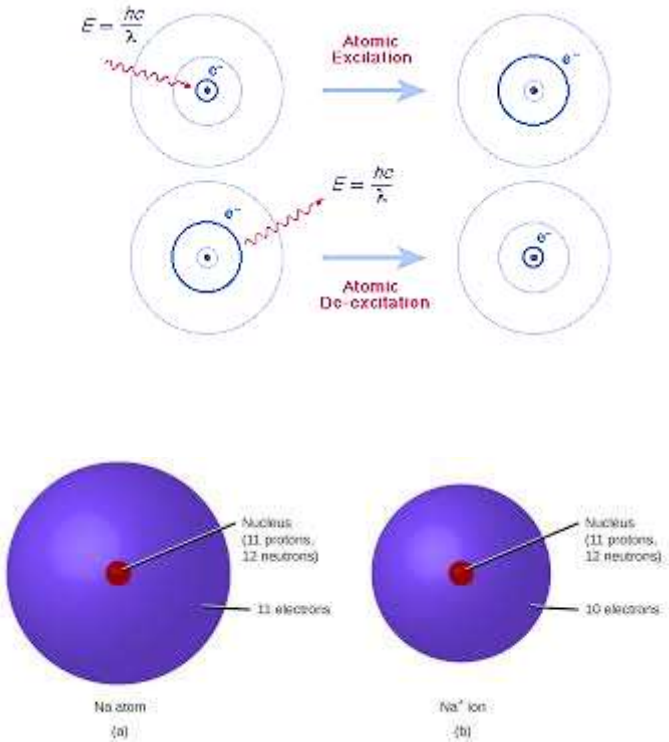
Excitation of atoms in key molecules can also occur, resulting in bond breaks; in this case, energy can be transferred along the molecule to aside of bond

weakness and cause a break, also tautomeric shifts can occur where the energy of excitation can cause predominance of one molecule form.



imidol (enol) amide (ketol)

The imidol and amide are tautomers in equilibrium with the amide (ketol) predominate, and in the amide from the molecule reacts in the proper biochemical chain.



The figure explain direct-action damage and indirection damage to DNA

The introduction of excitation energy shifts the equilibrium to the imidol (enol), this causes either no reaction or misread.

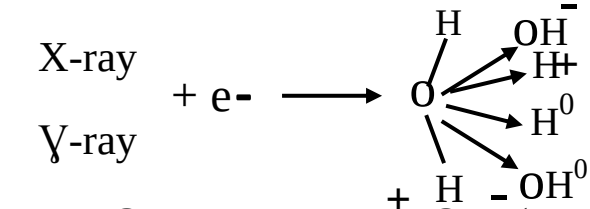
The direct effect is the predominant cause of damage in reactions involving high "LET" radiation such as alpha particles, neutrons and heavy ions in the active site of an enzyme in the chain. [Daniels Grosch,1979].

2-2-1-2 Indirect action:-

Indirect action involves the in the production of reactive free radicals whose toxic damage to the key molecule has biological effect.

And it involves the transfer of energy to an atom with a subsequent "decay" to free radical species, a free radical is an electrically neutral atom with an unshared electron in the orbital position.

The radical is electrophilic and highly reactive, and the predominant molecule in biological systems is water, it is usually the intermediary of the radical formation and propagation



$$H - O - H \longrightarrow H^{+} + OH^{-} \text{ (ionization)}$$

$$H - O - H \longrightarrow H^{0} + OH^{0} \text{ (free radicals)}$$

Free radicals readily recombine to electronic and orbital neutrality; orbital neutrality can be achieved by hydrogen radical dimerization (H_2) and the formation of toxic hydrogen peroxide (H_2O_2), also can be transferred to an organic molecule in the cell.

$$H^{0} + OH^{0} \rightarrow HOH \text{ (recombination)}$$

$$H^{0} + H^{0} \rightarrow H_2 \text{ (dimer)}$$

$$OH^{0} + OH^{0} \rightarrow H_2O_2 \text{ (hydrogen peroxide)}$$

$$OH^{0} + RH \longrightarrow R^{0} + HOH \text{ (radical transfer)}$$

The oxygen can modify the reaction by enabling creation of other free radical species with greater stability and longer lifetimes.

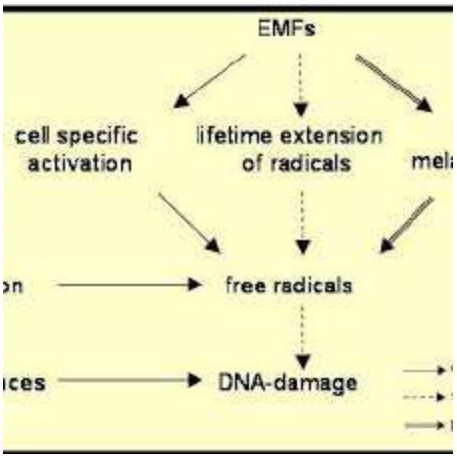
$$H + O2 \longrightarrow HO_2^{0} \text{(hydroperoxy free radical)}$$

$$R + O2 \longrightarrow RO_2^{0} \text{ (organic peroxy free radical)}$$

The transfer of the free radical to a biological molecule can be sufficiently damaging to cause bond breakage or inactivation of key functions; In addition,

the Organic Peroxy free radical can transfer the radical from molecule to molecule causing damage at each encounter, thus a cumulative effect can occurs greater than a single ionization or broken bond.

The indirect action is predominant with low LET radiation such as x and gamma rays. (Scala R.j.1994).



The figure above explain life time extension of radicals

2-2-2 Biochemical reactions with ionizing radiation:-

The primary target for cell damage from ionizing radiation is deoxyribonucleic acid (DNA), and the other type of nucleic acids found in living cells ribonucleic acid (RNA), they are complex macro molecules made of purine and pyrimidine bases on "a backbone "of alternating sugar and monophosphate molecules.

The bases are nitrogen ring compound adenine, guanine, cytosine, thymine and uracil. (3)

The carbohydrate sugar is either deoxyribose or Ribose, a fivecarbon sugars unique to nucleic acids.

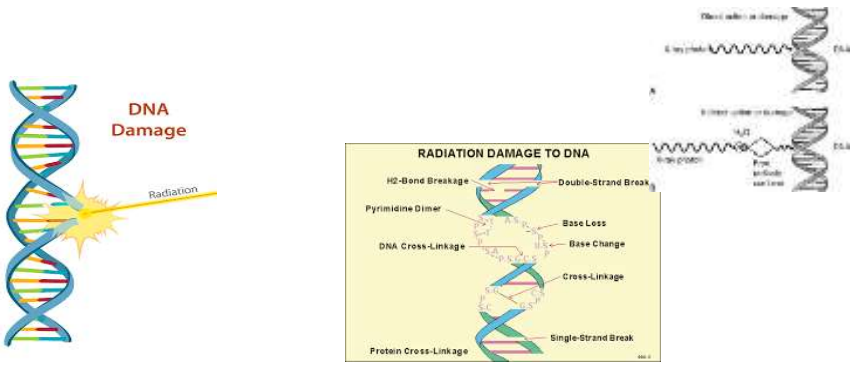
The types of radiation induced lesions in the DNA is a wide variety, and can range from complete breaks of the nucleotide chains of DNA, to point mutations which are essentially radiation induced chemical changes in the nucleotides which may not affect the integrity of the basic structure. [Daniel Grosh,1979].

The lesion considered the most likely to lead to chromosomal aberrations and cell death is double strand breaks, especially unrepaired breaks and two breaks that occur close together.

Residual unrejoined double strand breaks are lethal to the cell, whereas incorrectly rejoined breaks may produce important mutagenic lesions, in many cases this DNA misrepair apparently leads to DNA deletion and rearrangement, such large-scale changes in DNA structure are characteristic of most radiation induced mutations.

The toxic effects of low to moderate doses (cell killing, mutagenesis, and malignant transformation) appear to result from damage to cellular DNA.

Intermediate effects, such as abnormal bonding between adjacent molecules and alteration in viscosity, have also been observed, the single strand DNA lesions do not seem to cause chromosome aberrations, because 90% of these lesions are repaired in less than one hour, even when caused by very high doses, DNA double breaks are the principal cause of chromosomal aberrations also radiation can cause structural aberrations where pieces of the chromosome break and form aberrant shapes like Dicentrics, translocation and acentric fragments. (Scala R.j.1994).



The figure explain damage of DNA

2-2-3 The effect of radiation on cell kinetics:

The cell cycle is the generation time from one cell division to the next, and it is dependent on species, tissue type, age and environmental influences.

The cell cycle can be divided into phases G_1 (gap), S (synthesis), G_2 (gap) and

M (mitosis).

All living cells fit somewhere into the cell cycle, non-dividing cells usually remain in the G_0 phase their entire lives.

Cells of rapid cell renewal system however are continuously cycling and producing new cells in order to maintain the homeostatic function of the body. (Daniel Grosch, 1979).

The cell going through the division phase (M) is generally the most sensitive to ionizing radiation injury, exceptions, however are lymphocytes and some bone marrow stem cells, which exhibit interphase death, and these cells are destroyed by very low doses of radiation even when they are in the dividing phase. (Daniel Grosch, 1979).

2-2-3-1 Radio sensitivity of cell in cell cycle:

The cell is most vulnerable to cell killing during the period shortly before the M phase at late interphase (G_2), and during the M phase.

Greater resistance is seen in cells in the S phase and late G_1 phase and in the $G_{0.}$

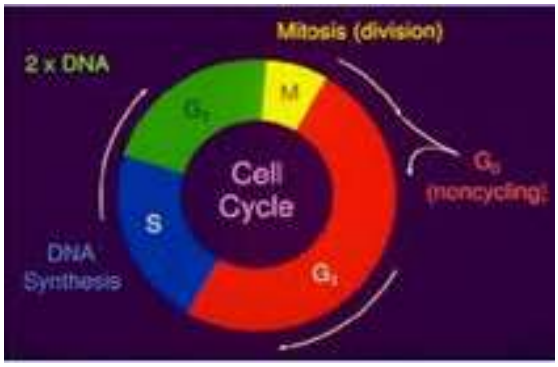
Due to the presence of synthetic enzymes capable of prompt repair of DNA, repair breaks, Mutation frequency increase in cells in or just before the S phase.

Mitosis delayed or inhibited after radiation exposure, dose dependent inhibition of mitosis is particularly common inactively proliferating cell systems, and this inhibition occurs approximately 40 minutes before the prophase in the mitotic

cycle, at a time when the chromosome discrete but prior to the breakdown of the nuclear membrane.

Subsequent irradiation after this radiation transition point does not delay mitosis; delay in mitosis can cause profound alterations in cell kinetic patterns resulting in depletions of all populations.

Irradiation of the cell causes cell death at mitosis as a result of the inability to Divided the unequal division of nuclear chromatin material between daughter cells may result in the production of non-viable abnormal nuclei. (Daniel Grosch, 1979).

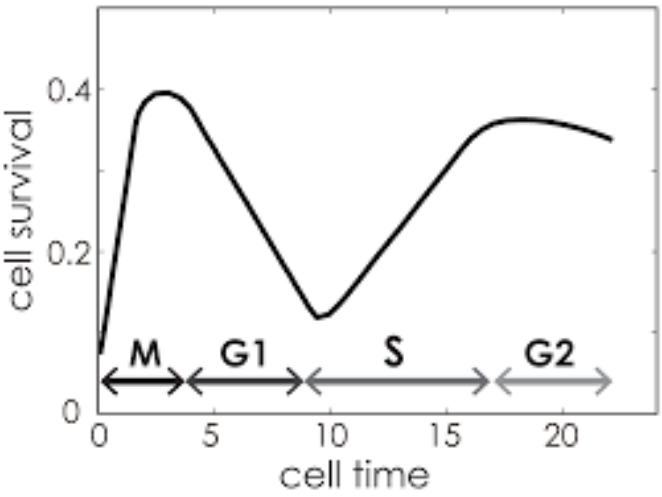


The figure represented the effect of radiation on cell kinetics

2-2-3-2 Bergonie and Tribondeau laws:

According to the Bergonie-Tribondeau law (1960), the Radio sensitivity of tissues depends on a high number of undifferentiated cells in the tissue, a high number of active mitotic cells, and the length of time the cells remain inactive proliferation, the greater their sensitivity to radiation.

In many cell types, radiation induced damage results in cell death only if the cell goes into mitosis, but in some cell types, such as Lymphocytes and Oocytes at certain stages of development, death occurs in interphase most probably due to radiation induced membrane damage. (Daniel Grosch, 1979).



The figure above represented curve of cells survival and cell times

Biological membranes serve as highly specific mediators between the cell and the environment, radiation changes within the lipid bilayers of the membrane may alter ionic pump and this lead to change in the viscosity of intracellular fluids associated with disruptions in the ratio of bound to unbound water ,other changes in an impairment of the ability of the cell to maintain metabolic equilibrium.

