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Presented By:

Brahimi Aida Nour Elimane

Azza Khaira

Theme

Activity measurement upon receipt of the generator: dose measurement absorbed by Personnels.

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In front of the jury:

❖ BENHAMIDA Soufiane	MCA	Univ.Ouagla	President
❖ AYAT zahia	MCA	Univ.Ouargla	Examiner
❖ KHODJA Sebti	MCA	Univ.Ouargla	Supervisor
❖ CHEBOUB a.elrrahmane	ING	HMR.Ouarla	Co-Supervisor

University year: 2022 / 2023

Dedication

I dedicate this work to
my dear parents
For all their sacrifices, their love, their tenderness, their support and their encouragement, thanks to which I was able to continue my studies,
Mom, thank you very much for always being by my side.
my dear brothers and sisters
Thank you very much for your encouragement and support to complete this work, especially my sister Zahra. Thank you very much.
All my beautiful family and all my nephews and nieces
All my colleagues, friends and all physics students.

Azza kheira

Praise be to God who has brought us to our desire, After that....

I dedicate this research to the owner of the fragrant biography and the enlightened thought. He was the first credit for my obtaining higher education (my beloved father), may God prolong his life.

To the one who put me on the path of life and inspired me with strength, and accompanied me with her prayers (my dear mother) may God prolong her life, to my older sister and my second mother, and to my sister Nadia, permanent support.

To the owner of the short shadow and to my brothers and their wives, each in his name, who had a great impact in overcoming many obstacles, and to the children of the family.

To my colleague at work and my teachers from primary school to this day.

Thank you all.

Brahimi Aida Nour Elimane

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Finally, we would also like to thank all the people who participated directly or indirectly in the realization of this work.

Abstract:

Nuclear medicine is a branch of medicine that is divided into two sections therapy and diagnosis, this branch uses radioactive nuclides generators that are combined with a carrier molecule, the patient is injected with one of these pharmaceutical compounds according to the purpose, which has the property of binding to the targeted organs and tissues for treatment, at this point the patient becomes a source of radiation, in addition to the radioactive materials used and some device, the abundance of radioactive source becomes very harmful to department employees in order to maintain this dose within the recommended ranges.

Therefore, employees or professionally exposed individuals to radiation should benefit from monitoring the dose measurements for their job file, the aim of this work is to estimate and reduce the dose absorbed by employees.

Keywords:

Nuclear medicine, radiopharmaceuticals, radiation protection, dosimetricmonitoring of the job profile.

Résumé :

la médecine nucléaire est un branche de la médecine qui se divise en deux section: le traitement et le diagnostique, ce domaine utilise des radiopharmaceutiques contenant de radio-isotope extrait de générateurs radioactive qui sont associés à une molécule porteuse, le patient est alors injecté avec l'un de ces composés pharmaceutiques, selon l'objectif du traitement, qui a la capacité de se lier aux organes et aux tissus ciblés, ainsi le patient devient une source de rayonnement, en plu des substance radioactives utilisées et de certains appareils, et le grand nombre de sources radioactives devient très nocif pour le personnel de service si la dose absorbée cumulée dépasse la limite minimale, d'où la nécessité de contrôler les activités des employés afin de maintenir cette dose dans les tolérances recommandées En conséquence, les salariés ou professionnellement exposés aux rayonnements doivent bénéficier d'un suivi des mesures de dose pour leur dossier de travail. Dans ce travail, nous visons à estimer et réduire la dose absorbée par les salariés.

Mots.Clés:

Médecine nucléaire, produits radio pharmaceutiques, radioprotection, suivi dosimétrique du profil de poste.

ملخص :

الطب النووي هو فرع من فروع الطب ، و ينقسم إلى قسمين هما العلاج و التشخيص ، يستخدم هذا الفرع النيكليودات المشعة المستخرجة من المولدات الإشعاعية و التي تكون مع جزيء حامل ,يتم حقن المريض بأحد هذه المركبات الصيدلانية حسب الغرض ، و التي لها خاصية الارتباط بالأعضاء و الأنسجة المستهدفة من العلاج ، و حينها يصبح المريض مصدر للإشعاع ، بالإضافة إلى المواد المشعة المستخدمة و بعض الأجهزة ، و كثرة المصادر المشعة يصبح ضارا جدا لموظفي القسم إذا تجاوزت الجرعة الممتصة التراكمية الحد الأدنى ، و من هنا تأتي الحاجة إلى التحكم في أنشطة الموظفين من أجل الحفاظ على هذه الجرعة ضمن التفاوتات الموصى بها .

وعليه فإن الموظفين أو المعرضين مهنيا للإشعاع يجب أن يستفيدوا من مراقبة قياس الجرعات لملف الوظيفة، و نهدف في هذا العمل إلى تقدير وتقليل الجرعة التي يمتصها الموظفون.

الكلمات المفتاحية:

الطب النووي، الحماية من الإشعاع، المواد المشعة، مراقبة قياس الجرعات.

Table of Contents

List of Figures

List of Tables.

List of Abbreviations and Symbols.

SPECT: Single Photon Emission Computed Tomography.

SPECT-CT: Single Photon Emission Computed Tomography – Computed Tomography.

PET: Positron Emission Tomography.

PET-CT: Positron Emission Tomography – Computed Tomography.

ICE: International Electrotechnical Commission.

AAPM: American Association of Physicists in Medicine.

ATSDR: Agency for Toxic Substances And Disease Registry.

IAEA: International Atomic Energy Agency.

EURATOM: The European Atomic Energy Community.

ICRP: International Commission on Radiological Protection.

ICRE: International Commission on Radiation Units and Measurements.

IPEM: Institute of Physics and Engineering in Medicine.

COMENA: Atomic Energy Commission.

CIPM: international committee for weight and measurement.

CCU: advisory committee for units.

IXRPC: International X-ray and Radium Protection Committee.

ITER: International Fusion Reactor.

IRNS: Institute for Radiation Protection and Nuclear Safety.

ICR: International Congress of Radiology.

ALARA: As Low As Reasonably Achievable.

PCR: Person Competent in Radiation Protection.

RSO: Radiation Safety Officer.

DNA: Deoxyribonucleic acid.

FDA: Food and Drug Administration.

FDG: Fludeoxyglucose.

3D: Three-dimensional.

RX: X-ray.

MUGA: Multigated Acquisition.

GBPS: Gated Blood Pool Study.

PMTs: Photomultiplier Tube.

QA: quality assurance.

QC: quality control.
RPP: Radiation Protection Program.
UNIDOS: universal dosimeter.
SI: international system.
GY: Gray.
C: coulomb.
KG: Kilogram.
R: roentgen.
Bq: Bequerel.
Sv: sievert unity.
KeV: kilo electron-volt.
Z: atomic number of atom.
A: mass number.
LET: linear energy transfer

General Introduction

General Introduction

Before 1895, nobody knew anything about nuclear radiation, nor was it possible to measure radiation, but only after the discovery of radiation by scientist Wilhelm Conrad Roentgen in the same year and with the development of studies and research on the nature of these rays and their Effects On living organisms, research went in a different direction and attempts were made to use them for the benefit of humans, especially in medicine by reducing the risk of exposure. Thus, different instruments for measuring radiation activity and radiation doses were discovered and developed, fully dealing with international and even national organizations to maintain public health, but the risk is not a directly measurable quantity, worse, not all definitions of dose and risk are the same. The problem with measuring risk and dose at levels close to the environment is that risk-based definitions imply very low risk, which makes measuring dose very cumbersome [1]. The difference between exposure and doses is that exposure relates only to the energy that is present in the air. The types of radiation deposited in the air and exposure are defined by the amount of electrical charge created by the radiation in one kilogram of air is generated (C/kg). Using physical principles beyond the scope of this project, this (charge/mass) can be converted into an air dose. The air dose can be converted into a tissue dose if the atomic composition of the tissue is known, in the result the dose corresponds to the amount of charge (energy) stored in the matter. This means it is only a fraction of the exposure energy, as objects absorb only a fraction of the radiation energy and not all exposures result in a dose. Depending on the type of radiation, the interaction with tissues, the distance traveled by the radiation in the body, when time is added, exposure becomes an exposure index (exposure/time) or a dose rate (dose/time) [2].

Radiation dose measurement consists of determining the amount of radiation that is present at specific location or to which a person is exposed at work or in the vicinity of a radioactive source. Radiation meters (e.g. UNIDOS) consist of a sensor, a radiation detector and a unit of measurement, the radiation dose value is determined by measuring the radiation intensity and the Exposure time and the determined value is displayed on the screen of the device or stored for use in later operations. The purpose of measuring radiation doses and exposures is to assess the risk and take the necessary preventive measures to minimize the effects and risks of radiation. In addition to dose measurement, international organizations have developed a radiation protection system and issued some regulations to ensure safe practices and obtain benefits while minimizing harm, including limiting radiation exposure dose limits and setting guidelines for driving, especially in the medical field, due to certain violations for patients or employees of medical institutions. The purpose of this work is to assess the radiation doses and medical exposure of nuclear medicine personnel, in particular to keep the health and exposure of workers within acceptable limits. In this project, we started with the following organization: The first chapter is devoted to the description of nuclear medicine and its basic aims, as well as the basic physical concepts of nuclear medicine and the description of the interactions of radiation with matter.

In the second chapter, we described measures related to radiation exposure and contamination and focused on a general description of the biological effects resulting from radiation exposure.

The third chapter is devoted to highlighting the importance of radiation protection and its basic principles, and listing improvements in this area.

The fourth chapter is reserved for the experimental part of our work and the discussion of the results of measurements of radiation doses for workers.

Chapter I: Introduction to Nuclear Medicine

Chapter I Introduction to Nuclear Medicine

I.1 Introduction:

Nuclear medicine is a branch of medicine that uses radioactive substances to diagnose and treat specific diseases. The goals of nuclear medicine vary, from early disease detection to treatment [3].

Understanding the physical principles behind nuclear medicine is essential to understand how it works. This medical field relies on the decay of radioactivity, and ionizing radiation's ability to penetrate and interact with matter.

Nuclear medicine investigations include various types of imaging, which provide valuable diagnostic and therapeutic information. Finally, there are different functional descriptions in nuclear medicine.

I.2 Objectives of Nuclear Medicine:

The main goal of nuclear medicine is to enable the diagnosis and treatment of many diseases. However, it also allows for more specific studies, such as determining the morphology of an organ or tracking the path of a radioisotope through blood vessels or lymphatic pathways [4].

I.3 Basic Physics in Nuclear Medicine:

I.3.1 Types of Radiation:

I.3.1.1 Non-ionizing radiation:

Non-ionizing radiation has insufficient energy to ionize matter. This type of radiation consists mainly of electromagnetic radiation (such as radio waves, ultraviolet, infrared, and microwaves) with a wavelength greater than 100 nanometers.

I.3.1.2 Ionizing radiation:

Radiation is said to be ionizing when it is capable of tearing electrons from matter. This means "ionizing radiation is energy transport in the form of particles or electromagnetic waves of a wavelength less than or equal to 100 nanometers, or of a frequency greater than or equal to 3x1015 hertz, capable of producing ions directly or indirectly.”. The energy equivalent corresponds to 12.4 eV. Two types of radiation are distinguished: directly ionizing radiation and indirectly ionizing radiation [5].

- Direct ionizing radiation: These particles are considered so charged that they transfer their energy directly to matter by means of Coulomb forces. We classify them as heavy charged particles (protons, deuterons, alpha, heavy ions) and light particles (electrons, positrons).
- Indirect ionizing radiation: It is radiation capable of transferring part or all of its energy in one interaction to charged particles. This type of radiation mainly consists of electromagnetic radiation (X, gamma) and neutrons.

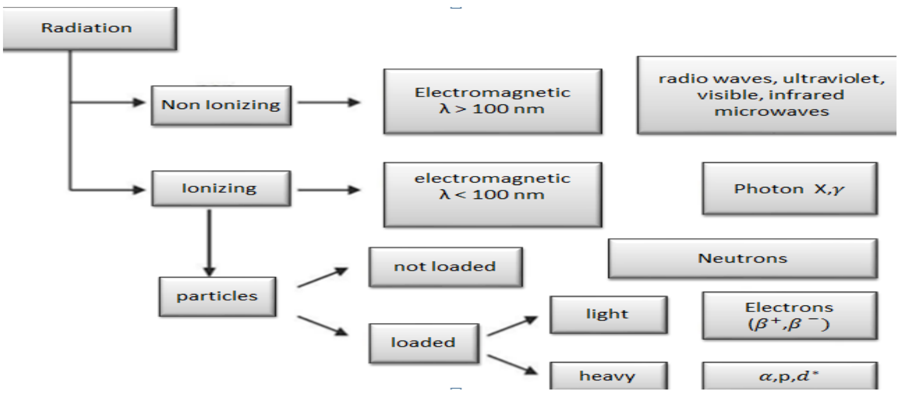


Figure I-1: The different types of radiation.

