ChapterTwo

Literature view

2.1Classification of radiation

Radiation is the transport of energy by electromagnetic waves or atomic particles, which can be classified into two main categories depending on its ability to ionize matter. The ionization potential of atoms, i.e. the minimum energy required to ionize an atom, ranges from a few electron volts for alkali elements to 24.6eVfor helium which is in the group of noble gases. Ionization potentials for all other atoms are between the two extremes. Non-ionizing radiation cannot ionize matter because its energy per quantum is below the ionization potential of atoms. Near ultraviolet radiation, visible light, infrared photons, microwaves and radio waves are examples of non-ionizing radiation. Ionizing radiation can ionize matter either directly or indirectly because its quantum energy exceeds the ionization potential of atoms. X rays, γ rays, energetic neutrons, electrons, protons and heavier particles are examples of ionizing radiation (E.B PodgorSaketal, 2006).

2.1.1 Classification of ionizing radiation

Ionizing radiation is radiation that carries enough energy per quantum to remove an electron from an atom or a molecule, thus introducing a reactive and potentially damaging ion into the environment of the irradiated medium. Ionizing radiation can be categorized into two types:

(i) Directly ionizing radiation

(ii) Indirectly ionizing radiation.

Both directly and indirectly ionizing radiation can traverse human tissue, thereby enabling the use of ionizing radiation in medicine for both imaging and therapeutic procedures. Directly ionizing radiation consists of charged particles, such as electrons, protons, α particles and heavy ions. It deposits energy in the medium through direct coulomb interactions between the charged particle and orbital electrons of atoms in the absorber. Indirectly ionizing radiation consists of uncharged (neutral) particles which deposit energy in the absorber through a two-step process. in the first step, the neutral particle releases or produces a charged particle in the absorber which, in the second step, deposits at least part of its kinetic energy in the absorber through coulomb interactions with orbital electrons of the absorber in the manner discussed above for directly ionizing charged particles. (E.B PodgorSaketal, 2006).

2.1.1.1 Classification of indirectly ionizing photon radiation

Indirectly ionizing photon radiation consists of three main categories: (i) ultraviolet, (ii) X ray and (iii) γ ray. Ultraviolet photons are of limited use in medicine. Radiation used in imaging and/or treatment of disease consists mostly of photons of higher energy, such as x-rays and γ rays. The commonly accepted difference between the two is based on the radiation's origin. The term 'γ ray' is reserved for photon radiation that is emitted by the nucleus or from other particle decays. The term 'X ray', on the other hand, refers to radiation emitted by electrons, either orbital electrons or accelerated electrons (e.g. bremsstrahlung type radiation). With regard to their origin, the photons of the indirectly ionizing radiation type fall into four categories: characteristic (fluorescence) X rays, bremsstrahlung X- rays, photons resulting from nuclear transitions and annihilation quanta.(Canadian nuclear safety commission (CNSC), 2012).

Two types of biological effects of ionizing radiation are known: deterministic effects and stochastic effects. Deterministic effects are those caused by the decrease in or loss of organ function due to cell damage or cell death. For these effects threshold doses exist: the function of many organs and tissues is not affected by small reductions in the number of available healthy cells. Only if the decrease is large enough, will a clinically observable pathological dysfunction appear. In the case of treatment of thyroid cancer, metastases, hyperthyroidism and euthyroidgoiter, the objective are to bring about the cell-killing effect while not affecting other organs in such a way that deterministic effects occur. Due to the capacity of thyroid cells to take up iodine thyroid diseases can be treated with radioactive iodine. The β-emitting I-131 is often the radionuclide of choice for these treatments, although the associated γ-emission gives rise to exposures to other tissues and even to other individuals. The probability of a radiation-induced fatal cancer for the average population has been estimated (ICRP-60) at approximately 5 percent per sievert2 for low doses and at low dose rates and at 1 percent for serious genetic diseases. For elderly people, older than about 60 years, the probability seems to be 3 to 10 times lower. This is because the future life span of elderly people may not be long enough for the cancer to become apparent and it is also unlikely that genetic damage is passed to offspring. For children up to the age of 10 years, the probability of fatal cancer induction seems to be about 2-3 times higher. For pregnant women the risk is the same as for the average population; however, the unborn child is assumed to have the same risk of developing a fatal cancer as young children. Deterministic effects have been observed after massive irradiation *LQ - XWHUR*, but dose levels incurred by family or close friends from a treated patient are far below the threshold for such effects. As sensitivity to ionizing radiation is different for different age categories, instructions to reduce the risk for these groups will also vary accordingly. (Radiation protection 97, European commission, 1998).