Also alterations in the proteins that form part of a membrane structure can cause changes in permeability to various molecules, the ionizing radiation also playing a role in plasma membrane damage, which may be an important factor in cell death.

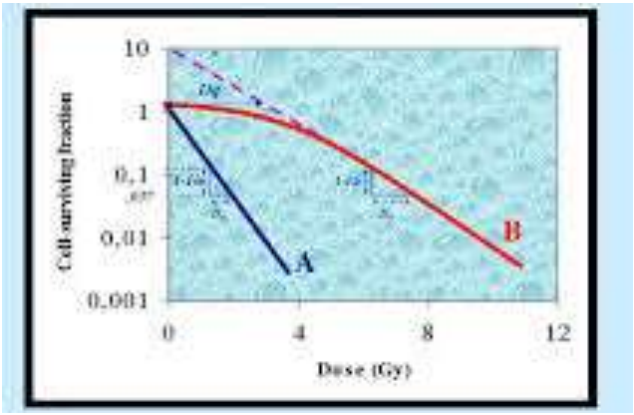
In modification of radiation injury, there are several environmental factors, which in general modify the degree of damage due to radiation; physical factors include dose rate and fractionation, radiation quality, and temperature, also find several chemicals can modify the radiation effect. (Daniel Grosch, 1979).

The lower rate of delivery of radiation dose and the more time between radiation exposures, the more resistance the biological system becomes.

In the DNA, a single broken bone can repaired, but a breakage of both strands has been often irreparable, and repair is possible if the two breaks occur for apart in time, or at different ends of the DNA molecule.

Radiation quality or densely ionizing or high linear energy transfer radiation such as alpha particles, neutrons and heavy charged particles are more effective in the induction of chromosome aberrations and killing than sparsely ionizing or linear energy transfer (LET) radiation, such as X and gamma rays.

The increase in the relative biological effectiveness (RBE) for cell killing with increasing LET is largely attributable to the reduction in repair. (Daniel Grosch, 1979).



The figure represented survival curve for mammalian cells high (A) and low let (B) radiation

Survival curves above for both high and low LET radiations appear to be exponential.

The slopes of the curves are steeper in the case of high LET.

The cell survival curves with lines exposed to low LET radiation show a shoulder that is attributed to the capability for repair.

Also the temperatures, while many cells at higher temperatures are sensitized to radiation damage, several chromosome aberrations increase at lower temperatures, this is due to the suppressions of the repair process at low temperatures.

For cell killing effects, tissues of higher temperatures are more radiosensitive (Daniel Grosch, 1979).

The chemical factors can modify the radiation effect dissolved oxygen in the tissues increase the stability and toxicity of free radicals.

The degree by which the effect is increased as a result of oxygenation is called the oxygen enhancement ratio (OER) and is determined by:

$$\text{OER} = \frac{Dose\ required\ to\ cause\ effect\ without\ oxygen}{Dose\ required\ to\ cause\ effect\ with\ oxygen}$$

The OER has maximum value of 3.0.

Other chemical factors can increase the damaging effects of radiation analogues of purines and pyrimidine's have this effect halogenated and substituted analogues of the DNA bases can interfere with DNA repair after radiation damage.

Actinomycin D inhibits nuclear RNA synthesis and potentials radiation damage nitroimidazoles are electron affinic compounds that increase Radiosensitivity of cells with a sensitization enhancement ratio (SER) of 1.2 to 1.4 where :

$$\text{SER} = \frac{Dose\ required\ to\ cause\ effect\ without\ agent\ present}{Dose\ required\ to\ cause\ effect\ with\ agent\ present}$$

Other agent, radioprotective agents are chemicals able to diminish the effect of radiation.

The dose reduction factor (DFR) measures this protection and is derived from:

$$\text{DRF} = \frac{Dose\ to\ cause\ effect\ with\ protector\ present}{Dose\ to\ cause\ effect\ without\ protector\ present}$$

Thiols are sulphur containing reducing agents such as cysteine,2-mercaptoethylamine, cysteamine, and thiourea; Thiols have a DER ratio of 1.4 to 2.0.

They are thought to protect cells by scavenging free radicals, producing hypoxia and forming disulphide bonds in proteins, thereby strengthening them.

They also temporarily inhibit DNA synthesis, allowing time for the repair enzymes to complete repair of sublethal damage. (Daniel Grosch, 1979).

2-2-4 The classes of radiation injury:

A radiation – induced biological effects are divided into two main classes somatic and hereditary effects.

2-2-4-1 Somatic effects: Arise from damage to the ordinary cells of the body resulting from the depletion of the numbers of mitotic dividing, also may be from interference with the processes of cell division, and it falls into two classes, the acute effects and the long – term effect.

2-2-4-1-1 acute effects: Acute damage is most likely to occur in those cells which are undergoing very rapid cell division, the doses are relatively large and observed within a few days or weeks after exposure.

The acute effect happens with doses greater than about 25rads (0.25Gy), the lymphocyte count in the peripheral blood falls rapidly.

The lymphocyte count begins to rise again after a few days in fairly small doses, but full recovery may take some months, and it is a useful indicator of the radiation dose received over the range of 25 to 400 rads of whole body exposure, but in the doses is very large greater than 400 rads to a few cells survive to permit accurate counting.

The platelet count and the red blood count in the peripheral blood also fall a few days after exposure and recover in the radiation doses received is not large. (Daniel Grosch, 1979).

The monitoring of the red and white blood cell counts provides useful information on the severity of, and a pattern of recovery from radiation exposure.

Blood counts are used extensively to monitor patients undergoing radiation therapy and also in the surveillance of persons occupationally exposed to serious risk of radiation injury at higher doses of radiation 400 – 600 rads of X and gamma rays, Observed the sequence of symptoms also temporary or permanent sterility produced by exposure to acute irradiation as a result of damage to the germ cells in the gonads.

The severity of the symptoms observed following exposure to a large dose of radiation appears to show wide individual variations.

Exposed to doses of around100 rads about 15% of exposed person would show some of the symptoms, but at 200 rads almost all the exposed individuals would

exhibit symptoms and a few deaths, and the death rate would rise to 50% after exposure to doses of 450 to 500 rads.

Exposed to radiation dose in excess of 1000 rads to the whole body are likely to cause death within three to five days as a result of gross destruction of the cells lining the gastrointestinal tract, exposure to doses of between 500 and 1000 rads the death happen after about two weeks due to secondary infections result from severe damage to the immune system. (Daniel Grosch, 1979).

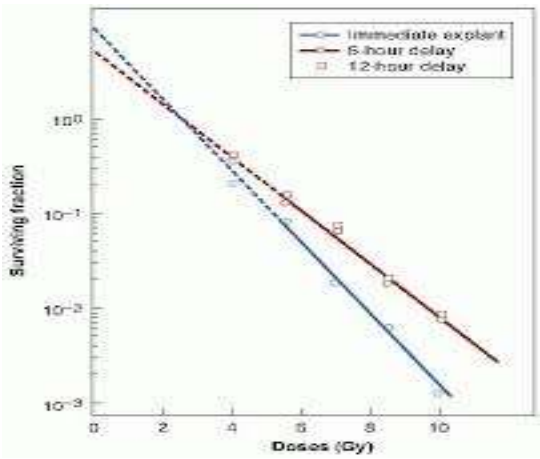
Table "1":

Time	Symptoms
0 – 48 hours	Loss of appetite, nausea, vomiting, fatigue, and lethargy.
2 days to 2 – 3 weeks	Recovery from these symptoms, the patient appears quite Good
2 – 3 weeks to 6 – 8 weeks	Purpura, haemorrhages, diarrhoea, loss of hair, fever, severe lethargy, some deaths may occur.
6 – 8 weeks to several months	Recovery stage, surviving patients show general Improvement and severe symptoms disappear.

The table above represented the relation between symptoms and time

The severity of the biological effects observed varies with the rate at which the radiation is received, the dose – rate, and the type of radiation to which the organism is exposed also the effects vary with proportion of the total body, or the specific organ which is irradiate.

The figure represented curve explain Dose (GY) and surviving factor.



2-2-4-1-2 Long – term effects:

The biological effects of radiation, which arise a long time after the radiation dose is received, include the induction of leukaemia and other types of cancer, cataract formation, and life shortening.

The long – term effects happen with, exposed to radiation doses much lower than those which will produce the acute effects.

Cancer induction requires periods ranging from about 7 to 30 years to become apparent but cataract formation appears to occur after a period of 5 to 10 years, and the threshold dose of cataract formation is 400 rads below this cataract are not seen. (Daniel Grosch, 1979).

2-2-4-2 Hereditary effects of radiation:

The hereditary effects of radiation arise from radiation-induced mutations, which occur in the egg cells, or ova in the ovary of the female, or the sperm cells of the testis in the male.

The most genetic damage will probably result in embryonic or fetal death, however, some maybe non lethal and permit the birth of a viable child suffering from severe abnormalities of one type or another, so in all medical investigations involving radiation care is taken to avoid any unnecessary irradiation of the gonads of either the patients or the investigators.

Irradiation of the pregnant female causes serious damage to the developing embryo or fetus lead to serious abnormality in the offspring, a variety of defects have been observed including mongolism, hydrocephalus, microphthalmia and limb malformation.

The risks of damage to the embryo are greatest during the first two months of pregnancy and gradually decrease at later times, the risks of intra – uterine death

or severe malformation are probably greatest during the first 38 days of pregnancy that is during the pre – implantation stage up to day 11 and the period of organogenesis.

The women are possible a fertile and not be aware that, she is in the early stages of pregnancy when she attends for a radiographic or radionuclide investigation and this is called ten – day rule and this is must be introduced into clinical practice particularly of the abdomen and pelvis, and the dose induced effects on embryo around 20 rads and more. (Daniel Grosch, 1979).

2-3 The detectors use in nuclear medicine:

The ionizing radiation impossible to smell, see, taste, therefore on having to develop detectors to replace the missing capability to see, smell, and taste.

The necessity for the measurement of radiation exposures originates from the fact that type of radiation has to be surveyed, controlled, and limited.

Human also have limitation to be protected against unexpected exposures.

On the one hand, of the radiation exposures surveillance of radiation – exposed worker, the measurement of external radiation exposures, contamination and incorporations, in particular, in working areas is very important.

Single – photon emitting or positron – emitting radionuclides employed in nuclear medicine are detected by using sophisticated imaging devices, whereas simpler detection devices are used to quantify activity for the following applications: measuring doses of radiopharmaceuticals, performing radiotracer bioassays, and, monitoring, controlling radiation risk in the clinical environment.

The detectors are categorized in terms of function, the physical state of the transducer, or the mode of operation. (Ta Pank. Gupta,2013)

The performance of detector is described by the parameters efficiency, energy resolution and discrimination, and dead time.

A detector may be used to detect single events (pulse mode) or to measure the rate of energy deposition (current mode).

Some detectors operate as simple counting systems by using a single – channel pulse height analyzer to discriminate against background or other extraneous events.

Other detectors are operated as spectrometers and use a multichannel analyzer to form an energy spectrum.

The types of detectors encountered in nuclear medicine are gas – filled detectors, scintillation detectors, and semiconductor detectors.

The ionization detector, Geiger – Muller detector extremity and area monitor, dose calibrator, well counter, thyroid up take probe, anger scintillation camera, positron emission tomographic scanner, solid-state personnel dosimeter, and intra operative probe are examples of detectors used in clinical nuclear medicine practice. (Ta Pank. Gupta,2013)

2-4 Radiation protection dose quantities:

The ionization process is the primary event which finally can result in a biological effect.

Define a physical quantity that gives the absorbed energy per unit mass, it could be used to give the relation to the risk of biological damage.

In the field of radiation dosimetry and radiation protection, two organizations are active:

- ICRP works with assessments of the biological effects and provides recommendations and guidance.

- ICRU working with the physical aspects of dosimetry.

The quantities are linked to radiation exposure risks, and there are two types of quantities defined for specific use in radiation protection:

- Protection quantities defined by the ICRP.
- Operational quantities defined by the ICRU.

Protection quantities are mean absorbed dose in tissues or organs, equivalent dose in tissues or organs, and effective dose. (Soren Mattsson. Christ. Ophttoeschen,2013)

2-4-1 Absorbed dose of organs and tissue is a quantity related to tissue reaction (deterministic) effect, but equivalent dose, effective dose is quantities related to stochastic effects.

The mean absorbed dose in a specified tissue or organ T is given the symbol D_T.

The absorbed dose is equal to the ratio of the energy imparted ε_T to the tissue or organ to the mass (m_T) of the tissue or organ thus:

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

The unit of absorbed dose is a gray, which equally absorbed energy per mass unit.