I.3.2 Notions of Radioactivity:

I.3.2.1 Definition:

Radioactivity is a phenomenon in which certain nuclei spontaneously disintegrate into another nucleus, emitting particles or radiation. The radioactive nucleus that decays is called the “father” nucleus and the nucleus that forms the “son” nucleus. The particles that form depend on the type of decay [5].

I.3.2.2 Properties (Decay law And Radioactive Activity):

Consider a population N_t of radioactive nuclei of the same isotope present at time t. The number n of nuclei which decays during the time lapse d_t:

$$\boldsymbol{n = N_t \, . \lambda . dt} \qquad \textbf{(I-1)}$$

And the variation of the number of nuclei over time:

$$\boldsymbol{\frac{dN}{dt} = -\lambda . N_t \qquad Or \qquad \frac{dN}{N_t} = -\lambda . \mathrm{dt}} \qquad \textbf{(I-2)}$$

The – sign indicates that the number of radioactive nuclei decreases with the passage of time. By integrating this differential equation:

$$\boldsymbol{N_t = N_0 e^{-\lambda \Delta \mathrm{t}}} \qquad \textbf{(I-3)}$$

N_t = Number of radioactive nuclei present at time t.

N_0= Number of radioactive nuclei present at time t_0.

Δt =Time elapses between t_0 and t, i.e. $(t - t_0)$.

λ =Represents the characteristic decay constant of the considered isotope [6].

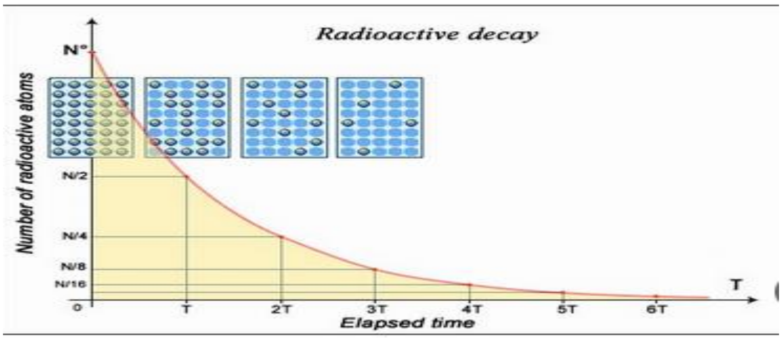


Figure I-2: Radioactive decay [73].

I.3.2.3 Activity:

The activity of a radioactive substance is the number of disintegrations per unit time [7].

This is the absolute value of the $\frac{dN}{dt}$ ratio:

$$\boldsymbol{A = \frac{dN}{dt}} \tag{I-4}$$

And $$\boldsymbol{A = \lambda . N = \lambda . N_0 . e^{-\lambda t}} \tag{I-5}$$

The unit used to measure the radioactive activity of a source is the Becquerel (Bq). 1becquerel corresponds to 1 disintegration per second. It is important to note that the activity of a radioactive source therefore depends not only on the nature of the substance but also on the quantity of the radioactive material [6].

Radioactive nuclei are emitted from three types of radiation called alpha, beta and gamma, so that:

*β- radiation, which are electrons from the nucleus.

* β + radiation, which are positrons from the nucleus. With a positive charge.

* Gamma rays, which are high-energy electromagnetic waves.

* Alpha radiation is a characteristic of heavy elements.

I.3.2.4 Different Types Decay:

Three different types of radioactive decay are distinguished, as shown in (Table I.1).

Radioactivity	**emitted particles**	**decay equation**	
		general expression	Example
$\boldsymbol{\gamma}$	Gamma photon $^0_0\gamma$	$^A_ZY \rightarrow {}^A_ZY + {}^0_0\gamma$	$^{80}_{34}Se \rightarrow {}^{80}_{34}Se + {}^0_0\gamma$
α	helium nucleus ^4_2He	$^A_ZX \rightarrow {}^{A-4}_{Z-2}Y + {}^4_2He$	$^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^4_2He$
$\boldsymbol{\beta^-}$	Electron $^0_{-1}e$	$^A_ZX \rightarrow {}_{Z+1}^{\ \ A}Y + {}^0_{-1}e$	$^{60}_{27}Co \rightarrow {}^{60}_{28}Ni + {}^0_{-1}e$
$\boldsymbol{\beta^+}$	Positon ^0_1e	$^A_ZX \rightarrow {}_{Z-1}^{\ \ A}Y + {}^0_1e$	$^{80}_{35}Br \rightarrow {}^{80}_{34}Se + {}^0_1e$

Table I-1: The different types of disintegrations.

➢ Alpha disintegration:

Alpha radioactivity (or alpha radiation, symbolized α) is a form of radioactive decay where an atomic nucleus ejects an alpha particle and transforms into a nucleus with mass number A decreased by 4 and atomic number Z decreased by 2 [8].

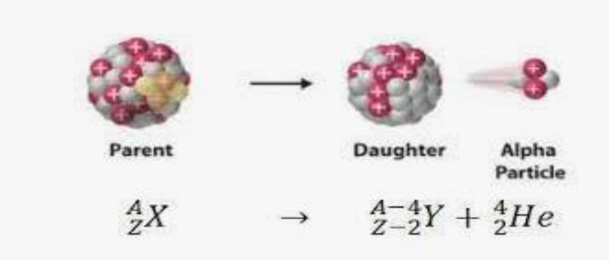


Figure I-3: Alpha disintegration [74].

➢ Beta disintegration:

Beta radioactivity or beta emission (symbol β) is a type of radioactive decay in which a beta particle (an electron or a positron) is emitted. We speak of beta minus (β-) (low energy) or beta plus (β+) (high energy) decay depending on whether it is an electron (negatively charged particle) or a positron (positively charged particle) that is emitted. The mass number A does not change during β decay [9].

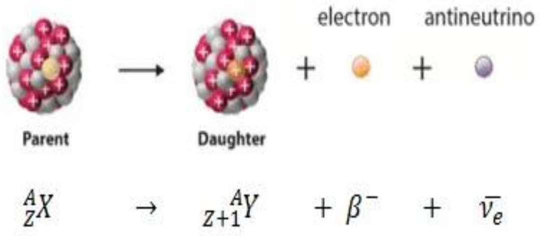


Figure I-4:Beta disintegration [75].

➢ Gamma Radioactivity:

After emission of the alpha or beta particle, the nucleus is still excited because its protons and neutrons have not found their equilibrium. It then quickly releases an excess of energy by emitting gamma radiation [10].

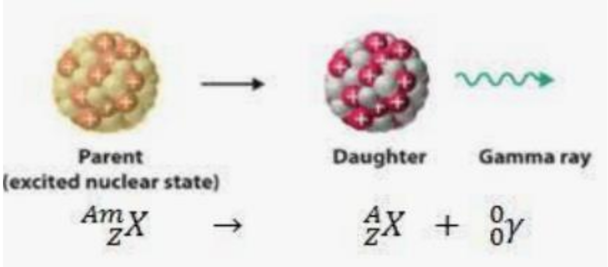


Figure I-5: Gamma radioactivity [76].

I.3.2.5 Radioactive Half-Life (Physical Half-Life):

The half-life Tp corresponds to the time after which the number of nuclei in a population of a given radionuclide has halved [6].

If at timet_0 the number of radioactive nuclei present is equal to N_0. At the end of a period T, only half will remain.

$$\boldsymbol{N_t = N_0 . e^{-\lambda T} \frac{N_0}{2} = N_0 . e^{-\lambda T} \qquad \lambda . \mathrm{T} = \ln 2} \qquad \textbf{(I-6)}$$

$$\textbf{Or} \qquad \boldsymbol{\lambda . \mathrm{T} = 0,693 \rightarrow T = \frac{0.693}{\lambda}}$$

In the international system, the radioactive period T is expressed in seconds.

I.3.2.6 Biological Half-life:

The biological period T_B corresponds to the time required for the disappearance from a given organism of half the mass of a biogenic element constituting a living being, or of any other element present in its biomass [11].

I.3.2.7 Effective Half-life:

The effective period T_{eff} is the time required for the radioactivity present at a given time to be divided by2 [9].

$$\boldsymbol{\frac{1}{T_{eff}} = \frac{1}{T_p} + \frac{1}{T_B}} \qquad \textbf{(I-7)}$$

I.3.3 Different Interactions of Ionizing Radiation with Matter:

The aim of the party is to recognize the types of interaction ionizing radiation with matter.

When radiation passes through matter there can be the following interaction:

I.3.3.1 Interaction of Charged Particles with Matter:

the charged particles moving rapidly through matter and loses her energy due to his interaction with by atoms of target substance, and they are a radiation with the ability to produce ions in living tissue ,and their interaction are related to the transfer of energy to matter in two ways (ionization – excitation) [12] .

The charged particles considered here are:

- Alpha particles (α)
- Beta particles (β - and β +)

➢ Interaction with an Electron of the Target Atom:

The energy ΔE given up by the incident particle issferred to the electron of the target atom, and the phenomenon (excitation – ionization) is determined depending on whether ΔE is sufficient or not to eject the electron from its orbit, let $W_L$be the binding energy of this electron.

The ionization When $\Delta E \geq W_L$: the electron is ejected from its orbit with kinetic energy ($W_L - \Delta E$), there is an ionization of the target atom. The ejected electron, known as the secondary electron, can in turn create other ionization if its kinetic energy is sufficient [13], as the picture below shows:

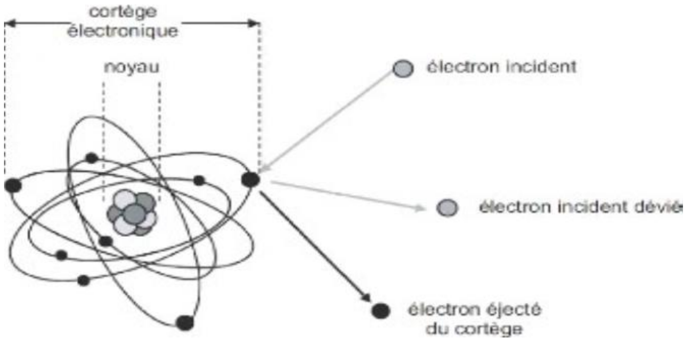


Figure I-6:ionization phenomenon [77].

The excitation When $\Delta E < W_L$: the energy transfer ΔE cannot produce any ionization but can take the target electron to higher energy level with excitation of the target atom when ΔE is reliable, this excitation results in heat dissipation, and when ΔE is higher, the transferred energy can secondary de dissipation in the form of a low-energy electromagnetic emission[13] , as shown in the following picture:

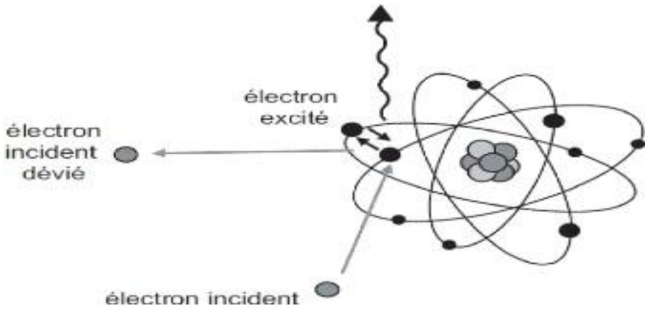


Figure I-7: The excitation phenomenon [77].

➢ Interaction with the Nucleus of the Target Atom:

When a charged particle passes near the nucleus of the target atom, it is repelled or attracted by the nucleus depending on the charge is negative or positive. The trajectory of the particle is deflected, which leads to a loss of kinetic energy, emitted in the form of electromagnetic radiation (braking radiation) [13].

When the incident particle passes close to the nucleus, it is strongly slowed down and deflected with the emission of a very energetic photon. And when the particle passes far from the nucleus, it is little deflected and braked and the braking photon has a low energy.

I.3.3.2 Interaction of Electromagnetic Radiation (X-rays and Gamma rays) with Matter:

Electromagnetic radiation interacts with matter through several processes, but in most health physics applications that involve x or gamma rays, at least one of three principal interaction mechanisms with atoms:

- Photoelectric effect.
- The Compton effect.
- Pair production.

➢ Photoelectric Effect:

The photoelectric effect is preponderant for energies between 0.01 and 0.1 MeV, when the incident photon transmits all her energy to electron in the medium and ejects it while imparting a certain kinetic energy to it [14], the following picture shows the photoelectric action.

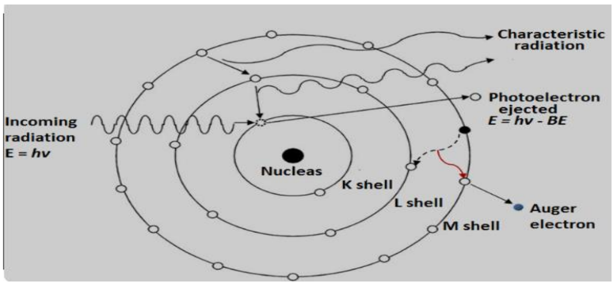


Figure I-8: The photoelectric Effect [78].