The biochemical changes produced by ionizing radiations are the fundamental events leading to radiation damage in tissues. Radiation is measured either as exposure or as absorbed dose, the absorbed dose is the amount of energy absorbed in a system and generally regarded as the best way to quantify the irradiation absorption .(faizkhan^{3th}eddtion)

2.2 Radioactivity

First discovered by Henri Becquerel in 1896, is a phenomenon in which radiation is given off by the nuclei of the elements. This radiation can be in the form of particles, electromagnetic radiation, or both.α particles (helium nuclei) are positively charged and (β^-) particles (electrons) are negatively charged, they are deflected in opposite directions. The difference in the radii of curvature indicates that the (α) particles are much heavier than particles. On the other hand, (γ) rays, which are similar to x-rays except for their nuclear origin, have no charge and, therefore, are unaffected by the magnetic field.(faizkhan3eddtion).

2.2.1The half-life (T1/2)

The half-life of a radioactive substance is defined as the time required for either the activity or the number of radioactive atoms to decay to half the initial value. By substituting $N/N_0 = 1/2$, or A/A_0= '1/2 at $t = T_{1/2}$. (faizkhan 3eddtion).

2.2.2 Modes of radioactive decay

2.2.2.1Alpha (α) Particle Decay

Radioactive nuclides with very high atomic numbers; (greater than 82) decay most frequently with the emission of an (α) particle. It appears that as the number of protons in the nucleus increases beyond 82, the Coulomb forces of repulsion between the protons become large enough to overcome the nuclear forces that bind the nucleons together. Thus the unstable nucleus emits a particle composed of two protons and two neutrons. This particle, which is in fact a helium nucleus, is called the particle. As a result of decay, the atomic number of the nucleus is reduced by two and the mass number is reduced by four. Thus a general reaction for decay can be written as:

Where Q represents the total energy released in the process and is called the disintegration energy. This energy, which is equivalent to the difference in mass between the parent nucleus and product nuclei, appears as kinetic energy of the (α) Particle and the kinetic energy of the product nucleus. (Gopal B. Saha, Ph.D, 2003).

2.2.2.2 Beta (β) Particle Decay

The process of radioactive decay, which is accompanied by the ejection of a positive or a negative electron from the nucleus, is called the β decay. The negative electron, or negatron, is denoted by jiI-, and the positive electron, or positron, is represented by β+. Neither of these particles exists as such inside the nucleus but is created at the instant of the decay process. The last two particles, namely antineutrino and neutrino, are identical particles but with opposite spins. They carry no charge and practically no mass. A nucleus can remain in several excited energy states above the ground state that are defined by quantum mechanics. All these excited states are referred to as isomeric states and decay to the ground state, with a lifetime of fractions of picoseconds to many years. The decay of an upper excited state to a lower excited state is called the isomeric transition.(Gopal B. Saha, Ph.D, 2003).

2.3 Radiation units

2.3.1 Gray

The gray (symbolized Gy) is the standard unit of absorbed ionizing-radiation dose, equivalent to one joule per kilogram ($1Jkg^{-1}$). Reduced to base units in the International System of Units (SI).

$$1Gy=1J/kg.$$

2.3.2 Rad

Before the introduction of the SI units . Radiation dose was measured by a unit called the rad (radiation absorbed dose). One rad is an absorbed radiation dose of 100 ergs per gram.

$$1rad = 100ergs/g \text{ and } Gy=100rads.$$

Although the gray is the newer unit and will eventually replace the rad, the rad nevertheless continues to be widely used.

2.3.3The coulomb per kilogram (C/kg)

The coulomb per kilogram (C/kg) is the SI unit of ionizing radiation exposure, and it is the amount of radiation required to create one coulomb of charge of each polarity in one kilogram of matter.

2.3.4 Roentgen (R)

Is an obsolete traditional unit of exposure, which represented the amount of radiation, required to create one electrostatic unit of charge of each polarity in one cubic centimeter of dry air.

$$\text{Roentgen} = 2.58\times10^{-4}\ \text{C/kg.}$$

2.3.5 Sievert (Sv)

The sievert is the SI unit of equivalent dose, which for X-rays is numerically equal to the gray (Gy).the traditional unit of equivalent dose. For X-rays it is equal to the rad or 10 mill joules of energy deposited per kilogram Sv (Ream) is = 100 rem. (IAEA Radiation oncology physics: 2005)

2.4 radiation quantities

2.4.1 Exposure

The radiation exposure is a measure of radiation based on its ability to produce ionization in air under standard temperature and pressure, and is the quantity indicated by many radiation detectors such as ionization (eg Geiger-Muller) chambers. The (S.I.) unit for exposure is Coulombs/kg in air (or Roentgen R in old units: (1 R = 2.58 x 10 C/kg air).