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

1Gy is a relatively large quantity, in radiotherapy doses greater than 1Gy, but dose from nuclear medicine examination typically (0.05-0.001Gy).

2-4-2Equivalent dose:

The equivalent dose, HT to an organ or tissue for a type of radiation R is the product of radiation weighting factor W_R for radiation R and the organ dose D_T

$$\text{thus:} \quad H_T = W_R D_T$$

and the unit is a sievert (sv).

W_R allows for differences in the relative biological effectiveness of the incident radiation in producing stochastic effects at low doses in tissue or organ T(E.B.Podorsak,2006)

Table No (2):

Type and energy range	Weighting factors (W_R)
Photons : all energies	1
Electron : all energies	1
Neutrons : energy < 10Kev	5
Neutrons : 10Kev to 100Kev	10
Neutrons : >100Kev to 2Mev	20
Neutrons : 2Mev to 20Mev	10
Neutrons : >20Mev	5
Protons : 2Mev	5
Alpha particles, Fission fragments, Heavy nuclei	20

The table above represented the relation between type and energy range with weighting factors.

2-4-3 Effective dose:

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

$E = \Sigma W_T H_T$

W_T for organ T represents the relative contributions of that organ to the total detriment arising from stochastic effects for uniform irradiation of the whole body, the effective dose measured by unit sievert (sv). (Soren Mattsson. Christ. Ophttoeschen,2013)

Table No (3):

Tissue	W_T	ΣW_T
Bone-marrow, breast, colon, lung stomach, remainder tissues (14)	0.12	0.72
Gonads	0.08	0.08
Bladder, oesophagus, liver, thyroid	0.04	0.16
Bone surface, brain, salivary glands, skin	0.01	0.04

The table above represent effective dose of tissue.

Reminder tissues include: Adrenals, Extrathoracic (ET) region, Gallbladder, Heart, Kidneys, Lymphatic nodes, Muscle, Oral mucosa, Pancreas, Prostate (M), small intestine, Spleen, Thymus uterus / cervix (F).

The effective dose (E) is a risk–related quantity and should only be used in the low–dose range, not for the assessment of the possibility of tissue reactions, and the primary use to demonstrate compliance with dose limits, also in regulations for prospective planning of radioprotection.

Also the effective dose (E) can be of value for comparing doses from different diagnostic procedures, similar procedures in different hospitals and countries, and different technologies for the same medicine examination. (Soren Mattsson. Christ. Ophttoeschen,2013).

2-4-4 Collective dose:-

The total equivalent dose or effective dose to a certain population, such as all patients in a nuclear medicine department, all staff in the department, or the whole population in a country and it measures by 1 man sv.

The effective dose (E) and equivalent dose (H) are not measurable quantities, in radiation protection dosimeters are used in areas and individual monitoring.

To can measurable effective dose (E) and equivalent dose (H) to some tissue or organ, we need to use the concept of operational quantities.

The different operational quantities are necessary to relate, field doses (air kerma, absorbed dose, fluence) to dosimeter doses. The effective dose and the equivalent dose values are determined by a radiation monitor using operational quantities.

Operational quantities are intended to serve as surrogates for the protection quantities, can measure in the field to provide good estimates of the protection quantities under specified exposure conditions, exposure conditions, and the based on dose equivalent at a point in a phantom or in the body.

For radiation measurement purpose, find some of operational quantities, ambient dose equivalent, directional dose equivalent, and personal dose equivalent.

The doses are estimated from area monitoring results, the relevant operational quantities are:

- Ambient dose equivalent H* (d).
- Directional dose equivalent H* (d, Ω).

The doses for individual monitoring, has recommended the use of the personal dose equivalent H_P (d). All three quantities are defined using tissue–like objects to simulate radiation interaction properties of tissue. (E.B.Podorsak,2006)

2-4-5 Ambient dose equivalent:-

The ambient dose equivalent H*(d), at point is the dose equivalent that would be produced by the corresponding field, and in the ICRU sphere at a depth d in (mm) on the radius opposing the direction of the field, for measurement of strongly penetrating radiation, the reference depth is (10mm) and the quantity denoted as H*(10) and the unit is Joule per Kilograms, and the special name for the unit is the Sievert (sv).

2-4-6 Directional dose equivalent:-

The directional dose equivalent H (d , Ω), at a point is the dose equivalent that would be produced by the corresponding expanded field in the ICRU sphere at a depth (d) on a radius in a specified direction (Ω). And use in the assessment of dose to the skin or eye lens. And the unit is Joule per Kilogram, and the special name for the unit is the Sievert (sv).

2-4-7 Personal dose equivalent:-

The personal dose equivalent H_P (d) is the dose equivalent in soft tissue at an appropriate depth (d), below a specified point on the body.

H_P (d) can be measured with a dosimeter, which is worn at the surface of the body and covered with an appropriate thickness of tissue – equivalent material, the unit is Joule per Kilogram, and special name for the unit is the Sievert (sv).

H_P (10) measured at a depth of (10mm) in soft tissue, is the operational surrogate for the effective dose (E). (Soren Mattsson. Christ. Ophttoeschen,2013)

2-2 The radiation protection programs:-

The objectives of radiation protection for the prevention of deterministic effect, and limiting the probability of stochastic effect.

We need to apply radiation protection to all dose levels, because it is generally assumed that even very small doses of ionizing radiation can potentially be harmful, biological damage is directly proportional to the dose, and radiation is always considered harmful with no safety threshold.

To protect the people taking into account the main objectives of radiation protection and the system of protection, it should be based on individual and source related system.

The system of protection establishes that no individual shall be exposed as a result of controlled sources and practices in excess of the dose limits set by the standards, also it takes into account the sum of all doses delivered by the source regardless of location and time of the exposure, also in the system of protection, limitation on source achieve by shielding, protective clothing.

The system of radiological protection is defined by the international commission on radiological protection (ICRP), and nongovernmental professional

organization established in 1928 by the international congress of radiology.(IAEA, ICRP,2007)

The ICRP publication 103-200, its recommended system of radiation protection is based upon three principles:

2.2.1 Principles of radiation protection:-

- ***Justification of practice:*** It means that any exposure produces a sufficient benefit to offset the radiation harm that it might cause, therefore if the exposure has not any benefit, it is not justified.
- ***Optimization of protection and safety principle:*** it means doing the best you can under prevailing conditions, and radiation exposure should be limited as low as reasonably achievable(ALARA),this we need to be familiar with techniques and options to optimize the application of ionizing radiation, and must take into account the resources available, this includes economic circumstances and should be include the criterion. The concept of as low as reasonably achievable refer to the continual application of the optimization principle in the day-to-day practice. (IAEA, ICRP,2007)
- ***Dose limitation:*** the normal exposure of individuals shall be restricted so that neither the total effective dose nor the total equivalent dose to relevant organs or tissues, caused by the possible combination of exposures from authorized practices, exceeds any relevant dose limit, except in special circumstances. (U.N, C, H,C,2004)

  The objective of practical radiation protection, when radiation is justified, how do we optimize the exposure and do not exceed dose limits, we found in basic radiation protection strategies for hazard reduction methods, and there are three cardinal points (time , distance and shielding).

1- ***Time:*** because obviously the shorter the time of exposure the less the dose received, procedures should be practiced with inactive materials, and all operations with radioactive sources should be carried out as rapidly as inconsistent with the satisfactory and safe performance of the task. The dose is proportional to the time exposed:

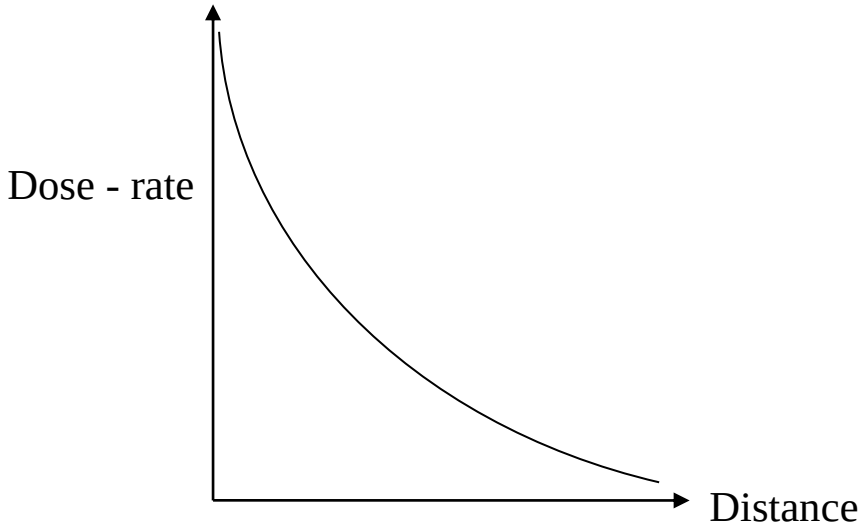
$$Dose = Dose - Rate \times Time$$

From the above equation, we can find the stay time with radiation sources or contact without the dose exceed the dose limit permissible.

$$Stay\ time = \frac{limit\ (mrem)}{Dose - Rate(mrem/hr)}$$

2- ***Distance:*** because the radiation intensity decreases by the square of the distance from the source, and this undergoes to Inverse square's law (ISL) the distances are very efficient for radiation protection as the dose falls off in square.(ICRP,2007)

$$Dose - Rate \propto \frac{1}{(Distance)^2}$$



the figure above explain the relation between dose rate and distance "inverse square laws"

3-Shielding: shielding with some materials which will absorb a large proportion of the radiation is necessary when the work cannot be carried out quickly enough or at such a distance that the radiation is reduced to an acceptable level.

The amount and type of shielding will depend on the type and intensity of the source, for x, and ɣ-rays we may need several centimeters of lead, because the photons is very penetrating, but high energy β particles will not be transmitted by the walls of a glass container. The bremsstrahlung will be produced with low efficiency with very active sources of penetrating radiation, such as an isotope generator it may be necessary to shield the source from all directions. The shielding easy to do during construction and typically thick shielding required in radiotherapy which cannot be incorporated in personal protection. .(ICRP,2007)

The shielding is based on the photon beam attenuation (μ), the linear attenuation coefficient (μ) describes the probability per unit path length that a photon will

have an interaction with the absorber, the most important parameter used for characterization of x-ray or gamma ray penetration into absorbing media and depend on the energy of the photon beam, atomic number (z) of the absorber.

$$I = I\, e^{-\mu X}_{0}$$

Where:

I_0 = is the initiation intensity.

I = is the intensity after time.

μ = is the linear attenuation coefficient (cm^{-1})

x = is the thickness of absorber.

Mass attenuation coefficient μ_m is the linear attenuation coefficient divided into the density of the material

$$\mu_m = \frac{\mu}{\rho}(cm^2/gm)$$

An interaction, such as photoelectric effect is called an absorbing process, and all interaction in which the x-ray photons are only partially absorbed such as the Compton effect is a scattering process, pair production, photodisintegration and classic scatter are scattering processes.

The total reduction in the number of x-rays remaining in an x-ray beam following penetrating through a given thickness of matter is called attenuation; they are reduced in number by a given percentage for each incremental thickness of the absorber.(Stewartc.Bushonge, 1993)

- Half-value layer (HVL) or $x_{1/2}$ the thickness of absorbing material needed to reduce the intensity by one half (50%) of it is original value.
- Tenth value layer (TVL) or $x_{1/10}$: is the absorber thickness attenuates the beam intensity to 10%.

The relationship between $x_{1/2}$ and $x_{1/10}$ is:

$$\frac{I}{I_0} = 0.5 = e^{-\mu X} = x = \frac{0.693}{\mu} = HVL_{\frac{1}{2}}$$

The table above represented nuclide gamma energy HVL, TVL and Linear attenuation coefficient (μ)

Nuclide	Gamma energy (kev)	HVL	TVL	Linear attenuation Coefficient (μ cm^{-1})
Tc^{99m}	140	0.03	0.10	23.1
Ga^{67}	89 – 389	0.10	0.33	6.93
I^{123}	156	0.04	0.13	17.3
I^{131}	364	0.3	1.0	2.31

The international commission radiation protection publication – 103 considers exposure to humans only, and in three categories (occupational, medical and public exposure).

2.2.2 Occupational exposure:

The term occupational exposure has been used by the ILO (international labor organization) to refer to the exposure of a worker that is received or committed during a period of work the BSS (basic safety standard) provides for the exclusion of those exposures whose magnitude or likelihood is essentially un amenable to control, and for the exemption of those practices and sources within a practice that give rise to radiation risk that are sufficiently low as to be of no regulatory concern in order that protective and preventive action can be focused and effective, the BSS give a more limited definition of occupational exposure, namely “all exposures of workers incurred in the course of their work, with the exception of exposures excluded from the standards and exposures from practices or sources exempted by the standards”. (IAEABss,1999)

2.2.2.1 Responsibilities:

The optimization of staff protection requires commitment by the management of the nuclear medical facility.