➢ Compton Effect:

In a simple way, the Compton Effect is attributed to the elongation of the wavelength and the change in the direction of the trajectory of a photon in the diffusion of this one on a particle of matter, The variation in wavelength therefore gives a variation in energy [15], the following image summarizes this explanation:

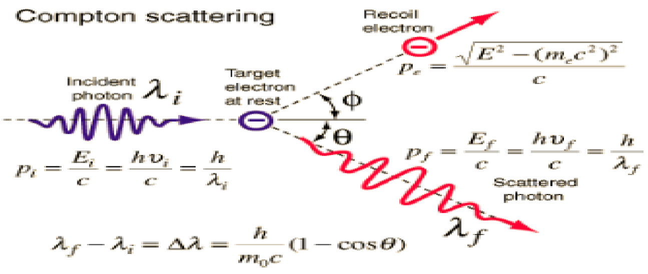


Figure I-9: Compton Effect [79].

➢ Pair Production:

Absorption of a photon by an electron in a negative energy state is called pair production. and the photon energy is converted into the total energy of the pair, in which a photon with energy $h\nu \geq$

1.022 MeV disappears, and an electron-positron pair appears with particle kinetic energies T+ and T- [16], it is expressed by the following equation:

$$hv = 2mC^2 + T_- + T_+ \tag{I-8}$$

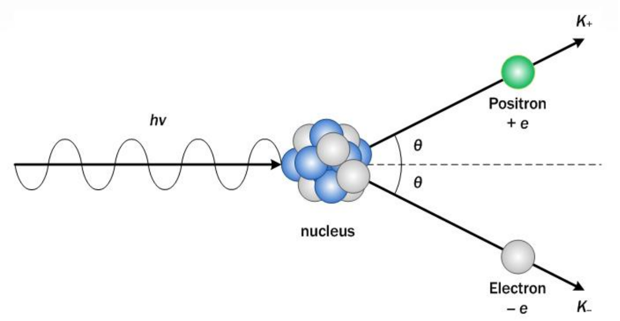


Figure I-10: pair production [80].

➢ Comparison of the Three Effects:

The following table shows a comparison of the three effects.

	Relative Incident beam	Relative Target	energy	Z
Photoelectric effect	Total absorption	Electrons K or L layer	Low energy	High Z
Compton effect	Partial absorption and scattering	Peripherals electrons	Average energy	Average Z
Pair production	Full absorption	nucleus	High energy	High Z

Table I-2: comparison of the three effects

I.3.3.3 Interaction of Neutrons:

A neutron can react with a nucleus in different ways, the principal mechanisms of importance here are nuclear reactions, which are inelastic, and elastic scattering.

➢ Radiative capture for slow neutrons (E<1KeV):

The neutron is absorbed by the nucleus which gives a new nucleus, and these interactions are considered an important in the process of producing isotopes, if they happen to heavy nuclei, then gamma rays are emitted with the resulting isotope, the reaction is written [17]:

$$ {}^{A}_{Z}\mathrm{X} + {}^{1}_{0}\mathrm{n} + \gamma \rightarrow {}^{A}_{Z}\mathrm{X} \qquad \textbf{(I-9)} $$

$$ {}^{235}U(n,\gamma)^{236} \quad \mathbf{U} \qquad \textbf{(I-10)} $$

As for light nuclei, they emit alpha rays or protons with the resulting isotope:

$$ {}^{10}_{5}\boldsymbol{B} + \boldsymbol{n} \rightarrow {}^{7}_{3}\boldsymbol{Li} + \boldsymbol{\alpha} \qquad \textbf{(I-11)} $$

$$ {}^{14}_{7}\boldsymbol{N} + \boldsymbol{n} \rightarrow {}^{14}_{6}\boldsymbol{C} + \boldsymbol{\rho} \qquad \textbf{(I-12)} $$

➢ Elastic Scattering for Fast Neutrons (E>1KeV):

The fast neutron hits a nucleus to which it loses part of its kinetic energy, and there is no change in the total kinetic energy of the two. An initially stationary nucleus recoils with initial kinetic energy exactly equal to the amount of kinetic energy that the neutron loses, the maximum possible energy transfer is ***E***, The As a result, fast neutrons are very penetrating [17].

I.4 Radionuclides:

A radiopharmaceutical is a drug used for diagnostic or therapeutic purposes. It consists of a radioactive isotope called a radionuclide or radioelement and most often combined with a vector,.it is based on the properties of the radioactive emission of a radioelement.

Radioactive isotope (radioelement) +Vector=pharmaceutical radio (tracer) It is chosen according to certain criteria:

- Nature of the radiation.
- Radiation energy.
- Physical period.
- Parentage.

The following radionuclides are most commonly used in diagnostic nuclear medicine procedures: 99mTc, 201Tl,67Ga, 111In, 123I, 131I, 133Xe, and 18F. All except 99mTc, 131I,and 133Xe are produced in particle accelerators, and are not under the control of the NRC, The various positron emitting radiopharmaceuticals used in positron Emission tomography (PET) is also produced by particle accelerators [18].

I.4.1 Routes of Administration of the Tracer:

- Venous route: the most common, the radiopharmaceutical product will be transported and will follow the metabolism of the vector.

- Oral route: this method concerns in particular studies of gastric emptying or gastro esophageal reflux.
- By inhalation: this concerns the study of pulmonary ventilation.

I.4.2 Half-Life:

The half-life should be of a similar length to that of the examination, usually a few hours, because the half-life of the radionuclide determines how quickly the radioactivity will decay, so if it is very short then the activity will have decayed to a very low level before imaging has started.

On the other hand, if it is too long then the patient will remain radioactive for a considerable time and in order to reduce the possibility of radiation damage the amount of activity administered will have to be kept low relatively.

I.5 Iratherapy:

Iratherapy, also known as molecular radiotherapy or targeted radionuclide therapy, is a form of radiation therapy that uses radioactive molecules to selectively target cancer cells. The radioactive molecules, also known as radiopharmaceuticals, are designed to bind to specific molecules or receptors on cancer cells, delivering a high dose of radiation directly to the tumor cells while sparing the healthy tissues.

The radiopharmaceuticals emit different types of radiation, such as beta particles, alpha particles, depending on the specific type of cancer and the targeted molecule. Beta particles, for example, can travel a short distance in tissue and are effective in treating tumors close to the surface of the body, while alpha particles have a higher energy and can penetrate deeper into tissues, making them suitable for treating tumors, iratherapy is typically administered through an injection or infusion, and the radiopharmaceuticals travel through the bloodstream to reach the cancer cells. Once they reach the targeted cells, the radioactive molecules emit radiation, damaging the DNA of the cancer cells and ultimately killing them.

These results in fewer side effects compared to traditional radiation therapy, such as fatigue, nausea, and skin irritation. Iradiotherapy is also effective in treating tumors that are resistant to other treatment options, such as chemotherapy, iratherapy is currently used to treat various types of cancer, including prostate cancer, neuroendocrine tumors, and lymphomas. It is also being investigated as a potential treatment option for other types of cancer, such as breast cancer and pancreatic cancer [20].

I.6 Scintigraphy:

Scintigraphy is a medical imaging technique (diagnostic) that uses radiopharmaceuticals to produce images of the body; these compounds are injected, swallowed, or inhaled by the patient and then targeted to a specific organ or tissue in the body, where they accumulate.

Scintigraphy works by detecting the gamma rays emitted by the radionuclide using a special camera called a gamma camera. The gamma camera contains a crystal scintillator that converts the gamma rays into light, which is then detected by photomultiplier tubes. The data from the photomultiplier tubes is then used to produce images of the distribution of the radiopharmaceutical in the body.

One of the advantages of scintigraphy is its ability to provide functional information about the body, rather than just anatomical information. This is because radiopharmaceuticals can be targeted to specific physiological processes, such as blood flow, metabolism, or receptor binding. For example, a radiopharmaceutical that is taken up by cells in the bones can be used to diagnose bone cancer or other bone disorders [21].

There are many scintigraphy tests, the most famous of which are:

- ✓ **Bone Scintigraphy:**

It is a nuclear radiological procedure to examine the distribution of the radioactive product in the skeletal system, The areas where the radionuclide collects are called "hot spots , and it is used also to study the change in the physical or chemical condition of the bones corresponding to the lesion, or to determine the areas of metastasized , or to study the progression and development of certain conditions, and bone trauma not seen on ordinary X-rays, the following image shows an example of bone scintigraphy[22]:

Figure I-11: Example of bone scintigraphy [80].

- ✓ **Pulmonary ventilation :**

is a diagnostic test, to evaluate lung perfusion and ventilation, And study the distribution of the tracer in the alveoli and pulmonary arteries, This test consists of two phases, a ventilation scintigraphy (V) , and a perfusion scintigraphy (Q) [23] .

- ✓ **Renal scintigraphy (kidney) :**

Renal scintigraphy it i a test to evaluate kidney function and anatomical, and determine whether they are working properly.

- ✓ **Myocardial scintigraphy :**

After injection with radiopharmaceutical the patient undergoes myocardial scintigraphy (through both resting and stress phases) for verification, the presence of major cardiac events in asymptomatic patients or those with atypical symptoms (atypical chest pain or dyspnea), and possible predictors for major cardiac events.

As it can also detect regions of myocardial infarction by showing areas of decreased resting perfusion. And the function of the myocardium is also evaluated by calculating the left ventricular ejection fraction (LVEF) of the heart. This scan is done in conjunction with a cardiac stress test [24].

✓ **Thyroid scintigraphy:**

Thyroid scintigraphy) is a diagnostic test that provides information about the structure and function of the thyroid, A thyroid scan can help assess:

- neck masses
- hypothyroidism
- hyperthyroidism
- Thyroid malignancy.
- Thyroglossal duct cyst.
- Benign diffuse goiter.
- Radiation therapy planning.

✓ **Brain scintigraphy:**

This test is used to assess the function and perfusion of the brain, blood flow to it, and cases of brain death

I.6.1 Image Acquisition:

There are different forms of obtaining scintillation images from the gamma photons emitted by the patient; static or dynamic tomograms, gated or planar.

- **Static imaging:**

Is used to collect images of different regions of the body or differently angled (oblique) views of a particular region of interest.

- **Dynamic Images:**

If the distribution of nuclide in the organ is changing rapidly and it is important to record this change, multiple rapid images of a particular region of interest are acquired. This type of image acquisition is called dynamic imaging, and it is used, for example, to collect sequential in one second images (called frames).

- **Gated Images:**

Gated images are a variation of dynamic images, Continuous images are obtained of a moving organ (generally the heart) and data are coordinated with the rate of heart beat (using electrocardiographic leads to keep track of the R–R interval for heart imaging). Gating is used to divide the emission data from the radioactive blood pool in a Gated Blood Pool Study (GBPS) or Multigated Acquisition (MUGA) into “frames” so that wall motion can be evaluated and a left ventricular ejection fraction can be calculated, During gated imaging [26].

I.6.2 Diagnostic Devices Used in Nuclear Medicine:

I.6.2.1 Gamma Camera:

This camera derives its name from its specialty, that is, it is specialized in capturing gamma rays emitted from the patient, and these are often shaped like a box and attached to a round, donut-shaped gantry. The patient lies on an exam table that slides in between two gamma camera heads that are above and below the patient. Sometimes, the doctor will place the gamma camera heads at a 90-degree angle over the patient's body, Depending on the rays falling on the detectors of the device, an image of the body is produced [27].

- **Principe :**

The principle of the gamma camera is to transform the gamma photons emitted by the patient, after the administration of a radiopharmaceutical product, into a measurable physical quantity (an electric current). Localization of these photons results in a scintigraphic image of drug distribution.

And the device looks like this:

Figure I-12: Gamma Camera [81].

- **The Components of the Gamma Camera :**

1. Collimator: A lead shield with tiny holes that allows only gamma rays coming from a specific direction to enter the camera.

2. Crystal: A scintillation crystal (usually made of sodium iodide or cesium iodide) that absorbs gamma rays and produces visible light.

3. Photomultiplier Tubes (PMTs): Sensitive detectors that convert the visible light produced by the scintillation crystal into electrical signals.

4. Signal Processing Electronics: Circuitry that amplifies, digitizes, and processes the signals generated by the PMTs.

5. Computer System: A computer that controls the camera and processes the data acquired from the signal processing electronics to produce images of the distribution of gamma-ray sources in the patient.

I.6.2.2 SPECT:

In SPECT, Scanner technology is combined with gamma camera is a technique in nuclear medicine for diagnosing and staging various diseases. The SPECT/CT scanner combines functional and anatomical imaging, providing highly accurate and precise information about the body's internal structures and functions. The gamma camera detects the radiation emitted by a radioactive tracer that is injected into the patient's body, while the SPECT scanner creates 3D images of the tracer's distribution throughout the body. The combination of these two technologies enables the visualization of the tracer's activity within specific organs or tissues, allowing for the detection of abnormalities, such as tumors or infections. SPECT/CT can also be used to monitor the effectiveness of treatment, and guiding the doctors in discovering the patient's condition .