The unit of exposure is only defined for air and cannot be used to describe dose to tissue. Nevertheless ionization chambers are widely used to calibrate medical radiation devices and conversion factors to calculate absorbed dose from exposure have been carefully documented for different radiation energies and tissues.(Radiation biology, iaea, Vienna 2010).

2.4.2 Absorbed dose

The amount of energy absorbed per mass is known as radiation dose. Radiation dose is the energy (Joules) absorbed per unit mass of tissue and has the (S.I.) units of gray

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

In the past the rad (radiation absorbed dose) was used, where 100 rad = 1Gy (1 rad = 1cGy). Various types of radiation dose units are used in radiobiology. (Radiation biology, iaea, Vienna 2010).

2.4.3 Equivalent dose

As discussed above the biological effectiveness (RBE) of each type of radiation varies greatly depending largely on LET. For radiation protection and occupational exposure purposes theterm 'equivalent dose' is used to compare the biological effectiveness of different typesofradiation to tissues. The (S.I.) dose equivalent (HT) in sievert (Sv) is the product of the absorbed dose (DT) in the tissue multiplied by a radiation weighting factor (WR), often calledthe quality factor .

$$H_T = \sum W_R \ D_T$$

2.4.4 Effective dose

Effective Dose is used to estimate the risk of radiation in humans. It is sum of the products ofequivalent doses to each organ/tissue (HT) and the tissue weighting factor

$$(W_T) \ E = \sum W_T \ H_T$$

The unit of effective dose is the Sievert (Sv).(Radiation biology, iaea, Vienna 2010).

2.4.5 Collective dose

Collective dose is defined as the dose received per person in Sv multiplied by the number of persons exposed per year i.e. man-sievert per year. This unit is generally used for protection purposes and in population response calculations. (Radiation biology, iaea, Vienna 2010)

2.5 Physical and Biologic Factors

When a cell is irradiated, three events may occur. These include the slowing down of cell mitosis, interphase death, and cell death. It has been proven in experiments that low doses of radiation delay cell mitosis in humans. The specific cause for this slow-down, known as division delay, is unknown. Interphase death, which is cell death before entering mitosis, depends on which cell is irradiated. Highly mitotic cells demonstrate interphase death at doses lower than cells that are not highly mitotic. It is theorized that when there is a change in the cell membrane, electrolytes become imbalanced. The consequence for cells that do not divide repetitively, or that divide numerous times resulting in dead cells being produced, is failure of cell reproduction. When noting biologic changes that occur in cells caused by irradiating them, the following should be emphasized. Radiation interaction with cells has to do with chance and probability. The radiation may or may not interact; if it does interact, there may or may not be cell damage. The first deposit of radiation is given very rapidly, approximately within 10^{17} seconds. The interaction of radiation within the cell is random. It cannot be determined if visible changes to cells, tissues, and organs are caused by radiation or other sources. Radiation doses to cells cause biologic changes only following a period of time that is dose dependent, and may vary from minutes to years. The factors affecting cell response include linear energy transfer (LET), relative biologic effectiveness (RBE), and oxygen enhancement ratio (OER), (Radiation biology, IAEA, Vienna 2010).

2.6 radiation protection

The purpose of a radiation protection program is to monitor individuals' contact with radiation and to limit their exposure to as low a level as possible. In the US, Federal regulations that outline acceptable levels of exposure are issued by the Nuclear Regulatory Commission (NRC). In addition, the government has set forth a general policy principle referred to as ALARA.(.Mattsson,elt ,Essentials of Nuclear Medicine Physics and Instrumentation, 2013).

2.6.1 Categories of exposure

The Commission distinguishes between three categories of exposures: occupational exposures, public exposures, and medical exposures of patients. (Mattsson, elt,Essentials of Nuclear Medicine Physics and Instrumentation, 2013).

2.6.1.1Occupational exposure

Occupational exposure is defined by the Commission as all radiation exposure of workers incurred as a result of their work. The Commission has noted the conventional definition of occupational exposure to any hazardous agent as including all exposures at work, regardless of their source. However, because of the ubiquity of radiation, the direct application of this definition to radiation would mean that all workers should be subject to a regime of radiological protection. The Commission therefore limits its use of 'occupational exposures' to radiation exposures incurred at work as a result of situations that can reasonably be regarded as being the responsibility of the operating management. Excluded exposures and exposures from exempt practices or exempt sources generally do not need to be accounted for in occupational protection. The employer has the main responsibility for the protection of workers. However, the licensee responsible for the source (if not identical to the employer) also has a responsibility for the radiological protection of workers. If workers are engaged in work that involves, or could involve, a source that is not under the control of their employer, the licensee and the employer should co-operate by the exchange of information and otherwise as necessary to facilitate proper radiological protection at the workplace. (Mattsson, elt,Essentials of Nuclear Medicine Physics and Instrumentation, 2013).