The protection of occupationally exposed individuals working in hospitals requires a rigorous organizational framework and a structure approach, this should be reflected in the local rules for each workplace, which must define safe systems of work.

A structured approach requires a prior evaluation of all aspects of practice with implications for the radiation protection program.

Successful implementation requires management commitment with a clear identification of responsibilities to establish objectives, authority to utilize sources and accountability of performance, responsibility in radiation protection affects, all members of the administrative system from the employing authority to the individual carrying out a nuclear medicine procedure. (IAEABss,1999)

The BSS state that:

(1.1) registrants and licensees and employers of workers who are engaged in activities involving normal exposures or potential exposure shall be responsible for :

(a) The protection of workers from occupational exposure, and

(b) Compliance with any other relevant requirements of the standards.

(1.2) Employers who are also registrants or licensees.

(1.3) Employers, registrants and licensees shall apply the requirements of the standards to any occupational exposure, from either human made or natural sources, which are not excluded from the standards. (IAEABss,1999)

(1.4) Employers, registrants and licensees shall ensure, for all workers engaged in activities that involve or could involve occupational exposure that:

(a) Occupational exposure is limited as specified.

(b) Occupational protection and safety be optimized in accordance with the relevant principle requirements of the standards.

(c) Decisions regarding measures for occupational protection and safety be recorded and made available to the relevant parties, through their representatives where appropriate, as specified by the regulatory authority.

(d) Policies, procedures and organizational arrangements for protection and safety be established for implementing the relevant requirements of the standards, with priority given to design and technical measures for controlling occupational exposures.

(e) Suitable and adequate facilities, equipment and services for protection and safety be provided, the nature and extent of which are commensurate with the expected magnitude and likelihood of the occupational exposure.

(f) Necessary health surveillance and health services be provided.

(g) Appropriate protective devices and monitoring equipment be provided and arrangements made for its proper use.

(h) Suitable and adequate human resources and appropriate training in protection and safety be provided, as well as periodic retraining and updating as required in order to ensure the necessary level of competence.

(i) Adequate records be maintained as required by the standards.

(j) Arrangements be made to facilities consultation and co-operation with workers with respect to protection and safety, through their representatives where appropriate, about all measures necessary to achieve the effective implementation of the standard and ;

(k) Necessary conditions to promote a safety culture are provided.

(1.10)Workers shall:

(a) Follow any applicable rules and procedures for protection and safety specified by the employer, registrants or licensee.

(b) Use properly the monitoring devices and the protective equipment and clothing provided.

(c) Co-operate with the employer, registrant or licensee with respect to protection and safety and the operation of radiological health surveillance and dose assessment programmes.

(d) Provide to the employer, registrants or licensee such information on their past and current work as is relevant to ensure effective and comprehensive protection and safety for themselves and others.

(e) Abstain from any wilful action that could put themselves or others in situations that contravene the requirements of the standards: and

(f) Accept such information, instruction and training concerning protection and safety as will enable them to conduct their work in accordance with the requirements of the standards.

1.12 Employers, the registrant or licensees shall record any report received from a worker that identifies circumstances which could affect compliance with the standards, and shall take appropriate action.

2.2.2.2 Conditions of service:

2.2.2.2.1 Special compensatory arrangements:

The BSS state that:

"The condition of service of workers shall be independent of the existence or the possibility of occupational exposure. Special compensatory arrangements or preferential treatment with respect to salary or special insurance coverage working hours, length of vacation, additional holidays or retirement benefits shall neither be granted nor be used as substitutes for the provision of proper

protection and safety measures to ensure compliance with the requirements of standards". (IAEABss,1999)

2.2.2.2.2 Pregnant workers:

The BSS state that:

"A female worker should, becoming aware that she is pregnant, notify the employer in order that her working conditions may be modified if necessary, the notification of pregnancy shall not be considered a reason to exclude a female worker from work, however the employer of a male worker who has notified pregnancy shall adopt the working conditions in respect of occupational exposure so as to ensure that the embryo or fetus is afforded the same broad level of protection as required for members of the public". (IAEABss,1999)

2.2.2.2.3 Alternative employment:

The BSS state that:

"Employers shall make every reasonable effort to provide workers with suitable alternative employment in circumstances where it has been determined, either by the regulatory authority or in the framework of the health surveillance programme required by the standards that the workers, for health reasons may no longer continue in employment involving occupational exposure". (IAEABss,1999)

2.2.2.2.4 Condition for young person:

The BSS state that:

(1.19)"No person under the age of 10 years shall be subjected to occupational exposure".

(1.20) "No person under the age of 18 years shall be allowed to work in a controlled area unless supervised and then only for the purpose of training".(IAEABss,1999)

2.2.2.3 Classification of areas:

Areas in a nuclear medicine department are generally classified as controlled or supervised (BSS 1.22 – 1.25).

2.2.2.3.1 Controlled areas:

The BSS state that: "registrants and licensees shall designate as a controlled area, any area in which specific protective measure or safety provisions are or could be required for:

a) Controlling normal exposure or preventing the spread of contamination during normal working condition; and
b) Preventing or limiting the extent of potential exposures".

The rooms for preparation, storage and injection of the radiopharmaceuticals shall be controlled areas.

Due to the potential risk of contamination, the imaging rooms and waiting areas should also be controlled areas, also the area housing a patient to whom therapeutic amounts of activity have been given shall also be a controlled area, in the case of pure beta emitters such as Y-90, Sr-89, or P-32, which are not excreted from the body, the area may not need to be classified as a controlled area, the room for temporary storage of radioactive waste shall be a controlled area.

The BSS state that:

"Registrants and licensees shall:

a) Delineate controlled areas by physical means or, where this is not reasonably practicable, by some other suitable means;
b) Where a source is brought into operation or energized only intermittently or is moved from place to place, delineate an appropriate controlled area

by means that are appropriate under the prevailing circumstances and specify exposure times.

c) Display a warning symbol, such as that recommended by the international organization for standardization (ISO) and appropriate instruction at access points and other appropriate locations within controlled areas.

d) Establish occupational protection and safety measures, including local rules and procedures that are appropriate for controlled areas.

e) Restrict access to controlled areas by means of administrative procedures, such as the use of work permits, and by physical barriers which could include locks or interlocks, the degree of restriction being commensurate with the magnitude and likelihood of the expected exposures.

f) Provide as appropriate at entrances to controlled areas:
    (i) Protective clothing and equipment.
    (ii) Monitoring equipment and
    (iii) Suitable storage for personal clothing.

g) Provide as appropriate at exits from controlled areas:
    (i) Equipment for monitoring for contamination of skin and clothing.
    (ii) Equipment for monitoring for contamination of any object or substance being removed from the area.
    (iii) Washing or showering facilities; and
    (iv) Suitable storage for contamination on protective clothing and equipment and

h) Periodically review conditions to determine the possible need to revise the protection measures or safety provisions, or the boundaries of controlled areas.” (IAEABss,1999)

2.2.2.3.2 Supervised areas:

The BSS state that:

"Registrants and licensees shall designate as a supervised area, any area not already designated as a controlled area, but where occupational exposure condition needs to be kept under review even thought specific protection measure and safety provisions are not normally needed". (IAEABss,1999)

It might be convenient to classify the whole nuclear department as a supervised area mainly due to the risk of contamination.

Each room of the facility should only be used for its specified work, on the basis of a safety assessment, including the planned use of each area, an evaluation of shielding and the potential for contamination, the licensee should determine whether an area where unsealed sources are handled or stored will be maintained as a controlled, supervised or uncontrolled area.

The licensee should also asses which other areas (e.g. other patient rooms, stairwells, nursing stations, waiting areas, toilets) should be controlled, supervised or uncontrolled areas.

The radiation dose – rate levels associated with these areas must be in compliance with the dose limits established by the regulatory authority.

The BSS state that:

"Registrants and licensee shall take into account the nature and extent of radiation hazards in the supervised areas:

a) Delineate the supervised areas by appropriate means.
b) Display approved signs at appropriate access points to supervised areas and

c) Periodically review the conditions to determine any need protective measures and safety provisions or changes to the boundaries of supervised areas." (IAEABss,1999)

2.2.2.3.3 Personal monitoring devices:

External radiation exposure is measured by personnel monitoring devices, three major types of monitoring devices in use today are the pocket dosimeter, the film badge, and the thermoluminescent dosimeter (TLD).

Personnel monitoring is required when it is likely that an individual will be exposed during any calendar year to a dose of 50msv to the whole body (head and trunk active blood forming organs, gonads), 150msv to the lens of the eye, 500msv to the extremities (hands, forearms, feet, leg below the knees, ankles), 500msv to the skin of the whole body, or in any work area where you can receive 1msv in any hour at 30cm from the source or source container, personnel monitoring provide a permanent legal record of an individual's occupational exposure to radiation. (IAEA Bss, 1999).

2.2.2.3.3.1 Pocket dosimeters:

Pocket dosimeters are small devices (about the size of a marking pen) one can carry in a shirt or lab coat pocket to record exposure to radiation, the dosimeter is set to zero prior to use with a separate battery, or Ac line operated charging device, when radiation passes through the sensitive volume of the dosimeter, the charge is dissipated in proportion to the amount of radiation received "self reading" dosimeters have an optical system to allow the weaver to view the amount of radiation received by looking through the dosimeter like a telescope "indirect reading" dosimeters require a separate read out device (that also serves as the dosimeter charger).

The advantage of a pocket dosimeter is that it can provide an on-the-spot result of individual's exposure to radiation, however pocket dosimeters are susceptible

to erroneous readings when exposed to excessive moisture, dust or physical abuse, in each case the dosimeter will read high for this reason, two dosimeters are usually worn for periods of one day or less. The lower reading dosimeter is considered to be the more accurate.

Another disadvantage is the dosimeter's limited exposure range if the dosimeter is exposed to radiation beyond its range, then the total exposure received cannot be determined pocket dosimeter.

2.2.2.3.3.2 Film badges:

The typical film badge; consist of a film packet and holder. The film packet usually contains two pieces of film, one sensitive to x and gamma radiation in the energy range 15Kev to 3Mev, and the other sensitive to beta radiation in the energy range from 200Kev to 1Mev, radioisotopes with energies below those values referenced above cannot be detected.

Film badges exposure to radiation causes the film to turn black upon development, the degree of film blackening is then related to the amount of radiation exposure.

The badge holder contains filters that allow different radiation types (beta, x-ray, gamma, and neutron) and energies to be distinguished on film, an "open" window no filter allows all radiations of sufficient energy to pass and expose the film.

A plastic filter absorbed most low energy beta radiation, other filters such as copper or lead absorb most high energy beta radiation and all but high energy gamma radiation, fast neutrons interact with cadmium filter to produce film blackening, slow neutrons interact with the nitrogen atoms in the film's gelatin layer and the resulting proton tracks are counted.

2.2.2.3.3.3 a Advantage of film badges:

i) They are relatively inexpensive compared to other dosimeter types.
ii) They provide a permanent record of an individual's dose (the film is kept on file).
iii) Films are processed and results reported by a disinterested third party.

2.2.2.3.3.3 b Disadvantages of film badges:

i) Films are susceptible to extremes of heat, pressure and moisture.
ii) Film processing and receipt of exposure result may take several weeks.

To eliminate this latter disadvantage, pocket dosimeters can be worn along with film badges. If the pocket dosimeter indicates a possible high exposure the film badge can be evaluated on an emergency basis, usually within twenty-four hours after the receipt by the vendor.

2.2.2.3.3.4 Thermo luminescent dosimeters (TLDs):

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

Advantages of TLD are:

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

Disadvantages are:

i) Once the chips are analyzed, the exposure information is lost and cannot be verified at a later date.
ii) Chips are subject to physical damage such as cracking or breaking etc.

2.2.2.3.4 Proper use of personnel dosimeters:

i) Personnel dosimeters must be worn only by the person to whom it was issued, any exposure information will then become a part of that person's exposure history record.

ii) Dosimeters should be worn on the part of the body where exposure to radiation is likely. Usually they are worn between the neck and waist. Care must be taken to prevent items like pens, buttons, lab benches, hood aprons from shielding the badge holder.

iii) Store dosimeters along with the "control" dosimeter in a designated area, away from extremes in temperature and radiation. The purpose of the control is to record any non-occupational exposure while the badge is not being worn.

Because the evaluation of dosage is an essential part of the radiation protection programme, 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.

If an individual's dosimeter is lost, the Rpo (radiation protection officer) should perform and document an evaluation of the dose the individual received and add it to the worker's dose record. This can be done using the workers' recent dos-history, dosed of co-worker or the result of workplace monitoring.