I.6.2.3 Positron Emission Tomography (PET):

Positron emission tomography (PET) is an isotopic imaging technique based on the use of radiopharmaceuticals labeled with isotopes positron emitters (β+). When emitted, the positron collides with an electron in the procession, resulting in an annihilation reaction and the production of two photons of 511 keV, emitted at 180° from each other.

These are detected by coincidence, using a PET camera. Coincidences are converted into tomographic images using mathematical reconstruction techniques that are corrected for tissue attenuation and for the physical half-life of the radiopharmaceutical to obtain 3D images [28].

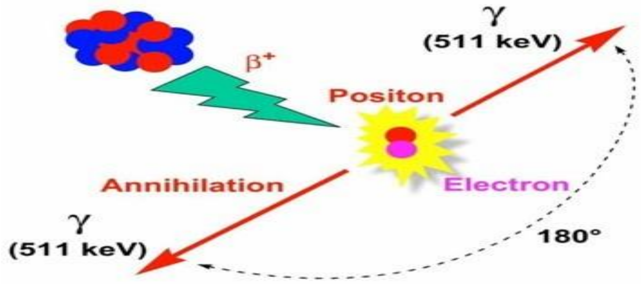


Figure I-13: Emission and annihilation of a positron.

I.6.2.4 Image Fusion:

Single photon emission CT/CT (SPECT/CT) and positron emission tomography/CT (PET/CT) units can perform both CT imaging and nuclear medicine exams at the same time; Image fusion allows the doctor to see information from two different exams in one image. This leads to more precise information and a more exact diagnosis.

I.7 Conclusion:

In conclusion, the nuclear medicine has made significant advancements in recent years, with new technologies and techniques improving diagnostic accuracy and treatment efficacy. Despite concerns over radiation exposure, nuclear medicine remains a safe and effective option for many patients. Ongoing research and development in the field hold promise for even more precise and Personalized approaches to patient care in the future.

Chapter II: Detection and measure of radiations and their effects

Chapter II : Detection and measure of radiations and their effects

II.1 Introduction:

Human senses cannot detect ionizing radiation. However, excessive and long-term exposure may cause adverse health effects. . Using the right type of radiation detection equipment provides an effective way to reduce exposure and helps reduce doses.

In general, the higher the activity, the greater the absorbed dose. While the absorbed dose would be a reasonable measure of the chemical or physical effects due to the absorbed energy of a radioactive source. Accordingly, some types of detectors calculate radiation events, while others measure the dose to humans. It is necessary to conduct correct radiation monitoring when there is a possibility of radiation exposure. It is equally important that the correct monitoring tool is chosen and used.

II.2 Dosimetric Quantities and Units:

II.2.1 Absorbed Dose (D):

Absorbed dose is the basic physical quantity for measuring radiation doses and is defined as the amount of energy absorbed in joules per unit weight of the substance in kilograms and measured in units of gray, where :

$$\boldsymbol{D(Gy) = \frac{E}{m}} \qquad \textbf{(II-1)}$$

Where D is the absorbed dose, E is the absorbed energy (joule) , and m is the mass (Kg) of the material [28].

II.2.2 Equivalent Dose H_T:

The absorption of a dose of radiation by living matter can cause a biological effect, the magnitude of which depends on the type of radiation involved. A weighting factor is assigned to each type of radiation, according to its potential to cause biological harm (Table II 1). We multiply the absorbed dose by a weighting factor, and we get the equivalent dose, expressed in milli sievert (mSv) [29].

$$\boldsymbol{H_T = DW_R} \qquad \textbf{(II-2)}$$

Such as:

H_T: The equivalent dose.

D: The absorbed dose.

W_R: The weight factor, sometimes called the quality factor.

If the irradiation comes from several kinds of particles, it is a matter of summing over all the D_R :contributions of each variety.

$$H_T = \sum_R W_R D_R \qquad \text{(II-3)}$$

A table representing a summary of the weighting factors as recommended ICRP 103 [30]:

Nature and Energy of Radiation	**Nature and Energy of Radiation** W_R
photons all energy	1
muon electrons (all energies)	1
Neutrons $E < 10\ Kev$	5
Neutrons $10Kev < E < 100Kev$	10
Neutrons $100Kev < E < 2Mev$	20
Neutrons $2Mev < E < 20Mev$	10
Neutrons $E > 2Mev$	5
Protons $E > 2Mev$	5
α particles, fission fragments, nucleiheavy	20

Tableau II-1: Summary of weighting factors according to ICRP 103.

II.2.3 Effective Dose (E):

The effective dose E is equal to the sum of the equivalent doses weighted by a factor linked to the sensitivity to radiation of the organs or tissues concerned, W_T [13].

$$E = \sum_T W_T H_T = \sum_T w_T \sum_R W_R D_{T.R} \qquad \text{(II-4)}$$

The unit for E is the Sievert (Sv). The currently accepted values for W_T are listed in the table below. They Taken from ICRP publication 103, Commission recommendation 2007 International Radiological Protection.

Tissue Or Organ	W_T	$\sum W_T$
Bone marrow, colon, lungs, stomach, breast, remnant tissues	0.12	0.72
Gonads	0.08	0.08
Bladder, esophagus, liver, thyroid	0.04	0.016
Bone surface, brain, salivary glands, skin	0.01	0.04
	Total	1

Table II-2: Tissue weighting factors.

II.2.4 Linear Energy Transfer (LET):

Linear energy transfer was introduced to account for the spatial distribution of ionizations. It makes it possible to characterize the quality of radiation by a quantity without having to describe each time the type of particle and its energy. The LET is defined as the amount of energy released by radiation when it travels a distance dx and is expressed in keV per micrometer (keV.µm-1) [45]:

$$\boldsymbol{TEL = -\frac{dE}{dx}} \qquad \textbf{(II-5)}$$

II.2.5 Units:

- **The Becquerel (Bq):**

The Becquerel (Bq) measures the activity of the radioactive source, corresponds to one nucleus disintegration per second.

$$1\,Bq \;=\; 1\,disintegration\,per\,second.$$

This unit on the scale of the atom is so small and so unsuitable for describing the activity of radioactive substances that one generally resorts to multiples:

$1KBq = 10^3 Bq$

$1GBq = 10^6 Bq$

$1MBq = 10^9 Bq$

- **The gray (Gy):**

This unit quantifies the density of energy deposited by radiation in an organism or an object exposed to a radioactive sample, this is called absorbed dose.

$$1Gray \;=\; 1\,joule/1\,kilogram\;and\;1Gray \;=\; 100\,rad$$

$1mGy = 10^{-3} Gy$

$1\mu Gy = 10^{-6} Gy$

$1nGy = 10^{-9} Gy$

- **The Sievert (Sv):**

The unit Sv stands for Sievert, which is a derived unit of the International System of Units (SI) used to measure ionizing radiation dose equivalent. It is used to quantify the biological effects of radiation on human tissue.

II.3 Origin of Exposure and Contamination:

II.3.1 External Exposure:

External exposure occurs when the radiation source is at a distance from the body [24].

This source can emit radiation which interacts with the human body by creating ionizations. [39], If the whole body is affected, there is global exposure, if only a part is affected, we speak of partial exposure [40].

External exposure is measured using dosimeters [38].

Figure II-1: External exposure [82].

II.3.1.1 Sources of External Exposure:

- Radiotherapy and radiodiagnosis,
- Sealed radioactive sources (massive sources that do not release material),
- Generators or accelerators [33].

II.3.1.2 Main Characteristics

- The possibility of obtaining very high doses.
- At very high dose rates.
- Irradiation ceases completely with the end of exposure (removal or shutdown of the source, protection, etc.)[33].

II.3.2 External Contamination:

It occurs when the source is outside the body, and in contact with the skin.

So that there are deposits of radioactive products on the skin, and skin contact with a radioactive product can lead to internal exposure by penetration of that product through the skin [27].

External contamination is measured with an external counter: probe or spectrometer targeted at the contaminated area, skin smear, etc [38].

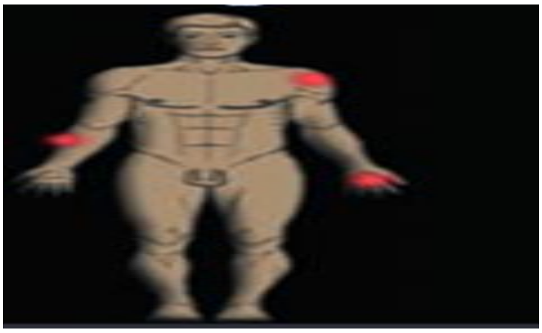


Figure II-2:external contamination [82].

II.3.2.1 Sources of External Contamination:

- Fallout after a nuclear accident or explosion.
- Radioactive dust, aerosols or solutions [33].

II.3.2.2 Main Characteristics:

- The possibility of obtaining high doses, especially to the skin.
- At high dose rates.
- The irradiation stops at the end of the treatment (elimination of the contaminant) [33].

II.3.3 Internal Contamination:

Occurs when radioactive substances penetrate the body by inhalation, ingestion or through the skin (wound) [39].Internal exposure continues until the radionuclide has been eliminated from the body. Internal exposure is assessed from anthropogammametric measurements andradiotoxicological measurements on biological samples (urine, stool, etc.) [38].

Figure II-3:internal contamination [82].

II.3.3.1 Sources of Internal Contamination:

- The consequences,
- Radioactive dust, aerosols or solutions.
- By deposit on the food, atmospheric contamination or objects that could cause injury, or by resuspension of external contamination [33].

II.3.4 Types of Contamination:

II.3.4.1 Surface Contamination:

- Fixed contamination: which is difficult to remove without vigorous mechanical action it cannot spread but can cause external exposure.
- Non-fixed contamination: which is easily transferable by contact, by resuspension or by production of aerosols [39,43].

II.3.4.2 Atmospheric Contamination:

- This inevitably leads to internal exposure of the organism by inhalation. It is often the consequence of labile contamination. Its concentration in the air must be measured or estimated in Bq/m3 [39,43].

II.3.4.3 Body Contamination:

- External contamination: caused when the radioactive substance is deposited on the skin, hair, clothing.
- Internal contamination: occurs when the radioactive substance is inhaled, ingested or if it migrates through the skin [36, 43].

II.3.5 Comparison of Exposure and Contamination:

The following table shows a simple comparison between radiation exposure and contamination:

Exposure	**Contamination**
Radiation waves or particles penetrate the body. If someone is exposed to external radiation • Do not become radioactive • Pose no hazard to nearby individuals • Do not become contaminated	Unwanted radioactive material in or on the body, or spread about the environment. If someone is externally contaminated, they can spread contamination: • About 80% can be removed by taking of clothing • Most remaining contamination can be removed by gently washing skin and hair Internal Contamination – Can result from inhalation, ingestion, absorption, puncture or open wound.

Table II-3: exposure Vs contamination.

II.4 Detectors and Measurement Devices:

II.4.1 Activity Meter:

An activity meter is a measurement system used for measuring the activity of variable-volume liquid radioactive sources, generally found in vials or syringes.

It consists of the following elements:

- An ionization chamber with a well.
- A stabilized high voltage power supply.
- An electrometer for measuring the ionization current intensity.
- Activity calculation electronics.
- A display device sometimes supplemented by a printer.

The radionuclides generally used in nuclear medicine services for activity measurements are 18F, 67Ga, 90Y, 99Tcm, 111In, 123I, 125I, 131I, and 201Tl [48].

Figure II-4: Activity meter models [83].

II.4.2 Detectors:

II.4.2.1 Semiconductor Detectors:

Semiconductors are increasingly used in radiation protection measuring equipment, such as electronic dosimeters or spectrophotometers.

It works like an ionization chamber. Ionizing radiation removes electrons from semiconductors; the number of collected charges is proportional to the energy given up by the particle.

Ionizing radiation affects a semiconductor where ion pairs (electrons and holes) are produced so that the generated ion pairs are collected between the two ends of the semiconductor material, which are equivalent to the collecting electrodes in gaseous detectors [44].

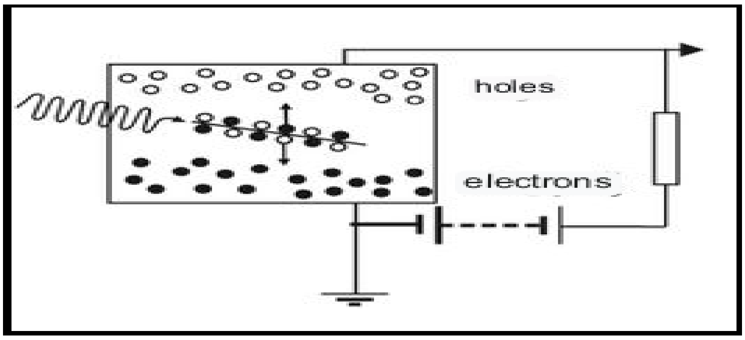


Figure II-5: diagram of solid state detectors [84].