2.6.1.2Public exposure

Public exposure encompasses all exposures of the public other than occupational exposures and medical exposures of patients as a result of a range of radiation sources. The component of public exposure due to natural sources is by far the largest, but this provides no justification for reducing the attention paid to smaller, but more readily controllable, exposures to man-made sources. Exposures of the embryo and fetus of pregnant workers are considered and regulated as public exposures. (Mattsson, elt,Essentials of Nuclear Medicine Physics and Instrumentation, 2013).

2.6.1.3Medical exposure of patients

Radiation exposures of patients occur in diagnostic, interventional, and therapeutic procedures. There are several features of radiological practices in medicine that require an approach that differs from the radiological protection in other planned exposure situations. The exposure is intentional and for the direct benefit of the patient. Particularly in radiotherapy, the biological effects of high-dose radiation, e.g., cell killing, are used for the benefit of the patient to treat cancer and other diseases. The application of these Recommendations to the medical uses of radiation therefore requires separate guidance. (Mattsson, elt, Essentials of Nuclear Medicine Physics and Instrumentation, 2013).

2.6.2Radiation protection quantities

A point quantity is not very useful for radiation protection. The average absorbed dose in a given tissue or organ is supposed to be a better indicator of the probability for radiation effects, to assess radiation exposures to humans and other organisms in a quantitative way and to describe dose/response relationships for radiation effects, the basis for risk estimation in radiological protection. This concept is based on the linear dose–effect relationship and the additively of doses for risk assessment as an appropriate approximation in the low-dose region. Otherwise, averaging of absorbed doses in organs and tissues and adding of doses over long periods would not be an acceptable procedure. Dose distributions that are highly heterogeneous (e.g. DNA precursors labeled with tritium or Auger emitters) may need special treatment. The protection quantities are mean absorbed dose in tissues or organs, equivalent dose in tissues or organs, and effective dose. (Mattsson, elt,Essentials of Nuclear Medicine Physics and Instrumentation, 2013)

2.6.2.1 Mean Organ or Tissue Dose:

The basic dosimetry quantity for use in radiation protection is the mean organ or tissue dose DT given by

$$D_T = \frac{\varepsilon_T}{m_T}$$

Where:

$m_T$is the mass of the organ or tissue T،and ε_T is the total energy imparted by radiation to that tissue or organ .

The international system of units (SI) unit of mean organ dose is joules per kilogram (J/kg) which is termed gray (Gy). Owing to the fact that different types of ionizing radiation will have different effectiveness in damaging human tissue at the same dose, and the fact that the probability of stochastic effects will depend on the tissue irradiated, it is necessary to introduce quantities to account for these factors. Those quantities are equivalent dose and effective dose. Since they are not directly measurable, the international commission on radiation units and Measurements (ICRU) has defined a set of operational quantities for radiation protection purposes (area is monitoring and personal monitoring): the ambient dose equivalent, directional dose equivalent and personal dose equivalent. Regarding internal exposure from radionuclide’s, the equivalent dose and the effective dose are not only dependent on the physical properties of the radiation but also on the biological turnover and retention of the radionuclide. This is taken into account in the committed dose quantities (equivalent and effective. .(D.L. BaileyJ.L ..etal, 2014).

2.6.2.2 Committed Dose

When radio nuclides are taken into the body, the resulting dose is received throughout the period of time during which they remain in the body. The total dose delivered during this period of time is referred to as the committed dose and is calculated as a specified time integral of the rate of receipt of the dose. Any relevant dose restriction is applied to the committed dose from the intake. The committed dose may refer to the committed effective dose and the committed equivalent (Nuclear Medicine Physics: a handbook for Teachers and students, 2014).

2.6.2.3Operational Quantities

The organ dose D_T, equivalent dose H and effective dose E are not directly measurable and there are no laboratory standards to obtain traceable calibrations for the radiation monitors using these quantities. For this reason, the ICRU has defined a set of measurable operational quantities for protection purposes: the ambient dose equivalent, directional dose equivalent and personal dose equivalent; the latter is used for comparing with regulatory requirements such as dose limits. (Radiation Oncology Physics, (2005).

2.6.2.4Ambient Dose Equivalent

The ambient dose equivalent at a point in a radiation field H*(d) is defined as the dose equivalent that would be produced by the corresponding aligned and expanded field in the ICRU sphere at a depth d on the radius opposing the direction of the aligned field. The ICRU sphere is a 30 cm diameter tissue equivalent sphere with a composition of 76.2% oxygen, 11.1% carbon, 10.1% hydrogen and 2.6% nitrogen. A depth d = 10 mm is recommended for strongly penetrating radiation. (Radiation Oncology Physics, (2005).