In nuclear medicine, the exposure due to internal contamination shall be monitored. It should be done by external monitoring of the thyroid for individuals handling large activities of radio iodine.(IAEA,Bss,1999).

A gamma camera with no collimator mounted can be used as a whole body counter.

2.2.2.3.5 Work place monitoring:-

The BSS state that:

"Registrants and licensees, in co-operation with employers if appropriate, shall establish, maintain and keep under review a programme for the monitoring of the workplace under the supervision, if so required by a regulatory authority of a qualified expert and radiation protection officer". (IAEA,1999)

The BSS state that:

"The nature and frequency of monitoring of work places shall:

(a) Be sufficient to enable:
   i) Evaluation of the radiological conditions in all workplaces.
   ii) Exposure assessment in controlled areas and supervised areas; and
   iii) Review of the classification of controlled and supervised areas.

And

(b) Depend on the levels of ambient dose equivalent and activity concentration, including their expected fluctuations and the likelihood and, the magnitude of potential exposures".

The BSS state that:

"The programmes for monitoring of the workplace shall specify:

(a) The quantities to be measured.
(b) Where and when the measurements are to be made at what frequency.
(c) The most appropriate measurement method and procedures; and
(d) Reference levels and the actions to be taken if they are exceeded." (IAEA,1999)

The result of finding of workplace monitoring should be recorded, and made available to line management and employees (through their representatives if appropriate).

This information should be used in support of pre- and-post job evaluations, job planning, contamination control and management of radiological control operations. Significant changes in monitoring results should be identifies and trends analyzed periodically; corrective actions should be taken as necessary. (ICRP,1982)

2.2.3 Medical exposure and protection:-

The population receives an exposure of radiation as part of planned medical procedures; this type of exposure is dependent on the individual's health needs and is not considered as part of the individual's occupational exposure.

Medical exposure is defined in the international basic safety standards for protection against ionizing radiation and for the safety of radiation sources (BSS the standards) as:

"Exposure incurred by the patient as part of their own medical diagnosis or treatment by persons other than those occupationally exposed, knowingly while ,volunteers helping in the support and comfort of patients, and by volunteers in a programme of biomedical research involving their exposure". (IAEA,Bss1999)

2.2.3.1 Responsibilities:-

With regard to responsibilities for medical exposure, registrants and licensees shall ensure that (BSS 11-1-3):

- No patient is administered a medical exposure unless the exposure is prescribed by a medical practitioner.

- Medical practitioners are assigned the primary task and obligation of ensuring overall patient protection and safety in the prescription of and during the delivery of medical exposure.
- Medical and paramedical personnel are available as needed, and are either health professionals or have appropriate training to discharge their assigned tasks in the conduct of the diagnostic or therapeutic procedure that the medical practitioner prescribes.
- The exposure of individuals incurred knowingly while voluntarily helping (other than in their occupation) in the care, support or comfort of patients undergoing medical diagnosis or treatment is constrained as specified, and
- Training criteria are specified or subject to approval as appropriate by the regulatory authority in consultation with relevant professional bodies.

The licensee should ensure that for diagnostic uses of radiation the image and (QA) requirement are fulfilled with the advice of a qualified expert in nuclear medical physics.

The licensee shall ensure that workers (medical practitioner, medical physicist, and technologist):

- Follow any applicable rules and procedures for the protection and safety of patient as establish by the licensee.
- Are competent in the operation and use of the equipment and sources employed in nuclear medicine of the equipment for radiation detection and measurement, and of the safety systems and devices, commensurate with the significance of the worker's function and responsibilities; and
- Know their expected response in the case of patient emergencies, nuclear medicine staff and their responsibilities: (IAEA,Bss 2004)

(a) Nuclear medicine specialist :

- Ensure overall patient protection and safety.
- Provide consultation and clinical evaluation of patients.

- Ensure that the exposure of patients be the minimum required to achieve the intended objective.
- Take into account relevant information from previous examination in order to avoid unnecessary additional examination.
- Take into account the relevant guidance levels for medical exposure.
- Determine dose prescription for therapy in consultation with the medical physicist, and
- Provide evaluation of any radiation incident and accident from a medical point of view.

(b) Medical physicist:

- Participate in continuing review of the nuclear medicine practice's resources (including budget, equipment, and staffing), operations, policies, and procedures.
- Develop requirements and specifications for the purchase of appropriate equipment assuring radiation safety.
- Plan in conjunction with the nuclear medicine physician the facilities for nuclear medicine practice.
- Carry out acceptance testing.
- Establish and implement QA procedures in nuclear medicine.
- Supervise equipment maintenance.
- Investigate and evaluate incidents and accidents.

(c) Nuclear medicine technologist:

- Patient identification.
- Patient information.
- Information to accompanying persons and staff nursing a patient after a nuclear medicine examination or therapy.
- Verifying that the female patient is non-pregnant.
- Assure that a mother in lactation is given information about the discontinuation of nursing.

- Make the calculation of administering activity to a child, according to the local rules.
- Verify the administered radiopharmaceutical and its activity.
- Perform regular workplace monitoring.
- Correct handling of the equipment and safety accessories.
- Inform the RPOs in the case of accident or incident.
- Inform the nuclear medicine physician in the case of misadministration.
- Participate in education and training of new personnel. (IAEA, Bass,2000)

The basic principles of protection for medical exposures can be summarized as follows:

- "Medical exposures should be justified by weighting the diagnostic or therapeutic benefits they produce against the radiation detriment they might cause, taking into account the benefits and risks of available alternative techniques that do not involve medical exposure".
- The doses from medical exposures should be the minimum necessary to achieve the required diagnostic objective or the minimum to the normal tissue for the required therapeutic objective. (IAEA,2004)

Medical exposures are usually intended to provide a direct benefit to the exposed individual, if the practice is justified and the protection optimized doses to patients will be as low as is compatible with the medical purposes, any further reduction in exposure might be to the patients' detriment. Consequently doses limits should not be applied to medical exposures, although comforters, cares and research volunteers should be subject to dose constraints. (6)

2.2.3.2 Justification:-

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

Justification in nuclear medicine should comply with the BSS (BSS, paras 11.4-11.9) and the recommendation of the ICRP. The regulatory authority should require that no patient be administered a radioactive substance for diagnostic purpose, unless the procedure is prescribed by a medical practitioner who fulfils the national requirements on training and experience for prescribing procedures involving medical exposure.

The prescriber should consider the efficiency, benefits and risks of alternative technology, for example, ultrasound, magnetic resonance imaging and endoscopy, ideally the prescriber often called the referring physician should consult the nuclear medicine specialist for the appropriate procedure to be performed.

In justifying each type of diagnostic nuclear medicine examination relevant guidelines will be taken into account, such as those establish by the WHO.

Nuclear medicine physicians are frequently required to make decisions on the use of a procedure, in doing so they should:

- Evaluate the potential role of the procedure.
- Evaluate the risks and benefits arising from the procedure (e.g. there a good chance of obtaining the necessary information and is it likely to influence the management of the patient's illness).
- Determine the best procedure to aid in the diagnosis.

- Consider the availability of results from previous examinations.

Justification implies that the referring physician and nuclear medicine physician make the decision on a radiological procedure on the basis of:

- The case history, clinical examination of the patient and clinical laboratory results.
- The availability of nuclear medicine techniques or alternative techniques.

Any nuclear medicine examination for occupational, legal or health insurance purposes undertaken without reference to clinical indications are deemed to be unjustified unless it is the justification of examinations in pregnant women requires special consideration, due to the higher Radiosensitivity of the foetus the risk may be substantial. (IAEA,2004)

2.2.3.3 Optimization of examination:

The basic aim of the optimization of patient protection in diagnostic and therapeutic procedures is to maximize the margin of benefit over harm, while taking into account social and economic circumstances. Since patients are deliberately exposed to radiation sources, the optimization of protection can be complex and does not necessarily mean the reduction of doses to patients, as priority has to be given to the acquisition of reliable diagnostic information and the achievement of the therapeutic effect respectively.

Licensees shall ensure that:

(a) Medical practitioners who prescribe or conduct diagnostic applications of radionuclides (BSS11.10-13,16-18):
    - Ensure that the exposure of patients is the minimum required to achieve the intended diagnostic objective.

- Take into account relevant information from previous examinations in order to avoid unnecessary additional examination; and
- Take into account the relevant guidance levels for medical exposure.

(b) The medical practitioner, the technologist or other imaging staff, as appropriate endeavor to achieve the minimum patient exposure consistent with acceptable image quality by:

- Appropriate selection of the best available radiopharmaceutical and its activity, nothing the special requirements for children and for patients with impairment of organ function.
- Use of methods for blocking the uptake in organs not under study and for accelerated excretion when applicable.
- Appropriate image acquisition and processing.

(c) Administration of radionuclides for diagnostic or radio therapeutic procedures for women pregnant or likely to be pregnant be avoided unless there are strong clinical indications.

(d) For mother in lactation discontinuation of nursing is recommended until the radiopharmaceutical is no longer secreted in an amount estimated to give an unacceptable effective dose to the nursling (examples of good practice are at least 3 weeks for ^{67}Ga, ^{111}In, ^{131}I and ^{201}Tl, at least 2 days for ^{123}I and at least 12 hours for ^{99m}Tc); and

(e) Administration of radionuclides to children for diagnostic procedures be carried out only if there is a strong clinical indication, and the amount of activity administered be reduced according to body weight, body surface area or other appropriate criteria. (IAEA Bss, 1999)

If more than one radiopharmaceutical can be used for a procedure consideration should be given to the physical, chemical and biological properties for each

radiopharmaceutical so as to minimize the absorbed dose and other risks to the patient while at the same time providing the desired diagnostic information.

Other factors affecting the choice include availability, shelf life, instrumentation and relative cost. (IAEA Bss, 2004).

The choice of optimal dosage in nuclear medicine is a complex matter.

Today the amount of administering activity is mainly based on local experience and tradition and there are considerable differences between clinics. The relation between activity and diagnostic accuracy is highly dependent on the type of examination.

It is also important to know whether the diagnosis is based on quantitative information or on visual evaluation. Both for a simple uptake measurement and in connection with imaging, the amount of activity needed will depend on the type of equipment used, the body constitution of the individual patient, the patient metabolic characteristics and clinical condition.

The administration of amounts substantially larger than the optimum in order to improve marginally the quality of the results obtained should be discouraged.

It should also be noted that limiting the administered activity below the optimum, even for well-intentioned reasons, will usually lead to poor quality of the result which may cause series diagnostic errors.

It is very important to avoid a failure to obtain the required diagnostic information; failure would result in an unnecessary (and therefore unjustified) irradiation and may also necessitate repetition of the test Substantial reduction of the absorbed dose from radiopharmaceuticals can be readily achieved by some simple measures such as hydration and frequent voiding, the use of thyroid blocking agents' laxatives and diuretic.

Equipment shall be operated within the limits and conditions established in the technical specifications and in the license requirements, ensuring that it will operate satisfactorily at all times, in terms of both the tasks to be accomplished and radiation safety for equipment operation, the manufacturer's operating manual, and the institutions procedural manual should be followed the data acquisition conditions shall be chosen such that the image quality is optimum, the choice of collimator, energy wind matrix size, acquisition time, angulations of the gantry, SPECT or PET parameters, and zoom factor shall be such as to obtain optimum quality image. For dynamic studies, the number of frames, time interval, and other parameters shall be chosen to obtain optimum quality of the image sequence.

The patient should be fully informed about the examination. Patient factors such as age, disease, size etc. should be considered in the optimization of the examination. (JAEA,Bss,2000)

2.2.4 Public protection:-

2.2.4.1 Responsibilities:-

Registrants and licensee shall apply the requirements of the standards as specified by the regulatory authority to any public exposure delivered by a practice or source for which they are responsible, unless the exposure is excluded from the standards or the practice or source delivering the exposure is exempted from the requirements of the standards. Registrants and licensee shall be responsible, with respect to the sources under their responsibility, for the establishment, implementation and maintenance of:

(a) Protection and safety policies, procedures and organizational arrangements in relation to public exposure in fulfillment of the requirements of the standards.

(b) Measures for ensuring:

(i) The optimization of the protection of members of the public whose exposure is attributable to such sources, and

(ii) The limitation of the normal exposure of the relevant critical group, which is attributable to such sources, in order that the total exposure be not higher than the dose limits for members of the public, in selecting the critical group account shall be taken of all those in present and future generations, whether in the countries or places where the sources are located or in any other country or place.

(c) Measure for ensuring the safety of such sources, in order that the likelihood of public exposure be controlled in accordance with the requirements of the standards.

(d) Suitable and adequate facilities, equipment and services for the protection of the public, the nature and extent of which are commensurate with the magnitude and likelihood of the exposure.