II.4.2.2 Scintillation Detectors:

A scintillation detector, also called a scintillation counter or more commonly Wind scintillator, is an instrument made of a material that emits light to Following a deposition of energy by interaction of radiation [44].

Inside the scintillator, the ionizing radiation is converted into luminescent radiation.

Miner. The photo-cathode then the photomultiplier which are both associated with the Scintillators transform light energy into electrons and then multiply them using dynodes [38].

The sensitive size of the detector consists of two main types of sensing materials:

- Organic scintillators :(based on benzene compounds: Anthrac ene, naphthalene, stilbene, terphenyl, etc.) Which are found in the form of plastics or in liquid solution.

- Inorganic scintillators: which are used in single crystals or in powder form (mainly alkali halides) [44].

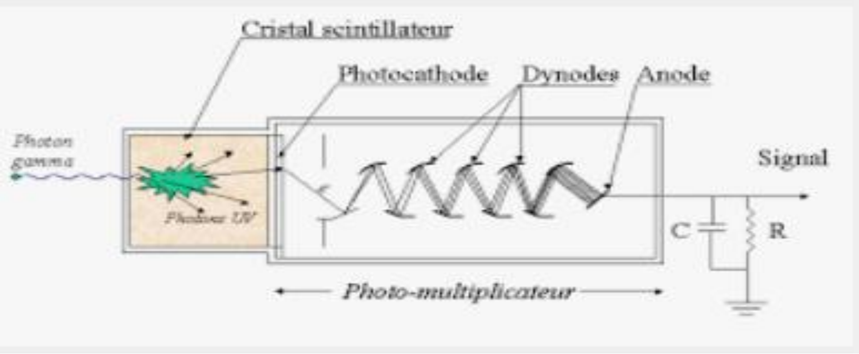


Figure II-6: diagram of a scintillation detector.

II.4.2.3 Gas Detectors:

Gas detectors operate based on the ionization and/or excitation of gas molecules when exposed to nuclear radiation. When the gas is ionized, electric charges are produced which move towards the electrodes within the detector. These charges can be collected to generate an electric signal that can be measured and analyzed. By measuring the intensity of this signal, the amount of nuclear radiation that has been absorbed by the gas can be determined, allowing for the measurement of the energy of the detected particles or photons.

Applying an appropriate voltage between the electrodes causes the charges within the gas to separate, increasing the effectiveness of ionization and reducing the rate of recombination. This leads to the collection of a greater number of electric charges and improves the accuracy of the measurement [46].

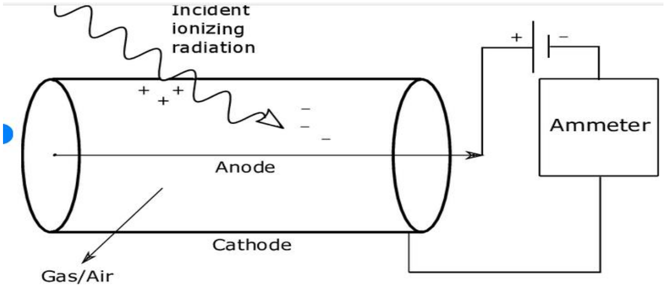


Figure II-7: diagram of a gas ionization detector [84].

II.4.3 Measurement Devices:

II.4.3.1 Portable Devices:

For surface or atmospheric control, portable devices can perform these measurements by translating them into dose (radiometers, in mSv) or activity (contaminometers, in MBq) [47].

II.4.3.2 Fixed Detectors:

Fixed detectors in the form of tags/alarms are also available. Samples (surface, etc.) can provide information on the instantaneous activity of a sample at a given time [47].

II.4.3.3 Internal Contamination Measurement:

Internal contamination measurement. Internal contamination can only be evaluated through blood radio toxicology and/or excreta (urine, mucus) measurements reported to the effective half-life of the radioactive material in the body, or through anthrop radiometry. These tests are prescribed by the occupational physician, who keeps the results confidential [47].

II.4.3.4 Personal Dosimetry (Operational Dosimeter, Passive Dosimeter):

For personal dosimetry, the devices can display a dose rate in real time (operational dosimeter) or be with deferred reading (passive dosimeter) [47].

➢ Operational (active) dosimetry :

Operational dosimetry is an individual and compulsory dosimetry for personnel working in a controlled area. It measures and analyzes the doses actually received during exposure with continuous recording and immediate reading. [6]

Characteristics of operational dosimetry:

- Operational dosimetry must display the dose received and the dose rate in real time.
- The dose rate threshold must be less than or equal to 0.5 µSv/h. [6]

➢ Passive dosimetry (reference dosimetry):

Passive dosimetry is mandatory for all exposed workers, regardless of their A and B classification. [6]

Characteristics of passive dosimetry:

- The duration of wearing the passive dosimeter is the calendar month for category A personnel or the quarter for category B personnel.
- For all the radiation likely to be measured, the measurement threshold for passive dosimetry must be no more than 0.2 msv and the minimum extent of the range covered 500 msv. [6]

The following picture shows the different measuring devices used.

Figure II-8: Examples of measuring devices (in order: chest passive dosimeter, chest operational dosimeter, ring passive dosimeter, crystalline passive dosimeter, contaminometer) [48].

II.5 Effects of Ionizing Radiation (Radiobiology):

II.5.1 Molecular Effects:

II.5.1.1 Direct Effects:

Direct impact is the interaction of a charged particle with the DNA atom of the cell responsible for the lesions. Therefore, DNA molecules are directly damaged by electrons [12].
The DNA molecule consists of two chains of nucleotides (strands) organized in duplicate, each of the strands consists of a chain of bases: adenine (A), thymine (T), cytosine (C), guanine (G), linked to each other by sugars (deoxyribose) and phosphoric acids [16].

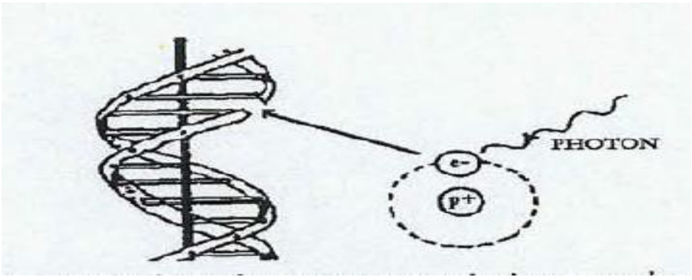


Figure II-9: Direct effect of ionizing radiation on the DNA molecule [33].

- Change in the chemical structure of nucleotides.
- Fracture of the sugar-phosphate backbone.
- Hydrogen bonds between bases are broken [32].

II.5.1.2 Indirect Effects:

At the level of the DNA molecule, the lesions are caused by the products resulting from the radiolysis of water. Unlike electrolysis which produces ions, water irradiation produces free radicals. Free radical is an atom or molecule that has an unpaired electron [16].

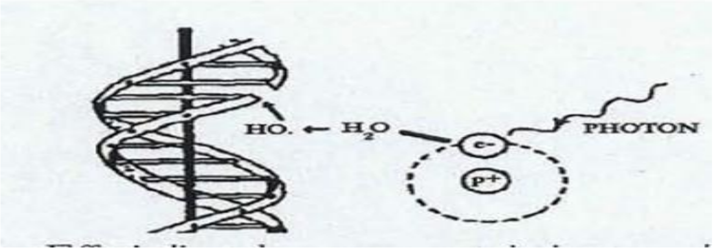
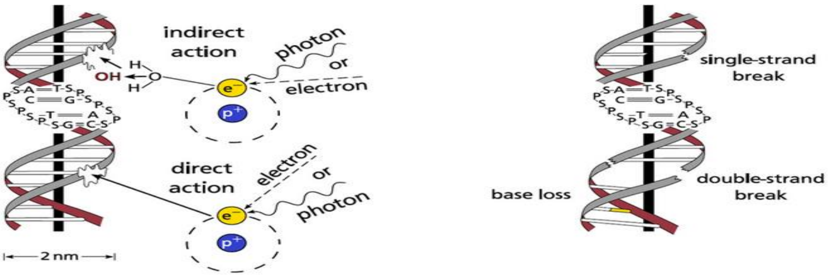


Figure II-10: Indirect effects of ionizing radiation on the DNA molecule [33].

The following figure (Figure II.11) shows the difference between the direct and indirect effects of ionizing radiation on the DNA.



(a) (b)

Figure II-11: The direct and indirect effects of ionizing radiation on the DNA [86].

II.5.2 Cellular Effects:

II.5.2.1 Immediate Cell Death:

It occurs for enormous doses, of the order of a thousand Gy. It is a rare phenomenon.

Two cell types are an exception to this rule and die for lower doses (of the order of Gy): lymphocytes and oocytes.

We distinguish:

Death by cellular necrosis, and, Apoptosis or genetically programmed death and, the presence of intracellular moderators including the p53 protein [33].

II.5.2.2 Delayed Cell Death:

For lower doses (1Gy), the cells continue to live for a longer or shorter time. A certain part loses their ability to divide; it is mitotic death which is the irreversible loss of the proliferative capacity of the cell [33].

II.5.2.3 Cellular Mutations and Cancer:

The effect of ionizing radiation on the DNA double helix is defined in the form of primary lesions. Damaged areas will most of the time be restored by rearrangements of (badly) DNA molecules. This reorganization will have an aspect that depends on the number of primary lesions involved, their location, repair kinetics and genome organization within the nucleus [34]. Thus, it becomes a viable mutant cell that is capable of dividing and reproducing without control, so it is not recognized by the immune system and becomes a cancerous cell [35].

II.5.2.4 Factors of Cellular Sensitivity:

Cell type, Dose fractionation, Dose rate, Radiation type, Oxygen effect, Role of the cellular environment (concept of cellular cooperation).

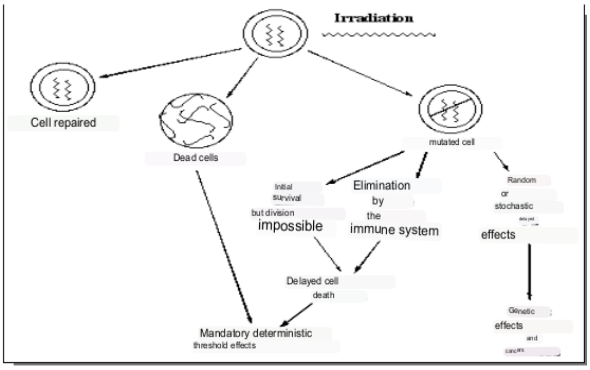


Figure II-12: Overall scheme of cell irradiation [37].

II.5.3 Tissue Effects:

Irradiation manifests itself through mutations, transformations, or the occurrence of death. Cellular, which means consequences at the tissue level. Radio intensity-Induced depends on radio sensitivity, repair ability, cell proliferation rate especially the time of survival of functional cells in the differentiated state.

II.5.3.1 Most Radio-Sensitive Tissues:

- Embryonic tissues.
- Hematopoietic organs.
- The intestinal mucosa.

II.5.3.2 Most Radio-Resistant Tissues:

- Connective tissue.
- Muscle tissue.
- Adult nervous tissue [36].

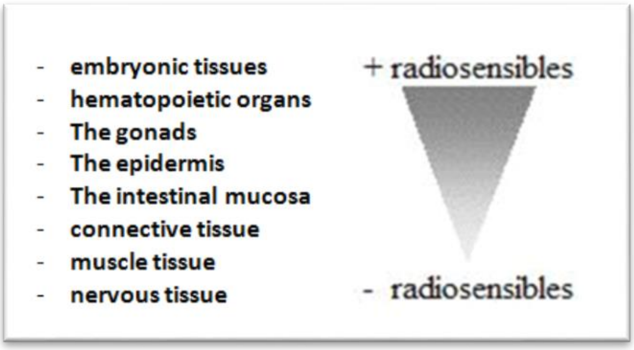


Figure II-13: Classification of tissues according to their sensitivity to ionizing radiation in general.

II.5.4 Pathological Effects of Ionizing Radiation in Humans:

II.5.4.1 Non-Stochastic (Deterministic) Effects:

- These are dose-threshold (non-random) effects.
- Early (a few hours or a few days)
- They are characteristic (diagnosis of certainty)
- Severity is dose dependent.
- More or less reversible depending on the severity [37].

Example :Radio dermatitis: dose>3Gry, Whole body radiation syndrome: D>0.1Gy, Radiation-induced cataract…ect

II.5.4.2 Stochastic (Late, Random, Non-Deterministic) Effects:

- Linked to faulty DNA repairs,
- No threshold dose.
- randomness (probability)
- late effects (several years)
- irreversible (spontaneous)
- Dose-independent severity.
- Non-specific (no Dc of certainty)

Example: Cancers and genetic effects [37].