2.6.2.5Directional Dose Equivalent

The directional dose equivalent at a point in a radiation field H‘(d, Ω) is defined as the dose equivalent that would be produced by the corresponding expanded field in the ICRU sphere at depth d on a radius in a specified direction Ω. A depth d = 0.07 mm is recommended for weakly penetrating radiation. Angle Ω is the angle between the beam direction and the radius of the ICRU sphere on which the depth d is defined. (Radiation Oncology Physics, (2005).

2.6.2.6 Personal Dose Equivalent

The personal dose equivalent Hp (d) is defined for both strongly and weakly penetrating radiations as the equivalent dose in soft tissue below a specified point on the body at an appropriate depth d. The relevant depth is generally d = 10 mm for penetrating radiations (photon energies above 15 keV), while depths d = 0.07 mm and d = 3 mm are used for weakly penetrating radiations (photon energies below 15 keV and b radiations) in skin and the eye lens, respectively (Radiation Oncology Physics, (2005).

Any statement of personal dose equivalent should include a specification of the reference depth d. For weakly penetrating and strongly penetrating radiation, the recommended depths are 0.07 mm and 10 mm respectively, although other depths may be appropriate in particular cases, for example 3 mm for the lens of the eye. In order to simplify the notation, d is assumed to be expressed in millimeters and hence the personal dose equivalents at the two recommended depths mentioned above are denoted by Hp(0.07) and Hp(10)(9). Hp(10), i.e. the personal dose equivalent at 10 mm depth, is used to provide an estimate of effective dose that avoids both underestimation and excessive overestimation. The sensitive cells of the skin are considered to be between 0.05 and 0.1 mm below the skin surface, and therefore Hp(0.07) is used to estimate the equivalent dose to skin. Hp (0.07) should also be used for extremity monitoring, where the skin dose is the limiting quantity. (IAEA, Assessment of Occupational Exposure Due to External Sources of Radiation1999).

2.6.3 Rationale for radiation protection

When humans are exposed to ionizing radiation, there is a risk of damage to their cells and offspring. The purpose of radiation protection is to lessen the likelihood of such occurrences. If human cells respond to a high dose of radiation within minutes, days, or weeks after exposure, this is termed an early effect of radiation. The primary early effects to humans include hematologic depression, skin erythematic, epilation, chromosome damage, gonad dysfunction, and death. In modern diagnostic radiology, doses of this quantity are not experienced. If damage to human cells is not detected for months or years after radiation exposure, this is termed a late effect of radiation. The primary late effects to humans include radiation-induced cancer and genetic effects. Exposure to intermittent low doses of radiation over a long period of time is what we experience in modern diagnostic radiology. Effective dose limits have been implemented to lessen the possibility of the occurrence of early and late effects of radiation. (Steve Forshier, M.Ed, R.T. Essential of radiation biology and protection, second edition, 2009).

2.7 Monitoring of personnel

2.7.1 The types of personnel dosimeters

2.7.1.1 Film Badges

Film badges are one type of personnel dosimeter (Figure 6–2). They measure occupational radiation exposure. Film badges consist of a small piece of special radiation-dosimeter film, similar to dental film, contained in a light-proof packet. This film packet is enclosed inside a plastic holder, which can be clipped to a person's clothing. The film packet is changed monthly. Metal filters composed of either copper or aluminum are placed inside the holder. These filters shield certain parts of the film that permit estimates of dosage and radiation energy. Shallow and deep doses can be calculated according to the amount of darkening of the film after processing. Film badges are usually worn at the collar level. If a lead apron is worn, the film badge must be worn at the collar level on the outside of the lead apron. Film badges must be worn with the correct side of the badge facing forward. This allows the film badge company to determine whether the radiation dose received by the person came from in front of or from behind the wearer. Companies who supply institutions with film badges provide a control badge, which is kept in a radiation-free area. It serves as a baseline when compared with the rest of the film badges after processing by the monitoring company. After processing, the monitoring company constructs a characteristic curve similar to those used to determine film speed and contrast.

When personnel undergo medical and/or dental radiographs as a patient, the film badge should never be worn. Badges should be stored away from sources of radiation, and must be kept away from excessive heat and high humidity. They must be worn only for the designated period of time, and only by the person assigned to that badge. (Steve Forshier, M.Ed, R.T. Essential of radiation biology and protection, second edition, 2009).

2.7.1.1.1 Advantages of film badges

Simple to use, Inexpensive, Readily processed by commercial laboratories, Provide a permanent record by laboratory and in radiology department. (Steve Forshier, M.Ed, R.T. Essential of radiation biology and protection, second edition, 2009).

2.7.1.1.2Disadvantages of film badges

Are not reusable, Low limit of sensitivity (approximately 10 mrem), Accuracy limited to 10–20%, Susceptible to heat, humidity, and light leaks. (Steve Forshier, M.Ed, R.T. Essential of radiation biology and protection, second edition, 2009).