(e) Appropriate protection and safety training to the personnel having functions relevant to the protection of the public, as well as periodic and updating as required, in order to ensure the necessary level of competence.

(f) Appropriate monitoring equipment and surveillance programmes to assess public exposure to the satisfaction of the regulatory authority. (IAEA,ICRP 1999)

2.2.4.2Sources of external irradiation:-

2.2.4.2.1 Radioactive patient:-

The radioactive patients consider being the main sources of radiation for the public, so a care should be taken in review for the contact between the patient and the others, according to the radioactivity on the patient.

The activities administered for diagnostic purpose are moderate, and the patient dose not normally needs to be hospitalized. For almost all diagnostic procedures the maximum dose that could be received by another person due to the external exposure from the patient is a 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. (IAEA, 2004)

The management of patients undergoing radionuclide therapy is designed to minimize radiation exposure to other persons, the precautions to be taken for ambulatory patients treated for thyrotoxicosis depends upon the amount of radioactivity administered, the radiation dose rate in the vicinity of the patient, expected, normal patterns of daily contact between the patient and others, and dose constraints that may apply.

All patients should be advised of basic hygiene measures (toileting, hand-washing, etc.) to minimize contamination of their home and work environment, females should avoid pregnancy for at least 6 months following therapy, in case follow-up examinations might discover the need for further radiation therapy, and males should take precautions for two months to avoid beginning a pregnancy. In addition, nursing mothers undergoing radioiodine therapy are advised that complete cessation of breastfeeding is necessary. (IAEA, 2004)

As stated in the basic safety standards "in order to restrict the exposure of any members of the household of a patient who has undergone a therapeutic procedure with sealed or unsealed radionuclides and members of the public, such a patient shall not be discharged from hospital before the activity of radioactive substances in the body falls below the level specified".

At the present time only iodine-131has been considered as needing this precaution and a guidance level of 1000MBq has been given in the standards.

However, in some countries a level of as low as 400 MBq is considered as a good practice.

In addition, as mentioned in the standards "written instructions to the patient concerning contact with other persons and relevant precautions for radiation protection shall be provided as necessary"

Example of advices for patients to minimize the exposure of the general public:

- Use only a WC and flush 2-3 times, keep the toilet and the floor clean.
- Wash your hands frequently and take a shower every day.
- Avoid close contact with members of the family, children and pregnant women etc.
- Avoid solid waste.
- Wear footwear when leaving the bed.
- In the event of vomiting or incontinence notifies the nurse immediately.

Control of visitors:-

- Ensure that visitors be accompanied in any controlled area by a person knowledgeable about the protection and safety measures for that area.
- Provide adequate information and instruction to visitors before they enter a controlled area so as to ensure appropriate protection of the visitors and of other individuals who could be affected by their actions, and
- Ensure that adequate control over entry of visitors to a supervised area be maintained and that appropriate signs be posted in such areas.

The following precautions are recommended for the visitors to hospitalized patients:

- Visitors are discouraged, particularly within the first 48 hours after treatment.

- Women who are pregnant and children under 18 years are not allowed to visit.
- Visitors should limit themselves to less than 30 minutes per day and should stay at least 2 meters from the patient;
- There should be no hugging or kissing between patients and visitors.
- Visitors are not to eat, drink or smoke in the patient's room.
- Visitors are not to use the patient's washroom.
- A visitor instruction card containing these restrictions should be affixed to the outside of the entrance door.

2.2.4.2.2 Radioactive contamination in enclosed space:-

Registrants and licensees shall ensure that:

(a) For sources for which they are responsible, measures that are optimized in accordance with the requirements of the standards be taken as appropriate for restricting public exposure to contamination in areas accessible to the public, and;

(b) Specific containment provisions be established for the construction and operation of a source that could cause the spread of contamination in areas accessible to the public. (IAEA,Bss, 1999)

2.2.4.2.3 Radioactive waste:-

Registrants and licensee shall:

(a) Ensure that the activity and volume of any radioactive waste that results from the sources for which they are responsible be kept to the minimum practicable, and that the waste be managed, i.e. collected, handled, treated, conditioned, transported, stored and disposed of, in accordance with the requirements of the standards and any other applicable standard.

(b) Segregate, and treat separately if appropriate different types of radioactive waste where warranted by differences in factors such as radionuclide content, half-life, concentration, volume and physical and chemical properties, taking into account the available options for waste disposal. (IAEA,Bss, 1999)

2.2.4.3 Dose limits:-

According to the basic safety standards, for radiation protection purposes, a member of the general public is considered to be anyone who is not occupationally exposed or someone knowingly and voluntarily helping in the care, support or comfort of a patient. The exposure of the general public is restricted by the application of dose limits and the constrained optimization of radiation protection. These dose limits do not apply to radiation exposures from natural sources, the standards state that "the estimated average doses to the relevant critical groups of members of the public that are attributable to practices shall not exceed the following limits". (IAEA,Bss, 1999)

2.2.4.4 Design considerations:-

The objectives of facility design to ensure: safety of sources, optimize exposure of staff, patients and general public.

Also to prevent uncontrolled spread of contamination, maintain low background where most needed, fulfill requirements regarding pharmaceutical.

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

The concept of categorization of hazard should be used in order to determine the special needs concerning ventilation, plumbing, materials used in walls, floors and work benches.

The categorization of hazard based on calculation of a weighted activity using weighting factors, according to radionuclide used and the type of operation performed.

Table no (6)

The table represented weighted activity and category of hazard

Weighted activity	Category
< 50 MBq	Low hazard
50 – 50000 MBq	Medium hazard
> 50000 MBq	High hazard

Table no (7)

Table represented weighting factors according to radio nuclide

Class	Radionuclide	Weighting factors
A	^{75}Se, ^{89}Sr, ^{125}I, ^{131}I	100
B	^{11}C, ^{13}N,^{15}O, ^{18}F, ^{51}Cr, ^{67}Ga,^{99m}Tc ^{111}In, ^{113m}In, ^{123}I, ^{201}Tl	1.00
C	^{3}H, ^{14}C, ^{81m}Kr, ^{27}Xe, ^{133}Xe	0.01

Table No (8)

The table represented weighting factors according to type of operation

Type of operation or area	Weight factor
Storage	100
Waste handling, imaging room (no inj), waiting area, Patient bed area (diagnostic).	0.10
Local dispensing, radionuclide administration, imaging room (inj), simple preparation, patient bed area (therapy).	1.00
Complex preparation.	10.0

The categorization of hazard for different rooms in a nuclear medicine department handling ^{99m}Tc, high hazard such as room for preparation and dispensing radiopharmaceuticals, also, temporary storage of waste, room for administration of radiopharmaceuticals, examination room and isolation ward, Medium hazard such as room for storage of radionuclides, waiting room, patient toilet ,and Low hazard such as room for measuring samples, radiochemical work' offices and reception.

2.2.4.4.1 Building requirements:-

The concept of categorization of hazard should be used in order to determine the special needs for the building.

- ***The floors should be***: impervious material, washable, chemical-resistance, curved to the walls, all joints sealed glued to the floor and no carpet is used.

- ***Walls and ceiling***: the walls and ceiling should be finished in a smooth and washable surface with joints being sealed, wherever practicable. The walls should be painted with washable, non-porous paint.
- ***Work top surfaces*** should be finished with a smooth, washable and chemical-resistant surface with all joints sealed.

  Some laminates do not resist certain chemicals, and the supplier should be consulted with regard to the specific chemicals to be used in the laboratory.

  Structural reinforcement necessary, since a considerable weight of lead shielding may be placed on counter tops, cover the surface with absorbing paper, or disposable tray.

  Also from requirements of buildings, open shelving should be kept to a minimum to prevent dust accumulation, services (e.g. gas, electricity) should not be mounted on top of the bench, but on walls or up stands, light fixtures should be easy to clean and of an enclosed type in order to minimize dust accumulation.

- ***Fume hood:*** fume hood in the facility must be constructed of smooth, impervious, washable and chemical-resistant material.

  The working surface should have a slightly raised lip to contain any spills and must be strong enough to bear the weight of any lead shielding that may be required, and the linear face velocity is between 0.5 and 1.0 m/s and this should be checked regularly.

- ***Ventilation***: aerosols or gases produced, the laboratories should have an appropriate ventilation system, it assure in the laboratory negative pressure relative to surrounding areas.

The airflow should be from areas of minimal likelihood of airborne contamination to areas where such contamination is likely, all air from the laboratory should be vented through a fume hood and must not be re-circulated.

Should be continuously monitored and an alarm system introduced, if there are regulations about air pressure gradients.

- ***Sinks***: a special sink shall be used, if the regulatory authority allows the release of aqueous waste to the sewer, also local rules for the discharge must be found, the sink shall be easy to decontaminate, special flushing units are available for diluting the waste and minimizing contamination of the sink.
- ***Washing facilities***: the wash-up should be located in a low-traffic area adjacent to the work areas, taps for these sinks should be operable without direct hand contact, and disposable towels or hot air dryer should be available, should be find an emergency eyewash installed near the hand-washing sink, an access to an emergency shower is also required.
- ***Patient toilet***: a separate toilet room for the exclusive use of injected patients, the patient washing facilities should not be used by hospital staff, as it is likely that the floor, toilet seat and sink handles will be contaminated frequently, should include a sign requesting patients to flush the toilet well and wash their hands.

  Be finished in materials that are easily decontaminated, and consider wall mounted sanitary ware so that floor is completely clear.

- ***Pipes:*** the drain-pipes from the radioisotope laboratory sink should go as directly as possible to the main building sewer.

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

Drain-pipes from isolation wards for patients undergoing radionuclide therapy shall end up in a delay tank.

- ***Shielding:*** much cheaper and more convenient to shield the source where possible, rather than the room or the person.

  Structural shielding is generally not necessary in a nuclear medicine department; the need for wall shielding should be assessed at the design of a therapy ward to protect other patients and staff, and in the design of a laboratory housing sensitive instrument to keep a low background in a well counter, gamma camera, etc.

2.2.4.5 Safety equipment:

- Shields such as bench top shield, vial shields, syringe shields and structural shielding.

  In the structural shielding, the absorbed dose is determined by factors such as source strength, length of exposure, distance from the source and transmission through the protective barrier.
- Protective clothing or personal protective equipment, appropriate clothing should as a minimum include labcoat and gloves, national regulations may require more.
- Tools for remote handling of radioactive waste such as forceps and tongs, these tools done by distance factor.
- Containers for radioactive waste, several containers should be available in order to segregate the waste at the point of origin (radionuclides, half lives, glass, paper, syringes, etc.).

  The number of containers should find in department depend on size of department big or small, in a small department it may be enough one

container for paper, gloves, etc. and one container for glass, needle and syringes.

- Dose rate monitor with alarm or monitoring equipments are two types of personal equipment such as film, thermoluminescent dosimeters (TLD), electronic dosimeters which mentioned before.

  Workplace monitoring to use evaluation of radiation condition, assessment of potential exposures and ongoing review of the classification of controlled and supervised areas, these instruments such as count rate meters use for contamination detection purpose, and dose rate meters use for measuring the dose rate.
- Signs, labels and records should be found, provided, explain and in local language.
- Decontamination kit or emergency kit: these kits should be kept readily available for use in an emergency, and it includes protective closing, e.g. over shoes, gloves, decontamination materials for the affected areas including absorbent materials for wiping up spills.

  Also decontamination materials for persons, warning notices, portable monitoring equipment, and bags for waste, tape, labels, pencils.

2.2.4.6 Contamination:

When unsealed radioactive materials are used, it is necessary to protect against external radiation and also against the possibility of contamination must be wearing gloves when dealing radioactive materials or containers that may have been contaminated, wash and monitor your hand frequently, observe the restrictions on eating, drinking and smoking to avoid the possibility of inadvertent ingestion of radioactive material.

Also by wearing a laboratory type coat, for some procedures a plastic apron is advisable all these to protect clothes, since the gloves are likely to become contaminated while working with radioactive materials, use a paper handkerchief to touch instrument switches, etc.

Keep paperwork from an area, in which unsealed radionuclides are handled, and if is necessary to use a calculator in a potentially radioactive area, put it in a clear polythene bag to avoid contaminating it.

2.2.4.6.1 Monitoring:

Radiation levels in a nuclear medicine department will be above background, monitoring of the environmental both for external radiation and contamination, and of staff for internal and external radiation.

Is necessary to assess the extent of this increase and ensure it is kept as low as reasonably achievable, national regulations and local rules and procedures may specify the monitoring required.

2.2.4.6.2 Incidents:

Even in well – organized departments mishaps occur from time to time, in general, in the event of any accident involving unsealed radioactive materials, the principal requirements are first to ensure the safety of all individuals and then to avoid the spread of radioactivity. Staff should therefore take the following actions:

1- Notify a supervisor and summon assistance.
2- Treat any injuries.
3- Decontaminate personnel.
4- Decontaminate the room.
5- Prepare a report.