II.6 Conclusion:

Given that exposure to radiation and contamination in all its forms poses a potential risk, radiation detection equipment plays a critical role in protecting individuals from the harmful health effects of ionizing radiation. The selection of the appropriate detector depends on the nature of the materials being measured, the type of nuclear radiation being exposed to,
as well as the energy range being measured.

Chapter III:

Radiation Protection

Chapter III : Radiation Protection

III.1 .Introduction

The main purpose of radiation protection is to identify, prevent and limit the health and environmental risks resulting from ionizing radiation, whatever their origin [51].

The health physicists are tasked by the ATSDR to evaluate radioactive substances in the environment, radiation measurements, and estimate the radiological doses resulting from environmental exposures, the IAEA also established the first expert team in 2006 consisting of nuclear medicine physicians, technologists, medical physicists and radiologists to conduct periodic and systematic audits of the clinical environment of Member States, as well as meticulous follow-up on findings, And periodic monitoring (quality control QC and quality assurance QA) of medical equipment, and it has been set laws and commandments to achieve safe practices as much as possible from these exposures, and to benefit from the many advantages of ionizing radiation through Better control of the risks associated with their use..

III.2 Definition of Radiation Protection:

Radiation protection is defined as all the rules, means and procedures for preventing the risk of exposure to ionizing radiation, whether from an external source or due to internal radiation and reducing its harmful effects on humans, and radiation protection is based on three main principles [50].

III.3 Basic Principles of Radiation Protection:

In previous recommendations of the International Committee on Radiological Protection, the main principles of radiation protection and how to apply them to radiation sources and individuals were explained.

There are two principles associated with the source that are applied in all exposures:

III.3.1 Justification:

Justification in radiological protection of patients is different from justification of other radiation applications; there are three levels of justification of a radiological practice in medicine [56]:

- At the first and most general level, the proper use of radiation in medicine is accepted as doing more good than harm to society.
- At the second level, a specified procedure with a specified objective is defined and justified. The aim of the second level; is to judge whether the radiological procedure will improve the diagnosis or treatment, or will provide necessary information about the exposed individuals.
- At the third level, the application of the procedure to an individual patient should be justified. Hence all individual medical exposures should be justified in advance, taking

into account the specific objectives of the exposure and the characteristics of the individual involved.

III.3.2 Optimisation:

Optimisation is also presented under the concept ALARA

- ➢ ALARA principle: “As Low As Reasonably Achievable”

the ALARA principle aims to keep radiation doses received by people “as low as logically achievable” taking into account economic and social factors [57].

The following aspects and tools have to be used to ensure optimization of protection and safety [58]:

- Appropriate design of medical radiological equipment and software.
- Operational considerations specific to the modality and application.
- Calibration of sources and dosimeters.
- Quality assurance program implemented and independent audits made of this program.
- Diagnostic reference levels established and used for most common diagnostic procedures.
- Dose constraints used in the optimization of protection and safety for persons acting as caregivers or comforters, or subject to exposure as part of a program of biomedical research.

III.4 Radiation Protection Rules:

Radiation exposure resulting from an external source of radiation may be from a radiation producing device, such as a radioactive generator or linear particle accelerators, or may be a radioactive substance; it depends on the type and energy of radiation.

As for internal exposure, it occurs through the entry of radioactive substances into the body through the digestive or respiratory system or the skin, which inevitably leads to the exposure of cells and tissues to the danger of radioactive nuclei, regardless of the radiation energy, so it is very important to adopt the necessary preventive measures [52].

Since the basic principle of radiation protection is to limit or reduce the value of radiation exposure as much as possible, the application of this principle is to work on developing mechanisms and rules for dealing with radioactive sources in professional practice, which are represented in three main rules [53]:

- ▪ Distance.
- ▪ Time.
- ▪ Shielding.

III.4.1 Distance:

Increasing the amount of distance from the radiation source reduces the amount of radiation exposure. As the effect of distance on the intensity of radiation is similar to the effect of distance on the intensity of light emitted from a point source. The closer the source of light is, the greater its intensity, and vice versa. This is called the inverse square law of distance [54],According to the following equation:

$$\mathbf{\dot{D}_1 \times d_1^2 = \dot{D}_2 \times d_2^2} \tag{III-1}$$

Where: $\mathbf{\dot{D}}$ is the dose rate ; $\mathbf{d}$ is the distance

This means that if the distance from the source is doubled, the radiation exposure will decrease by four times its value at the first distance, as shown in the figure:

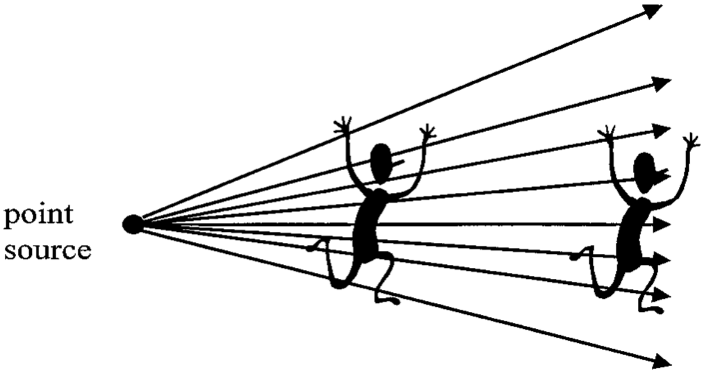


Figure III-1: Inverse square law [87].

Note: In order to employ the distance factor in the process of reducing the amount of radiation exposure in radiation protection, the physical form of the radiation source must be determined**.** In the case of a non-point radiation source; the physical form of the radiation source determines the amount of reduction in the radiation dose.

III.4.2 Time:

Time is an essential factor in the event of exposure to an external radiation source or during the period of taking radioactive elements in internal radiation exposure, as the increase in time during the period of dealing with radiation sources reflects negatively on the human body Based on the model used in radiation protection related to the linear response of cells under the threshold limit for radiation doses, regardless of the mechanism of cell regeneration so that the total damage to the cells is a cumulative sum, so Reducing the exposure time directly leads to a reduction in the radiation dose received [54].

$$\boldsymbol{Dose\ = doserate\ (\mu Sv/h) \times Duration(h)} \tag{III-2}$$

III.4.3 Shielding:

Screens or shields are barrier materials between the radiation and the object, and it absorbs or attenuates radiation energy, and the ability of the material it is made of to absorb depends on several factors, including the type of radiation, its energy, and the type of material, depending on this matter, different types of materials have been employed by making them shields that protect against radiation or work to reduce its level, The most famous of these materials is lead. These materials are called radiation shields or screens [55].

How to employ the three principles of radiation protection to work to reduce the amount of radiation doses resulting from an external radiation source can be summarized as follows:

- Reducing the time needed to deal with the source of radiation.
- Increasing the time before dealing with decaying radiation sources to ensure a decrease in the amount of their radioactivity, if possible.
- Work to increase the distance from the radiation source to the farthest possible distance.
- Use appropriate shields according to the type and energy of radiation.

III.5 Radiation Protection Program (PPP):

Assessment of the risks arising from exposure requires knowledge of the groups within the Nuclear Medicine Department, as well as the dose limits. It is also necessary to conduct medical monitoring.

III.5.1 Roles, Duties and Responsibilities:

The following is an explanation of the roles, duties and responsibilities of the professional groups that perform these tasks within the medical interest, as there are some duties that can only be performed by a specific professional group, for example medical matters and diagnostic reports that require a doctor specializing in nuclear medicine and not Any other employee, such as a radiology technician, can act on his behalf, and on the contrary, other roles, such as the role of radiation safety officer, can be performed by a group of professionals depending on the conditions within the center [42].

III.5.1.1 Administering Person:

The administering personis the person who fulfils the role of the operator, the administering person needs to comply with the centre’s operating, and managing his affairs procedures on how to identify the patient, The administering person needs to ensure that the correct procedure will be performed, and Monitoring and standing on administrative matters [42].

III.5.1.2 Responsible Person:

The Responsible Personis the legal entity which has overall management responsibility for radiation matters, and may be an individual person, a body corporate or a partnership. Whilst some tasks may be delegated to the nuclear medicine specialist or to the RSO, the ultimate responsibility lies with the Responsible Person, and among his tasks [42]:

- Develop a radiation management plan.
- Personal radiation monitoring and dose limits.
- Providing a qualified expert as a consultant on matters related to protection.

III.5.1.3 Nuclear Medicine Specialist (Radiation Medical Practitioner):

Being the person who fulfils the role of the radiation medical practitioner, is responsible for the clinical management of the patient undergoing a diagnostic or therapeutic nuclear medicine procedure.

The nuclear medicine specialist should:

- Consider medical practices, in relation to the appropriate use of imaging investigations and therapeutic procedures, and the approximate dose of radiation each modality will deliver.
- Ensure that a therapeutic or diagnostic procedure is clinically required.
- Advise the patient or his or her guardian about the potential risks associated with a therapeutic or diagnostic procedure and what the patient should do.
- Issuing reports and providing a copy and copy thereof for the patient's record, or when requested by another medical practitioner, taking into account the patients' clinical information.

III.5.1.4 Nuclear Medicine Technologist:

The nuclear medicine technologistis responsible for performing nuclear medicine procedures as prescribed by the nuclear medicine specialist in accordance with the centre’s written standard protocols [40].

This will include one or more of the following duties:

- Perform imaging and in vitroprotocols to ensure optimal data acquisition and analysis.
- Prepare, dispense and administer radiopharmaceuticals.
- Perform quality assurance procedures for radiopharmaceuticals. instrumentation and image quality.

III.5.1.5 Person Preparing Radiopharmaceutical:

He is the person responsible for extracting radioactive isotope from the generator and combining them with the tracer, in the specified doses[42].

The person responsible for radiopharmaceuticals needs to develop systems for the:

- Procurement of radionuclides/radiopharmaceuticals.
- Storage and waste management of radionuclides or radiopharmaceuticals.
- Development of safe procedures and practices for the preparation and manipulation of radiopharmaceuticals, in consultation with relevant staff.
- Implementation of a quality assurance program for radiopharmaceuticals.

III.5.1.6 Qualified Expert (Nuclear Medicine Physicist):

The nuclear medicine physicist works closely with the nuclear medicine specialist and technologists in the optimization of clinical studies through image treating, analysis and display optimization and ongoing oversight of the quality control of equipment and imaging devices. In many centers, some of these duties may also be undertaken by an experienced nuclear medicine technologist. The nuclear medicine physicist may also be appointed as the RSO; In addition, a medical physicist is required to provide Human Research Ethics Committees with a radiation dose estimation and risk assessment for any research studies that involve the research participants receiving an exposure from ionizing radiation [42].

III.5.1.7 Radiation Safety Officer (RSO):

The radiation protection officer, who may be a medical physicist with sufficient professional training to delegate radiation protection duties within the center, or he may be an outside consultant (not affiliated with the center)[42].

III.5.2 Application of Dose Limits:

Dose restrictions are used in conjunction with optimization, either as dose restrictions or as a reference level, to reduce unjustified exposures.

- **Occupational dose limits:**
  - **Category A:**

The responsibilities of professionals in the radiation services entail their continuous exposure to radiation during their work period and in a cumulative manner. Therefore, one of the basic principles of radiation safety is to keep the professional cumulative dose limits within the permissible limits.

The occupational exposure limits, for workers directly involved to work under radiation which is 20 mSv per year for the effective dose, should not be exceeded. If this excess occurs, it should not exceed 50 mSv per year. In this case, the worker must be monitored and followed up during the subsequent years, so that the rate of radiation exposure does not exceed 100 mSv in five years [12].

- **Category B:**

As for other employees who are not directly exposed to radiation or the trainees or students who do internships, the effective dose should not exceed 6 mSv [59].

Limits of exposure to ionizing radiation in mSv / year	public	Workers exposed to ionizing radiation	
		Category A	Category B
Effective dose limits	1	20	6
Dose Equivalent Limits with Endpoints	-	200	150
Lens dose equivalent limits	15	150	45
Skin dose equivalent limits	50	500	150
Pregnant woman	1mSv for the duration of pregnancy		
breastfeeding woman	Excluded from work at risk of contamination		

Table III-1: classification of categories of workers and their dose limits.

- **Patient dose limits:**

The radiation dose that the patient receives depends on the type of radioactive material and the amount in which the examination is performed, as the dose that the organ receives is greater than the dose received by the rest of the organs, as a result of the concentration of the radioactive substance in that organ, so it is important to know first the effective dose for the body, which is within the range of 1 mSv, and the effective dose for the cellular tissues and organs [60].

- **Dose limits for member of the public:**

The public and the public were protected by providing appropriate radiation shields and providing them with appropriate waiting places far from the imaging rooms, so that the effective dose for the public is within the range of 1 mSv, as is the case for pregnant women.

As for those accompanying patients and visitors, the dose should not exceed 5 mSv [61].