2.7.1.2 Thermoluminescent Dosimeters

Thermoluminescent dosimeters (TLD) contain lithium fluoride or calcium fluoride crystals when exposed to ionizing radiation, these crystals store radiant energy when heated. As they are heated, the crystals release energy as light, which is then measured by a machine that documents the radiation exposure based on how much light is emitted. There is a direct relationship between the intensity of light emitted and the radiation dose received by the crystals TLDs are commonly worn as finger rings by nuclear medicine personnel to measure occupational exposure to their hands from handling radioisotopes. (Steve Forshier, M.Ed, R.T. Essential of radiation biology and protection, second edition, 2009).

2.7.1.2.1 Advantages of TLDs

Can be made very small, Sealed in Teflon, minimizing chance of damage, Low exposure limit, to 5 mrem, Response to X-rays proportional up to approximately 400 R, Response almost independent of X-ray energy from about 50 kV to 50 mV, Accuracy to approximately 5%, Response very similar to tissues, Less sensitive to heat than film badge, Can be worn as a ring on fingers, Can be worn for three months, Are reusable. (Steve Forshier, M.Ed, R.T. Essential of radiation biology and protection, second edition, 2009).

2.7.1.2.2 Disadvantages of TLDs:

- Cannot be stored as a permanent record and More expensive than film badge. (Essential of radiation biology and protection, second edition). (Steve Forshier, M.Ed, R.T. Essential of radiation biology and protection, second edition, 2009).

2.7.1.3 Optically Stimulated Luminescence (OSL) Dosimeters

An optically stimulated luminescence (OSL) dosimeter contains filters composed of aluminum, tin, and copper. It also a house a thin strip of aluminum oxide. The strip is stimulated by using a laser light and becomes luminescent in relation to the amount of radiation it has received. OSLs are capable of measuring different energy ranges. This is determined by the amount of luminescence detected in the areas underneath the filters. These various ranges of energy correspond to deep, eye, and shallow doses. OSLs are sensitive to approximately 1 mrem. This makes their use especially desirable when monitoring pregnant workers. (Steve Forshier, M.Ed, R.T. Essential of radiation biology and protection, second edition, 2009).

2.7.1.3.1 Advantages of OSLs

Dose measurement range very wide: 1 mrem to 1,000 mrem, Accuracy 15% for shallow and deep exposures, Precision within 1.0 mrem, Energy range 5 keV to over 40 MeV, Complete re-analysis available – can be restimulated many times, Bar coding, color coding, graphic formats, and body location icons provide identification, Bimonthly readout offered, Tamper-proof sealed badge, Not affected by heat, moisture, or pressure, Services include badges for whole body, collar, waist, wrist, and tinge exposure to X-rays, gamma rays, and beta particles, Reports available in a great variety of forms.

2.7.1.3.2 Disadvantages of OSLs:

More expensive than film badges and TLDs. (Steve Forshier, M.Ed, R.T. Essential of radiation biology and protection, second edition, 2009).

2.7.1.4 Pocket Dosimeters

Pocket dosimeters are a very sensitive type of personnel monitoring device. They provide an instantaneous reading, but must be recalibrated daily. Also, they are capable of only a predetermined range. If exposure exceeds this range, any additional amounts of exposure cannot be documented. Externally, a pocket dosimeter resembles a fountain pen. It has a pocket clip for attaching to the person’s clothing. Inside the dosimeter is an ionization chamber. The chamber has a positive and a negative electrode. The electrodes and chamber are given a positive charge before use. There is a stationary electrode, and a moving electrode that is referred to as a hair or fiber. Giving a charge to the device with a charging base causes the fiber to be electrostatically repelled from a central electrode. This charge is calibrated until the fiber is set at zero on a visible scale. Ionization of air by radiation causes the hair to move. X- or gamma-radiation ionizes the air within the chamber, which neutralizes the charges present on the fiber and electrode. As the number of negative ions in the chamber increase, the charge on the hair reduces. This causes the hair to move closer to the stationary electrode. Pocket dosimeters are read by viewing a scale through an eyepiece located on the end of the dosimeter. Pocket dosimeters are normally used only in emergency situations in which an immediate reading is necessary. They may give false readings if subjected to trauma or high humidity. (Steve Forshier, M.Ed, R.T. Essential of radiation biology and protection, second edition, 2009).

2.7.1.4.1 Advantages of pocket dosimeters

Provides an immediate exposure reading, Sensitive to exposures up to 200 mR can be reset to record individual exposure readings.

2.7.1.4.2 Disadvantages of pocket dosimeters:

Does not provide a permanent legal record of exposure, Bumping or shock to unit can cause false high readings. (Steve Forshier, M.Ed, R.T. Essential of radiation biology and protection, second edition, 2009).