2.2.4.6.3 Decontamination of persons:

Every effort should be made to prevent external contamination entering the body through damaged skin or by ingestion. The following procedures should be carried out, repeatedly if necessary until the contamination is below the acceptable levels specified locally:

1- Remove contaminated clothing as soon as possible; taking care not to spread the contamination, the clothing if highly radioactive, should be put into a polythene bag and stored behind shielding.
2- When high – level contamination of any part of the body is suspected, do not take a bath or shower until the affected areas have been cleaned locally, wash contaminated hands repeatedly with large quantities of soap and running water, paying particular attention to the nails and do not break the skin.
3- For decontamination hair, use soap and water, if necessary try 2% Decon or similar. Do not use other chemicals.
4- To clean the face use damp but not dripping swabs with soap and water, and take care to ensure that the active liquid doesn't touch the lips or enter the eyes.
5- If the skin is broken or cut in the area of contamination, open the wound and irrigate immediately with tap water, bleeding to a reasonable extent, should be encouraged.

2.2.4.6.4 Decontamination of room:

1- In the event of a minor spill, involving less than about 5 MBq (150 µci) ^{131}I or 400 MBq (10 mci) ^{99m}Tc, put on gloves, cover the spill with paper towels to soak up the liquid, mark the area of contamination then, working inwards from the marked boundary, scrub the area with detergent.

2- Take great care not to spread the contamination, especially to counting or imaging equipment, put all contaminated towels, swabs, brushes, etc. in a polythene bag label the bag and take it to the radioactive waste store, monitor the cleaned surface and continue to clean until the activity is below acceptable levels as specified in national legislation and coodes of practice.
3- In the event of a major spill, vacate the room, leaving contaminated coats, etc. behind and close the room and put up warning signs, start treatment or decontaminated of persons, then assemble the necessary equipment for cleaning the room.
4- Put on over shoes, wear gloves and a plastic apron, carry a radiation monitor covered with polythene to prevent it becoming contaminated, proceed as for a minor spill, but first handle towels, swabs , etc. with forceps.
5- When the contamination is caused by short – lived radioactive materials (less than one day half – life), after initial cleaning prevents the spread of contamination by covering the affected area with polythene and let time reduce the activity, limit access to the area if necessary.
6- If long – lived contamination persists, try the following: cleaning materials; paint work, paint remover or carbon tetrachloride, plastics – organic solvents; wood – steel wool or sandpaper.

   Wear a face mask for these drastic treatments and have good ventilation, should contamination remain above the levels specified locally, equipment must be taken out of use and access to affected places controlled.

2.2.4.7 Transport of radioactive materials:

During the transport of radioactive materials, members of the public who are not specially trained in handling radionuclides may come into relatively close

contact with them, it is therefore most important to ensure that such persons are neither unnecessarily exposed to radiation nor likely to become contaminated.

International and national legislation are directed towards the achievement of these objectives.

Transport of radioactive materials can be considered in two categories – transport within the institution where the materials are used, such as hospital, and transport outside the institution. This latter case is the subject of IAEA regulations (19, 20) which are reflected in national legislation. (LAEA,1996)

- ***Internal transport:*** general principles to the transport of the material within an institution are as follows:
  1- Procedures should be such that it is clear who is responsible for the radioactive material at a particular time, even if the user is also the transporter of the material, adequate records must be made.
  2- The material must be transported in a suitable container, it should be doubly contained, with a rigid outer container designed to prevent leakage should the primary container break, the container should be lined with absorbent material to soak up any spill that does occur and must also provide adequate shielding from external radiation.
  3- While being transported, a container of radioactive material must not be left unattended in areas accessible to the public or staff not concerned with its use.
  4- Containers should be suitably labeled, and the label should give details of the radionuclide being transported, care should be taken to ensure that labels are removed from empty containers.
  5- Local rules should be written for the institution, detailing the procedures to be followed.

6- The local rules should take into account the possibility of any hazardous situation that is likely to arise during transport, in particular, they should describe the action to be taken in the event of damage to the container and/or its contents, procedures should also be such that they minimize the possibility of losing the source during transit, therefore documentation must be adequate instructions should be included as to the action to be taken should a source be lost or suspected of being lost. (IAEA,1996)

- ***External transport:***

  Each country has manifold items of legislation concerned with the safe transport of radioactive material but the definitive source document for all these regulations is the IAEA regulations for the safe transport of radioactive material (19.20), and the aim of these regulations is to provide an acceptable level of control to the radiation hazards to persons, property and the environment that are associated with the transport of radioactive materials.

  If it is necessary to transport radioactive materials, say to outlying hospitals, reference should be made to the detailed national legislation, if such transport occurs frequently; local procedures should be set down in consultation with the radiation protection adviser (RPO). (IAEA,1996)

The steps to be taken when organizing transport are:

1- Identify the radionuclide and its maximum activity.
2- Establish the type of packaging required, it is preferable to use package of a type which has been used previously for similar radioactive materials since the IAEA lays down rigorous type test procedures for the package, e.g. drop test water, spray test.
3- Pack the material in a legally acceptable way measure the dose – rate on the surface of the package and at 1m from it.

The transport index is defined as this latter quantity measured in $msvh^{-1}$ multiplied by 100, both these quantities must be within the limit set by the IAEA for example transport index less than 10 and surface dose – rate less than 2 $msvh^{-1}$.

4- Label the package with the correct international transport labels, the label must show the radionuclide, the activity and the transport index.
5- As consignor, fill in transport documents – the details to be included are given in the appropriate national legislation. (IAEA,1996)

2.2.4.8 Disposal of waste:

The clinical use of radioactive material will inevitably result in radioactive waste. This arises from three main sources:

1) Excreta from patients undergoing medical procedures.
2) Syringes and swabs used during preparation and administration of radioactive materials.
3) Waste from spills and resulting decontamination.

If not dealt with satisfactorily, waste will constitute a hazard to staff, patients and members of the public; the disposal of waste is subject to legislation which varies from country to country.

The advice which follows may only be implemented provided prior approval has been obtained under the appropriate legislation for both the method of disposal and for the types of radionuclide and quantities involved.

Waste may be dealt within two main ways, it may either be stored until it has decayed to levels where it may easily be dealt with by disposal, or it may be dispersed into the environment, such as through the drainage system, in a suitably controlled manner so that doses of radiation received by persons who may subsequently come into contact with the waste are insignificant.

The second method is generally most convenient for short – half-life ^{99m}Tc, although a short storage time is useful for articles such as syringes. (IAEA,1996)

Liquid and solid waste:

The majority of waste disposed of from a nuclear medicine department comes into the category of liquid waste, the major part of it arises from the excreta of patients, for ease of accounting it is assumed that a certain proportion of the administered radionuclide eventually becomes waste, obviously some of this waste will not be discharged from the nuclear medicine department itself, but from the ward to which the patient returns after the procedure, however the waste is recorded in the nuclear medicine records.

Other aqueous radioactivity for disposal may arise from out – of – date stock solutions, unsealed dispensed activities, or spills and may all be disposed of to the drain.

The sink used for disposal of radioactive waste should be clearly identified, and after disposals the tap should be clearly identified, and after disposals the tap should be allowed to run to flush through the waste thoroughly, pipes carrying radioactive waste should be identified so that they can be checked before any maintenance work is carried out on them.

Water – immiscible solvents from liquid scintillation counting should not be disposed of to the drainage system, not because of the radioactivity involved usually very low concentrations of ^{14}C or ^{3}H, but because of the organic material, such as toluene, in the scintillation, local authorities and the radiation protection adviser should be asked for advice. (IAEA,1996)

Solid waste:

Solid waste from the nuclear medicine department will mainly consist of contaminated swabs and syringes used during the preparation and administration of radiopharmaceuticals, since the majority of activity involved will be due to the short – half – life ^{99m}Tc.

Waste may be stored for a relatively short time (24 hours) and then discarded with ordinary inactive waste as exempt material.

It is helpful to keep two active waste containers labeled ^{99m}Tc and other authorizations for the disposal of exempt waste limit the amount of activity allowed in a particular volume (400 KBq in 0.1 m^3 of waste) with no single item having an activity greater than 40 KBq, the waste must not contain any alpha – emitters or strontium – 90.

Solid waste may also be disposed of via the hospital incinerator, depending on the chemical composition of the activity.

The material may be dispersed in the air, as in the case of radioactive iodine. Incinerators used for disposal of radioactive waste should be of good design, particularly with respect to the discharge of effluent gases and ash handling.

The stack height should be sufficiently above that of surrounding building to give efficient dispersal of any radioactive gases emitted.

This should be borne in mind when new building developments are planned in the vicinity of incinerator chimneys.

For disposal of activities above these limits, special permission must be sought.

Possible methods of disposal are special burial, incineration, or via a special disposal organization. (IAEA,1985)

2.2.4.9 Storage and transport of waste:

Storage:

Waste awaiting disposal should be stored in closed containers, the storage period should not exceed two weeks, long – lived materials, such as ^{131}I, may require longer storage before disposal by a convenient method is possible and application should be made to extend the storage period.

Each hospital should have at least one storage area for radioactive waste. The area must be lockable to prevent unauthorized access and should be clearly marked with a radiation warning symbol, it must be adequately shielded.

All items awaiting disposal must be clearly marked and it is a good idea to allocate areas in the store to particular types of waste and radionuclides. (IAEA,1985)

Transport:

Radioactive waste is subjected to the legislation which applies to the transport of radioactive substances generally and requires proper packaging, labeling and documentation.

However the waste arising from hospitals is normally of very low activity and subject to certain constraints, is exempt from transport regulations, persons wishing to transport waste should therefore refer to the relevant legislation. (IAEA,1985)

Waste records:

It is essential that comprehensive records are kept for all radioactive materials, including their disposal as radioactive waste; the waste record should indicate the radionuclide, its activity, the disposal route and the date on which the disposal was made.

In order to confirm at a glance that all waste authorization limits are being complied with, a central record should be kept in terms of the time limits given by the authorization a monthly summary may be appropriate. (IAEA,1985)

(3) Previously studies:

- Evaluation of radiation safety measures in a nuclear medicine department in Sudan, this a thesis prepared by Alghazaly Aabdallh Mohammed to attainment degree of M.sc in nuclear medicine technology 2008, the research of this a thesis marched out by important results and he recommended by some things such as increase the equipment needs for radiation protection, maintenance services, increase the safety culture programs for the workers, must be found adequate radiation protection program in nuclear medicine departments because the radiation protection officer (RPO)'s have not fully authorizes and adequate time for them to do their duties effectively, and the design of the nuclear medicine department were not compatible with international standards and regulation, also he recommended to do a lot of work in nuclear medicine departments.
- Evaluation of room design of Spect gamma camera in Alnilain and Rick nuclear medicine centers, this research prepared by Maiada Yousif Mohamed Abubaker in 2016.

Chapter three

(3.1) Material of the study

The Devices and equipment's uses in these departments, dose calibrator vents, S/W 2/401-2051-05 ges-filled detectors, are used for Dose measurements.

The generators type used , MO99/TC99m Gener and mongrel.

The devices use for monitoring of workers thermolumicent dosimeters (TLD), the device used for monitoring of area contamination monitor – medizinlechnik, survey meter, contamination monitor.

The imaging devices use in theses departments such as SPECT Gamma Camera Midiso, SPECT – CT simkia semisis.

(3-2) Study participants: Six participants

(3-3) place and duration of the study:

The study was conducted at three nuclear medicine departments in Sudan, namely Radiation and Isotopes Center Khartoum (RICK) , EL-MAK NIMR UNIVERSITY HOSPITAL AND NILEIN MEDICAL DIAGNOSTIC CENTER during the period from January 2020 to October 2020.

(3-4) Methods of the study:

(3-4-1) Methods of Data collection

The researcher used questionnaire , observation , text books and websites.

(3-4-2) Methods Data analysis:

SPSS program and the researcher used a number of test including percentages, correction and finding the meaningful value for all tests (0.5).

(3-5) Ethical Consideration:

All the information included in the study were kept secret – password is used to access to the study.