III.5.3 Classification of Areas:

III.5.3.1 Public Areas:

Public or Uncontrolled areas, are all other areas in the hospital or clinic and the surrounding environment, and are those occupied by individuals such as patients, visitors to the facility, and employees who do not work routinely with or around radiation sources [62].

III.5.3.2 Supervised Areas:

Supervised area is defined as any area not designated as a controlled area, but which occupational exposure conditions are kept under review even though specific protective measures and safety provisions are not normally needed, it is an area in which workers are likely to receive under normal working conditions [63].

- An effective dose of between 1 and 6 mSv per year for the whole organism.
- An equivalent dose of between 1/10 and 3/10 of one of the limits set for the skin, hands, forearms, feet and ankles (50 mSv), or the lens (15 mSv) [64].

III.5.3.3 Controlled Areas:

A controlled area is a limited access area in which the occupational exposure of personnel to radiation is under the supervision of an individual in charge of radiation protection, This Means that access, occupancy, and working conditions are controlled for radiation protection purposes, The workers in these areas are primarily radiologists and radiographers who are specifically trained in the use of ionizing radiation and whose radiation exposure is usually individually monitored.

The controlled area is divided into 4 zones: green zone, yellow zone, and orange zone, red zone (prohibited) [63].

Persons responsible for radiation protection shall make the following measurements in each area, and document all results in special records:

1. Conducting a periodic routine survey to verify the validity of the area classification.
2. Measure the radiation exposure rates that accompany the operation of the device for all employees in the area who may be exposed to radiation doses.
3. Place dosimeters, such as those carried by workers, in workplaces and the location of the radiation source, such as the hot laboratory in the Nuclear Medicine Department, and take their readings periodically.

III.5.4 Surveillance Interest:

III.5.4.1 Medical Surveillance:

In addition to the education and training of medical and paramedical medical staff and other personnel working in radiological services, the International Commission on Radiation Protection (ICRP) has recommended the urgent need for individual health monitoring of the staff of radiology departments, including the nuclear medicine department, and this monitoring includes:

- ❖ **First** : when hiring :

It is some clinical examinations, such as biological analyzes (FNS -Blood urea test) and a thoracic radiography and Ophthalmological examination, these analyzes determine the eligibility of the employee and his entitlement to the position or work in a place where there is radioactive exposure, because the results of these analyzes may not allow him to practice the job [63].

- ❖ **Second**: medical visits :

It is the employee’s visit to the work doctor, accompanied by the radiation protection officer on a regular basis, accompanied by the results of the aforementioned analyzes, who diagnoses the employee’s health condition based on the results of the analyzes and some examinations and monitors dosimetry for the employee, to determine the employee’s health condition or issue sick leaves for him if his health condition is worth it [65].

III.5.4.2 Individual Medical Follow-Up Card:

This card is often referred to as a "category A or B card".

It is a card issued or renewed by the occupational physician following the medical examinations for the fitness of exposed workers.

It must be held like a passport or a "work permit" by any worker of category A or B. He must be able to present it before any intervention in a restricted area.

Blank, numbered cards are made available to the occupational physician by IRSN and a stub of any card assigned to a person is sent back to IRSN to certify that the proficiency checks have been carried out [65].

III.5.4.3 Radiation Protection Equipment:

- ➢ Personal means of protection [42]:
  - ✓ Lead apron or laboratory coats or protective gowns.
  - ✓ Protective helmet.
  - ✓ Protective gloves (waterproof).
  - ✓ Safety glasses.
  - ✓ Face masks where there is a risk of airborne droplets or Dust mask.
  - ✓ Safety shoes.
- ➢ Collective means of protection [42]:
  - ✓ Lead barriers (fixed or mobile) with lead glass windows for work with photon emitters.
  - ✓ Perspex barriers for work with beta emitters.
  - ✓ Syringe shields.
  - ✓ Shielded containers.
  - ✓ Drip trays to contain any spillage.
  - ✓ Tongs or forceps to maximize the distance of the worker from the source.
  - ✓ Radiation and contamination monitoring equipment.

- ✓ Dose calibrators.
- ✓ Fume cupboards.
- ✓ Biohazard cabinets.
- ✓ Shielded transport containers.
- ✓ Equipment and materials to deal with spills.

III.6 Transport and Receive Radioactive Materials:

Radioactive materials are transported from one region to another by planes, ships, trucks, or even cargo vehicles and these materials are treated with caution as a great danger, so there are controls and regulations that must be adhered to during the process of transporting these materials [66].

The most important controls for the process of shipping and transporting radioactive materials:

- They are placed in special containers made of special metals, according to the type of materials inside them and the intensity of their radioactivity
- The packages are tested under harsh conditions to ensure their resistance to accidents.
- Stickers shall be placed on the packages to identify the types of materials and their radioactive activity, and if necessary, warning stickers shall be placed on the trucks or cars transporting them indicating the existence of the radiation hazard.
- The process of shipping and transportation is accompanied by some elements of the gendarmerie or the police to enhance safety and ensure the delivery of materials.
- Avoid side roads and densely populated areas
- Training drivers in charge of transportation on radiation sciences, radiation safety, and how to deal with emergencies.

As for the health sector, especially in the Nuclear Medicine Department, the process of shipping and transporting the generator from ...... to the hospital institution is subject to the previous controls.

The generator may be sent through the airport, it is received from the airport by the medical physicist or radiation protection officer of the receiving hospital institution accompanied by police or gendarmerie personnel, after the process of receiving and handing over at the airport it is delivered to the institution directly to the hot laboratory in the Nuclear Medicine Department.

III.7 Organisation of Radiation Protection:

There are many international and national organizations that manage the radiation field and work to ensure and manage safe practices due to the danger of this field to humans in particular and living organisms in general.

III.7.1 International Organisation:

III.7.1.1 Commission Internationale des Unités et de Mesures Radiologiques (ICRU):

Is the authority on units for metrology of ionizing radiation within the system international (SI) and member of the consultative committee for units (CCU) of international committee for weight and measurement CIPM.

The ICRU was conceived at the First International Congress of Radiology (ICR) in London in 1925, and officially came into being at ICR-2 in Stockholm in 1928, The ICRU has as its principal objective the development of internationally accepted recommendations regarding: quantities and units of radiation and radioactivity, and physical data needed in the application of these procedures, the use of which assures uniformity in reporting [67].

III.7.1.2 International Commission on Radiological Protection (ICRP):

The ICRP is an independent Registered Charity, established to advance for the public benefit the science of radiological protection, in particular by providing recommendations and guidance on all aspects of protection against ionizing radiation. The Main Commission is the governing body, setting policy and giving general direction, ICRP was established in 1928 It was her name at first (IXRPC) then it became ICRP [68].

III.7.1.3 United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR):

The UNSCEAR was established by the General Assembly of the United Nations in 1955. Its mandate in the United Nations system is to assess and report levels and effects of exposure to ionizing radiation [69].

III.7.1.4 International Atomic Energy Agency (IAEA):

The IAEA is the international centre for cooperation in the nuclear field. The Agency works with its Member States and multiple partners worldwide to promote the safe, secure and peaceful use of nuclear technologies [70].

III.7.1.5 European Atomic Energy Community (EURATOM):

EAEC or Euratom is an international organisation established by the Euratom Treaty, initially, it aimed to create a specialized market in nuclear energy, and later expanded its scope to include areas related to nuclear energy, and ionising radiation and construction of the International Fusion Reactor ITER [71].

III.7.1.6 IPEM:

The IPEM is the United Kingdom's professional body and learned society for physicists, engineers and technologists within the field of medicine, founded in 1995 [72].

III.7.1.7 AFRA:

It is an intergovernmental agreement created in 1988 by African member states entered into force in 1990, in 2013 membership of AFRA includes 39 African countries, among them is Algeria.

III.7.2 National Organisms:

III.7.2.1 Atomic Energy Commission (COMENA):

The COMENA represents the regulatory oversight body in matters of radiation safety and nuclear safety in Algeria, and it also represents a instrument for the design and implementation of the national policy for the promotion and development of nuclear energy and techniques”[49].

III.8 Conclusion:

A promising future awaits the nuclear medicine sector in light of the collaborative work of international organizations, as these organizations work to expand the scope of their activities to include a larger number of countries in the world. They also seek to develop radiation protection in all sectors and the health sector in particular, and to ensure safe practices in coordination with local national bodies.

Chapter IV:

Experimental study

Chapter IV Experimental Study

IV.1 Introduction:

Dosimetry is the measurement of ionizing radiation at a specific location or person, the purpose of which is to estimate quantities such as absorbed dose or effective dose due to exposure. One of the most important tools for this is the operational dosimeter. All employees occupationally exposed to ionizing radiation should conduct dosimetry monitoring to ensure they do not exceed the dose that could cause adverse health effects.

IV.2 Objective:

Evaluation of absorbed doses for workers in the Nuclear Medicine Department of the Military Hospital in Ouargla, and verification of their compliance with radiation protection standards.

IV.3 Materials and methods:

IV.3.1 Equipment used:

To monitor the staff, a dosimeter (thermal radiometer) was used.

Figure IV-1: Operational dosimeter [89].

Device definition:

The Thermo Scientific RadEye GN+ Gamma Neutron Pager this small, lightweight device provides clear visual and audible warnings to help emergency responders locate radioactive material in a variety of situations, and has very high neutron sensitivity that exceeds ANSI 42.32 and IEC 62401 periodic requirements. RadEye GN+ features a single high-sensitivity scintillation detector equipped with a miniaturized photomultiplier to detect very low levels of gamma radiation and neutrons from any source. The RadEye GN+ pager contains a Ce-doped Cs2LiYCl6 (CLY C) crystal.CLY C provides excellent gamma neutron separation, making the RadEye GN+ pager an effective tool even in high-energy gamma combined gamma-neutron field scenarios.

Energy range	**17 keV to 3 MeV(± 30%); 17 keV to 3.0 MeV according to IEC 60846-1 (2009)**
Battery Type	2 AAA
Measuring ranges	0.01 µSv/h to 2 mSv/h
Response time	Approx. 4 cps per µSv/h
Linearity	± 10% within the measurement range
Type of radiation	Gamma, X-Ray
Depth (metric)	62mm
Sensitivity	0.01µSv/h to2 mSv/h
Dose rate limit	2 mSv/h (200 mrem/h)
Display Type	Backlit LCD
Operating temperature (metric)	Backlit LCD
:Operating temperature (imperial)	-4°F to 122°F
Units	(Sv/h)/ (rem/h)
Height (metric)	13cm

Table IV-1 : Operational dosimetere dvice data

IV.3.2 Methods:

The study was conducted in the nuclear medicine department of the military hospital in OUARGLA (CHAHID TIRICHINE IBRAHIM).

During our practical training in the department of nuclear medicine, the dose absorbed by service personnel was monitored throughout the period of radioactivity. This study was allocated to the following tasks only because they are the most exposed to radiation among all employees, and they are:

- ✓ Manipulator.
- ✓ Radiology pharmacist.
- ✓ Nurse.

The places where the study was conducted:

- ✓ Hospital door
- ✓ Hot lab
- ✓ Injection room.
- ✓ Waiting room/ corridor.
- ✓ Gamma camera room / interpretation room.

IV.3.3 Explanation of the method:

When it comes to dosimetry, it is inherently a very broad field. Therefore, we have shortened the work into a few stages, the most important of which is what is implemented during the first two days of the arrival of the generator, as it is the main source of radiation

- ✓ On the first day, a measurement of the absorbed dose was taken upon receiving the generator in front of the hospital door at two different distances and at two different moments. The details are as shown in the results below.
- ✓ The next day after inserting the generator and observing its activity, we proceeded to measure the absorbed dose of the radiopharmaceutical during the preparation of the pharmaceutical preparations.
- ✓ We then measured it to the nurse while injecting the patients in the injection room.
- ✓ We measured it in the corridor near the patients' waiting room; these measurements were also taken at two different distances.
- ✓ Finally, some measurements of the manipulator were taken again while the patient was being prepared for the examination in the gamma camera room.

IV.4 Results:

To clarify the impact of the three basic principles mentioned in the previous chapter in reducing exposure and thus radiation protection, the following studies were conducted for each principle

IV.4.1 The results measure the effect of both distance, time and shielding

- **First (distance):** To study the effect of distance, measurements were taken in two different tasks and at two different distances for each task, and the inverse square law were used in that:

$$\dot{D}_1 \times d_1^2 = \dot{D}_2 \times d_2^2 \tag{IV-1}$$

The following table shows the obtained results:

Task	Distance (m)	dose rate (µSv/h)
generator reception	1	40
	2	10
patient waiting	1	10
	2	2.5

Table IV-2: Measurements of dose rates for different distances.