2.8 Principles of Radioactive lodlne-131 Therapy

As the distance from a source of radiation increases, the intensity of the radiation from the source decreases as the increase square of this distance. This principle can be used to advantage by placing radioactive sources near cancer cells so they receive high doses of radiation, while normal, healthy cells further away receive lower, less damaging doses. This form of treatment is called brachytherapy. The ultimate approach is to place the radio-active material inside the cancer cells themselves. In such a case, the dose to the cell containing the radioactive material becomes extremely high. If the normal cells do not absorb the radioactive material, their dose remains quite low. Because iodine is taken into thyroid cells, radioactive iodine, usually the isotope1-131 can be used in just such a manner to treat some types of thyroid cancers, or for treatment of thyroid hormone overproduction (hyper-thyroidism). For treatment with1-131, a patient is given the material either orally (solution or capsules) or intravenously. For treatment of hyperthyroidism, patients usually take about1 GBq of1-131. Patients undergoing treatment for cancer therapy often take from 3 to 6 GBq of1-131.It is not recommended to let the patient return home immediately. Instead, he or she should be kept at the hospital for a period of between some hours and several days. The maximum activity at which a patient is allowed to return home depends on national practice and on the individual situation of the patient. It usually ranges between 0.2 and1 GBq. The physical characteristics of 1-131 are shown below.lodine-131 emits both beta and gamma radiation. The dose to the cells containing the iodine is mostly due to the emit-ted beta particles and the dose at a distance is mostly due to the gamma rays. (Radiation protection 97, European commission, 1998).

2.8.1 Characteristics of Iodine-131

The activity of a sample of 1-131 decays over time with a half-life of 8 days. Thus, a vial containing 2 GBq of 1-131today will contain 1 GBq in 8 days, 0.5 GBq in 16 days, and so on. In the body the amount of radioactive iodine decreases much faster, because, in addition to radioactive decay, the body also excretes iodine. In a normal person, the amount of 1-131 in the body decreases by half about every three days. The time required for the activity in the body to fall by half is called the effective half-time. The effective half-time can become much longer than 3 days (but never longer than 8 days) in patients with certain diseases which cause the retention of iodine. (Radiation protection 97, European commission, 1998).

2.8.2 Mechanism I^{131} therapy

Two types of biological effects of ionizing radiation are known: deterministic effects and stochastic effects. Deterministic effects are those caused by the decrease in or loss of organ function due to cell damage or cell death. For these effects threshold doses exist: the function of many organs and tissues is not affected by small reductions in the number of available healthy cells. Only if the decrease is large enough will clinically observable pathological dysfunctions appear. In the case of treatment of thyroid cancer, metastases, hyperthyroidism and euthyroidgoitre, the objective are to bring about the cell-killing effect while not affecting other organs in such a way that deterministic effects occur. Due to the capacity of thyroid cells to take up iodine thyroid diseases can be treated with radioactive iodine.The β-emitting I-131 is often the radionuclide of choice for these treatments, although the associated γ-emission gives rise to exposures to other tissues and even to other individuals. (Radiation protection 97, 98).

The probability of a radiation-induced fatal cancer for the average population has been estimated (ICRP-60) at approximately 5 percent per sievert[2] for low doses and at low dose rates and at 1 percent for serious genetic diseases. For elderly people, older than about 60 years, the probability seems to be 3to 10 times lower. This is because the future life span of elderly people may not be long enough for the cancer to become apparent and it is also unlikely that genetic damage is passed to offspring. For children up to the age of 10 years, the probability of fatal cancer induction seems to be about 2-3 times higher. For pregnant women the risk is the same as for the average population; however, the unborn child is assumed to have the same risk of developing a fatal cancer as young children. Deterministic effects have been observed after massive irradiation in utero, but dose levels incurred by family or close

Friends from a treated patient are far below the threshold for such effects. As sensitivity to ionizing radiation is different for different age categories, instructions to reduce the risk for these groups will also vary accordingly.(Radiation protection 97, 98).

2.8.3 Radiation Protection in lodine-131 Therapy

Radiation protection associated with 1-131 treatments must address the hazards of radiation exposure and radio-active contamination. Lost or unaccounted for radioactive material has also to be considered. (William D. Leslie , Nuclear Medicine. *Landes Bioscience LTD*, Texas, USA2003)

2.8.3.1 Radiation exposure

The three main considerations are time, distance andshielding.