Chapter four

Results

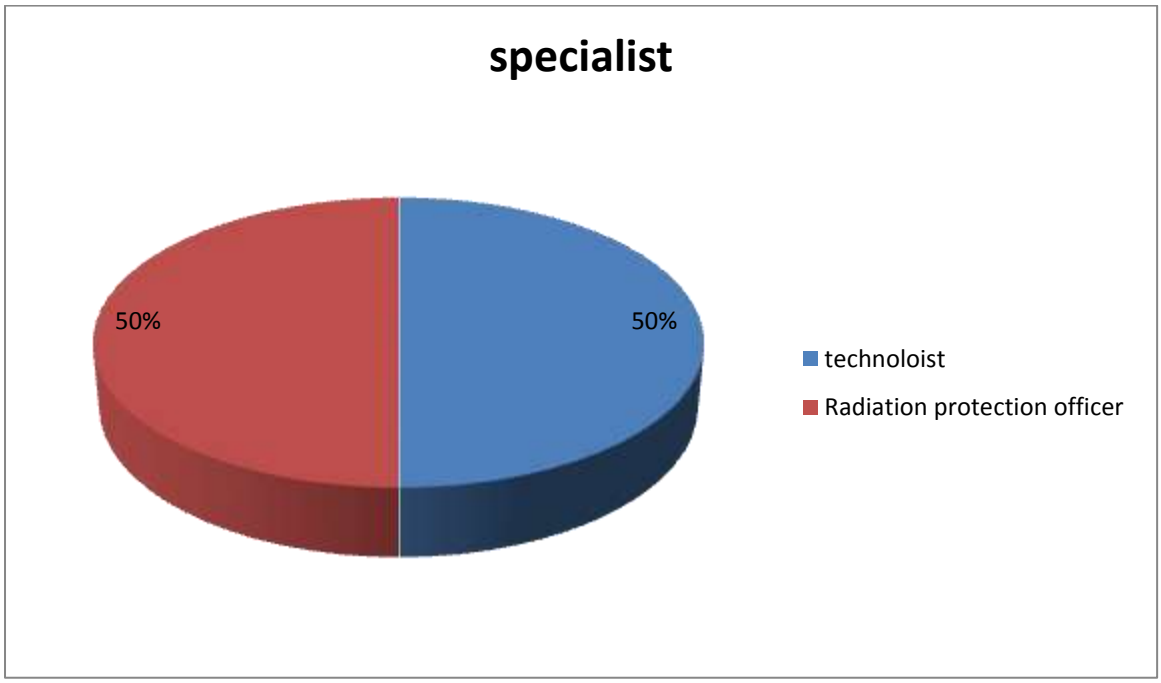


Fig (5.1) shows the NM staff in all the departments under study.

Table (5.4) explain first protection topic (Facility Design)

	Yes		**No**		**I don't know**	
	Nu	**%**	Nu	**%**	Nu	**%**
1.	5	83	1	16.67	-	-
2.	5	83	-	-	1	16.67
3.	6	100	-	-	-	-
4.	6	100	-	-	-	-
5.	5	83	1	16.67	-	16.67
6.	2	33	3	50	1	-
7.	4	66.67	2	33	-	-
8.	2	33	4	66.67	-	-
9.	5	33	1	16.67	-	-
10.	2	33	4	66.67	-	16.67
11.	-	-	5	83	1	-
12.	6	100	-	-	-	-
13.	3	50	3	50	-	33
14.	3	50	1	16.67	2	-
15.	4	66.67	2	33	-	-
16.	5	83	1	16.67	-	16.67
17.	-	-	5	33	1	-
18.	4	66.67	2	33	-	
19.	-	62.04		31.48	-	5.56

Table (5.2) explain Second protection topic

	Yes		**No**		**I don't know**	
	Nu	%	Nu	%	Nu	%
1.	5	83.33	-	-	-	-
2.	6	100	-	-	-	-
3.	4	66.67	1	16.67	1	16.67
4.	2	33.33	3	50	1	16.67
5.	6	100	-	-	-	-
6.	5	83.33	1	16.67	-	-
7.	4	66.67	1	16.67	1	16.67
8.	6	100	-	-	-	-
9.	2	33.33	4	66.67	-	-
10.	5	83.33	1	16.67	-	-
11.	5	83.33	1	16.67	-	-
12.	5	83.33	-	-	1	16.67
13.	3	50	3	50	-	-
14.	3	50	1	16.67	2	33.33
	61	72.62	16	19.05	6	7.14

Table (5.4) explain Fourth protection topic

	Yes		**No**		**I don't know**	
	Nu	%	Nu	%	Nu	%
1.	5	83.33	1	16.67	-	-
2.	6	100	-	-	-	-
3.	4	66.67	2	33.33	-	-
4.	5	83.33	1	16.67	-	-
5.	5	83.33	1	16.67	-	-
6.	6	100	-	-	-	-
7.	6	100	-	-	-	-
8.	6	100	-	-	-	-
9.	6	100	-	-	-	-
10.	6	100	-	-	-	-
11.	5	83.33	1	16.67	-	-
12.	4	66.67	1	16.67	1	16.67
13.	5	83.33	1	16.67	-	-
14.	5	83.33	1	16.67	-	-
15.	6	100	-	-	-	-
16.	6	100	-	-	-	-
17.	3	50	2	33.33	1	16.67
18.	5	83.33	1	16.67	-	-
19.	5	83.33	1	16.67	-	-
20.	1	16.67	5	83.33	-	-
21.	3	50	1	16.67	2	33.33
22.	5	83.33	1	16.67	-	-
23.	4	66.67	2	33.33	-	-
	112		22	15.94	41	3.80

Fourth Part monitoring

	Yes		**No**		**I don't know**	
	Nu	%	Nu	%	Nu	%
1.	5	83.33	1	16.67	-	-
2.	5	83.33	1	16.67	-	-
3.	5	83.33	-	-	1	16.67
4.	5	83.33	1	16.67	-	-
5.	3	50	3	50	-	-
6.	2	33.33	3	50	1	16.67
7.	3	50	2	33.33	1	16.67
8.	6	100	-	-	-	-
9.	6	100	-	-	-	-
10.	4	66.67	1	16.67	1	16.67
11.	4	66.67	2	33.33	-	-
	48	72.73		19.70	4	8.06

Table (5.5) explains fifth protection topic.

	Yes		No		I don't know	
	Nu	%	Nu	%	Nu	%
1.	3	50	2	33.33	1	16.67
2.	4	66.67	1	16.67	1	16.67
3.	5	83.33	1	16.67	-	-
4.	5	83.33	1	16.67	-	-
5.	5	83.33	1	16.67	-	-
6.	6	100	-	-	-	-
7.	2	33.33	4	66.67	-	-
8.	5	83.33	1	16.67	-	-
9.	5	83.33	1	16.67	-	-
10.	2	33.33	2	33.33	2	33.33
11.	a-1	16.67	a-4	66.67	a-1	16.67
	b-2	33.33	b-3	50	b-1	16.67
	c-2	33.33	c-2	33.33	c-2	33.33
	d-3	50	d-1	16.67	d-2	33.33
	e-3	50	e-1	16.67	e-2	33.33
	f-2	33.33	f-2	33.33	f-2	33.33
	g-2	33.33	g-1	16.67	g-3	50
	57	55.88	265	25.49	17	16.67

Table (5.6) explain six protection topic

	Yes		No		I don't know	
	Nu	%	Nu	%	Nu	%
1.	5	83.33	1	16.67	-	-
2.	5	83.33	1	16.67	-	-
	10	83.33	2	16.67	-	-

Table (5.7) explains Seventh protection topic

	Yes		No		I don't know	
	Nu	**%**	**Nu**	**%**	**Nu**	**%**
1.	4	66.67	2	33.33	-	-
2.	5	83.33	1	16.67	-	-
3.	5	83.33	1	16.67	-	-
4.	5	83.33	1	16.67	3	50
5.	4	16.367	3	16.67	2	33.33
6.	5	33.33	1	50	-	-
7.	a-6 b-2 c-6	100% 33.33% 100%	3	50	b-1	16.67
8.	6	100%				
9.	5	83.33%	1	16.67	-	-
10.	5	83.33%	1	16.67	-	-

Table (5.8) showing the protection topic percentages

Topic	%
1. Facility design	62.04
2. Security	72.62
3. Safety operation	81.16
4. Monitoring	72.73
5. Quality assurance	55.88
6. Emergency preparedness	83.33
7. Medial exposure	78.21

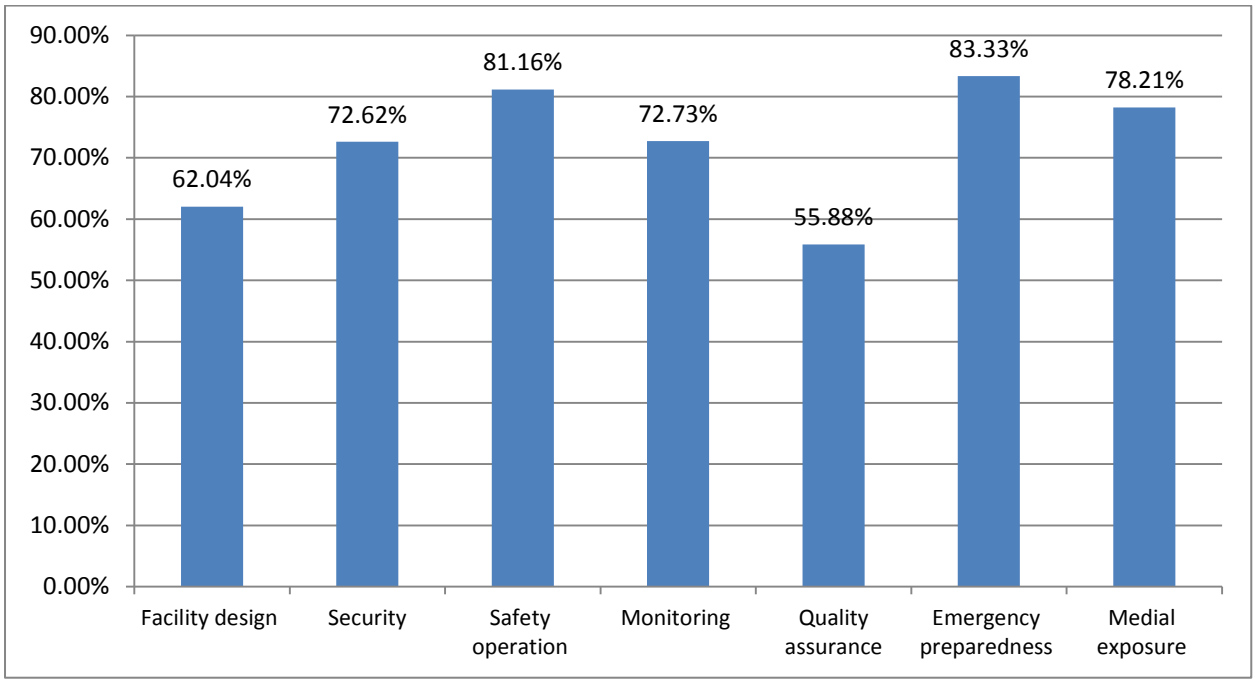


figure (5.1) showing the protection topic percentage

Chapter Five

5-1 Discussion

The first figure in the result explains the nuclear medicine staff in all the departments under study, technologist protection officer (PRO).

- The first table shows protection topic "facility design" in the nuclear medicine departments, most measures are consistent with international standards, and the little measures are inconsistent with international due to lack for resources.
- The second table shows security of sources, most procedures applied to prevent and save dealing with sources, these measures are consists with international standards, and ones are in consistent with intentional standers due to inaccurate operation.
- The third table shows operation management in nuclear medicine department, the high ratio of implementation measures of protection found here due to the radiation protection officer (RPO) always cares to implementation all his responsibilities.
- The fourth table shows monitoring for workers and places, outsmart procedures found are consistent with local rules, that are based on national regulation, and it found one case in consistent with international standards due to inaccurate operation of measurements.
- The fifth table shows emergency preparedness, it found consistent with international due to inaccurate operations.
- The sixth table shows emergency preparedness, it found consistent with international standards.
- The seventh table shows medical exposure and procedures which are applied in these cases, the most procedures are consistent with

international standards, and others in consistent due to lack of possibilities for apply the best modality.

- The eight table shows the topic protection percentages, the high ratio found in emergency preparedness (83.33%) and the low ratio found in quality assurance (55.88%) due to inaccurate operation in some cases, also the figure (5.2) showing these percentage by diagram, the high ratio (83.33%) in emergency preparedness, and the low ratio (55.88%) in quality assurance.

5-2 Conclusion

This study included the assessment of radiation protection implementation in nuclear medicine department.

This assessment involved different aspects of safety, in design facility was done apply by (62.04%) security of sources (72.62%) management of safety operation by (81.16%) monitoring (72.79%) quality assurance by (55.88%).

Emergency preparedness (83.21%) and medical exposures was done apply by (78.21%).

The average percentage achievement of all the protection measures was (72.28%).

5-3 Recommendations

- Safety culture programs for public and Co-patients should be adopt.
- Availability and periodic maintenance of equipment's should be adopted.
- Personal monitoring for workers should be done.
- Education programs for nuclear medicine safety should include intensive training and motivation.

Future studies including other nuclear medicine departments should be conducted for more reliability and accuracy.

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