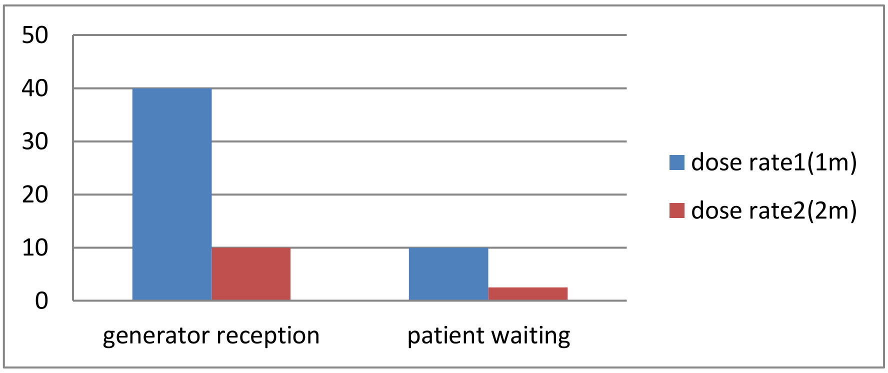


Figure IV-2 : Representation using a histogram of dose rates for different distances.

The results showed that the dose rate at a distance of 1 meter is higher compared to the dose rate at a distance of 2 meters, and from this we extract the effective role of distance in reducing radiation exposure, as the greater the distance, the lower the dose rates.

- **Second (time):** The second principle is time. To see the effect of time in reducing the dose, the dose will be calculated based on measurements of the dose rates taken from the two previous tasks in the time period specified for each task through the following law, then the duration for each task will be increased to notice the difference:

$$\boldsymbol{Dose} \ = \boldsymbol{dose\ rate}\ (\mu \boldsymbol{Sv}/\boldsymbol{h}) \times \boldsymbol{Duration}(\boldsymbol{h}) \qquad \textbf{(IV-2)}$$

The following table shows the obtained results:

Task	**Duration (min)**	**Dose (μSv)**
generator reception	5	3.33
	15	10
patient waiting	5	0.83
	15	2.5

Table IV-3: results of dose for different duration.

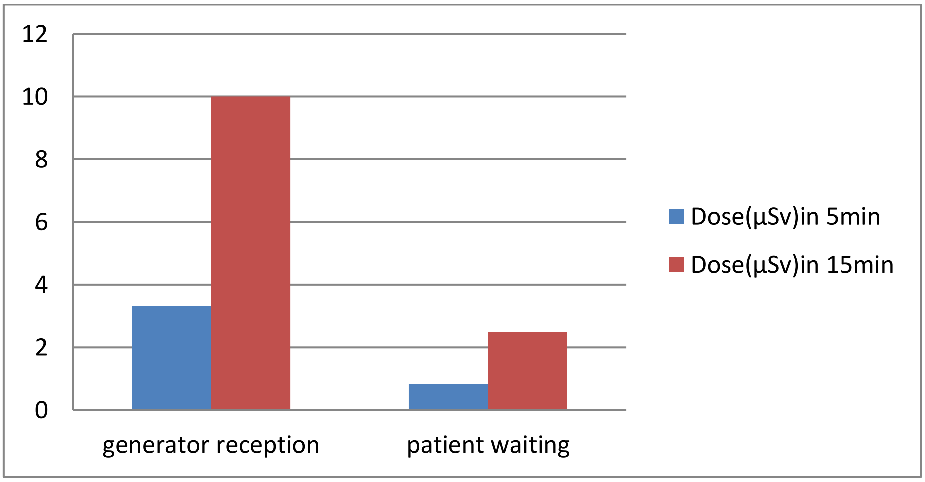


Figure IV-3: Representation using a histogram of dose rates for different duration.

The results showed that the longer the duration of the task, the higher the dose, and from it we conclude that time has a significant impact on exposure. Any employee must complete his tasks in radioactive places in the shortest possible time.

- **Third the (shielding):** to see the impact of the presence of lead barriers or other means of shielding, dose rates were measured for some employees with a lead apron as a barrier and without a lead apron, for specific tasks, the lead suit was considered the barrier.

Employee	Task	Dose rate (µSv/h)
manipulator	The course of the scintigraphy With Lead apron	1.46
	The course of the scintigraphy without a lead apron	15.43
nurse	Preparation of radiopharmaceuticals With Lead apron	.583
	Preparation of radiopharmaceuticals without a lead apron	112

Tableau IV-4: Measurements of personal dose rates with and without lead apron.

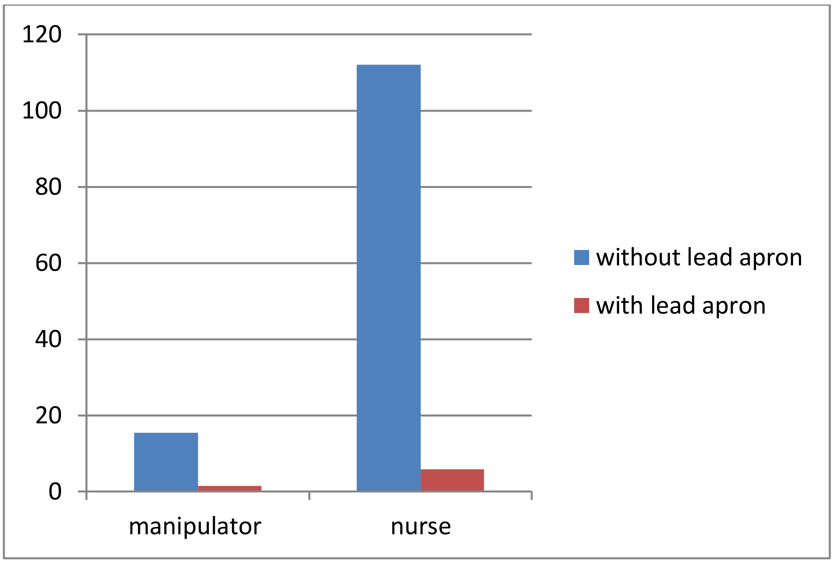


Figure IV-4: Representation of measurements of personal dose rates with and without lead apron.

The results of measuring absorbed doses for employees showed that; their dose rates without wearing a lead apron are high compared to the dose rate while wearing a lead apron and from this we conclude that the lead apron has an effective role in radiation protection for employees by reducing exposure and cumulative doses.

IV.4.2 The results of the dose rates at the level of the nuclear medicine service buildings.

The buildings	Dose rate (µSv/h)
reception room	.009
Hot lab	.026
injection room	.198
The waiting room	0.56
corridor	0.27
Gamma Camera room	4.60

Tableau IV-5: Dose rate measurements for nuclear medicine service buildings.

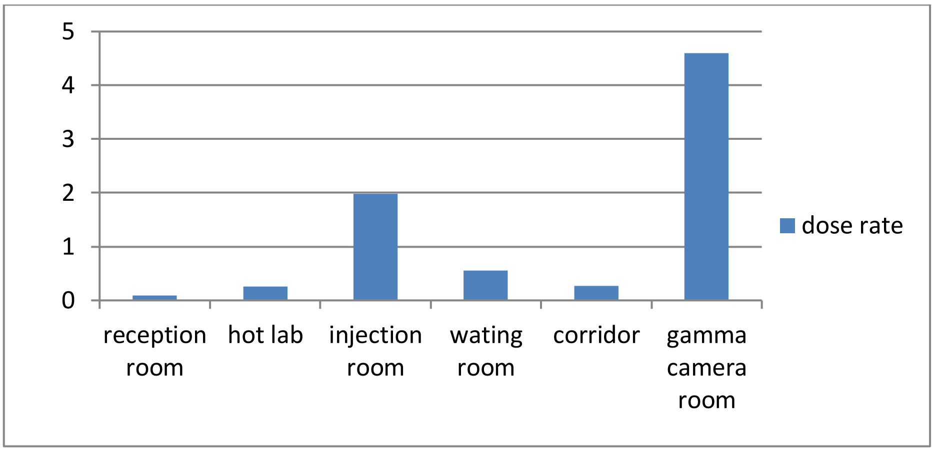


Figure IV-5: representation of results for dose rates for nuclear medicine service buildings.

Note: the results were taken on the last day of work, meaning that the generator activity has decreased significantly. This affected some of the results of the measurements, especially those that were made in the hot laboratory.

IV.4.3 Measure the absorbed dose for employees according to their different tasks, with calculating the duration of exposure and the number of recurrences per year:

Task	Dose rate (µSv/h)	Duration (min, h/D)	Periodicity (times a year)
Generator reception	40	5 min	10
Preparation of radiopharmaceuticals	40	30 min/D	60
Injecting patients	25	30 min/D	60
patient waiting	5-10	4 h/D	60
The course of the scintigraphy	5-10	4 h/D	60
In the rest existence time of Generator	3-1	8h/ D	100 days per year

Table IV-6: Dose rate measurement results, duration and Periodicity for personnel

The dose rate during scintigraphy varies according to the examination being performed.
The dose is very diminutive in the rest existence time of generator

IV.4.4 Calculate the annual dose for personnel under the above tasks

According to the results of the table and using the following relationship, we calculate the annual absorbed dose for individuals

Total absorbed dose =dose rate × number of hours per times × number of times per year **(IV-3)**

Task	The total absorbed dose per year (μSv/ year)
Generator reception	450
Preparation of radiopharmaceuticals	1200
Injecting patients	750
patient waiting	1200
The course of the scintigraphy	1680
The course of the scintigraphy	400

Table IV-7: The results of calculating the annual dose

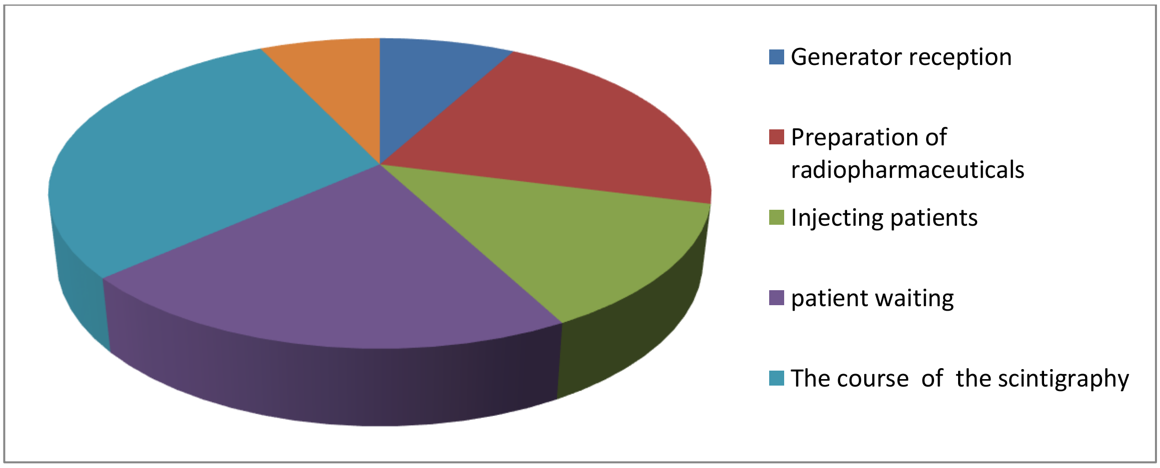


Figure IV-6 : Graphic representation of annual dose calculation results.

IV.4.5 Comparison:

Let's compare our study with that conducted in the department of nuclear medicine at the Mohamed Boudiaf hospital

- **Most exposed individuals:**

According to our study, the nurse, the manipulator, and the radiologist are more exposed to radiation than the rest of the staff. The same result was found in the Nuclear Medicine Department of Mohamed Boudiaf Hospital.

- **Most radiant buildings**

Through the results obtained, it was found that the most radiant buildings are the hot laboratory, the injection room, and the gamma camera room.

IV.5 Conclusion:

As part of our work on dosimetry and compliance with the rules and principles of radiation protection in the nuclear medicine department, the dosimetry results for the staff of the nuclear medicine department of the TERESHIN IBRAHIM Military hospital comply with the regulations and recommendations of international protection standards and reference doses, as well as the doses received by the staff remain below the thresholds. Annual medical surveillance, despite some abuses and negligence in the application of some regulations, therefore, diligence in their application remains necessary to limit more and more the increasing exposure, as well as to know how to behave in an emergency situation. The job profile of nurses and manipulator was found to be most vulnerable in the nuclear medicine department.

General Conclusion

General Conclusion

Radiation dosimetry is an important part of radiation protection measures in many radiation practices, both in the medical field, such as nuclear medicine and radiation therapy, and in other applications, such as nuclear reactors, mining ... etc. An important specialty in healthcare uses nuclear technology to diagnose and to improve treatment of diseases efficiently and accurately.

In general, the accurate measurement of radiation doses and the application of the necessary preventive measures contribute to reducing exposure to harmful radiation and must therefore be applied consistently and continuously to ensure the safety of workers and the public. In addition, radiation protection includes many procedures and measures necessary to reduce radiation, and these procedures include also the design of places designated for handling radioactive materials, radiation safety and security measures, personal protection measures, periodic monitoring and radiation reports.

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