2.8.3.1.1 Time

When preparing the radioactive material for a patient, be sure to plan what to do and have all equipment and containers ready before taking the material out of the shielded container. Staff coming in contact with a patient containing radioactive iodine should not stay near the patient longer than the time which is needed to nurse the patient properly. . (William D. Leslie , Nuclear Medicine. *Landes Bioscience LTD*, Texas, USA2003)

2.8.3.1.2 Distance

Never handle the radioactive material, either the capsules or the vial containing the material as a liquid, with the fingers; rather, use instruments such as forceps. At all times, stay as far from the sources as possible and still perform necessary functions quickly. Nurses should perform functions with as much distance between them and the patient as possible, without sacrificing patient care. (William D. Leslie , Nuclear Medicine. *Landes Bioscience LTD*, Texas, USA2003)

2.8.3.1.3 Shielding

Iodine-131 should be kept behind shielding(lead bricks in the storage room, or a shielded transportation container when in transit),except during assay and when being given tothe patient. Once the iodine is in the patient, shielding barriers should be used to provide some protection for the staff and visitors.

Usually, a centimeter or two of lead is required to reduce the dose rates to acceptable levels. Fluoroscopy aprons provide no protection against the radiation from1-131. For the safety of the patients and the public, the dose rate outside the room should be kept to acceptable levels, such as 6fiSv/h in areas to which the public has access. To comply with these requirements it may be necessary to shield the treatment rooms or to leave adjacent room empty (except for other iodine therapy patients). . (William D. Leslie , Nuclear Medicine. *Landes Bioscience LTD*, Texas, USA2003).

2.8.3.2 Evaluation of Exposure to Personnel

Monitoring personnel working with 1-131 must include evaluation of their exposure to the radiation from the iodine, and whether they took any iodine into their body. Their personal dosimeter indicates the exposure level. To make sure that there is no significant amount of iodine taken into their body, they could have a thyroid count, Justas the patients do. . (IAEA for Protection against Ionizing Radiation and for the Safety of Radiation Sources Safety Series No. 115, IAEA, Vienna 1996).

2.8.4 Radioactive iodine contamination

When working with1-131, radioactive contamination always presents a potential hazard. The danger from such contamination comes from the possibility that persons working with either the material itself or a patient containing some iodine may take some of the radioactive iodine into their body, giving high doses of radiation to their thyroids. Iodine can be absorbed into the body by the mouth, directly through the skin, or by inhaling vaporized iodine in the air. The first line of defense against radio-active contamination is to always wear. International Atomic Energy Agency. (IAEA for Protection against Ionizing Radiation and for the Safety of Radiation Sources Safety Series No. 115, IAEA, Vienna 1996).

2.8.4.1 Important sources of radioactive contamination include

Airborne iodine vapors. Iodine gives off vapors. Solutions containing 1-131 pose the greatest danger. Containers of 1-131 should always be stored and handled under a fume hood. With respect to this risk, capsules should be used instead of liquids. Patients body fluids. Approximately 80% of the iodine given to a patient comes out in the urine during the first24 hours. That means that the patient's urine contains large amounts of1-131. In all cases this urine must be collected and treated as radioactive waste, according to the local rules. It is good practice for thyroid cancer treatment to store the urine of the first 24 hours after treatment in closed containers in a locked and shielded room for approximately two months to allow for decay, and the release it to the sewer system. However, the best solution is to treat the patient in a special room where the toilet is connected to a separate storage container. When nursing the patient the staff should always wear disposable plastic gloves and aprons to protect clothing. Upon release of the patient, the linen and cloths must be checked for contamination, and if contaminated, must be cleaned separately. Any item which cannot be cleaned must be stored in the radioactive source storage room, where, over time, through radioactive decay, the contamination will eventually disappear. Contact with the source material. Radioactive iodine frequently contaminates the outside of containers. The contamination can be spread by people touching the container itself, or the instruments used to handle the container. (IAEA for Protection against Ionizing Radiation and for the Safety of Radiation Sources Safety Series No. 115, IAEA, Vienna 1996).

Assume that all handling tools used with 1-131 could be contaminated. Store them on disposable paper pads (to prevent contamination of the tabletop) near the hood. Never touch these instruments without wearing gloves, and never use them for other purposes , Spilling the material. To restrict the risk of contamination from a vial accidentally spilled it should always stay on disposable, plastic backed absorbent pad on a tray with lips around the edge to contain this contamination. Prevention of loss or unaccounted disappearance of radioactive material, a careful accounting system for radioactive material from its arrival through its use or disposal provides the best prevention against loss. The system should include a record book which contains at least the following information, isotope, date, lot or batch number and the vial's serial number, date of assay, total assay activity and volume. The same information must also appear on labels for the vials. After being used, the vials themselves can be stored in a locked storage room awaiting decay of the radioactivity before being disposed of as normal waste. (IAEA for Protection against Ionizing Radiation and for the Safety of Radiation Sources Safety Series No. 115, IAEA, Vienna 1996).

2.8.4.2 Preparation for an lodlne-131 Treatment Programme

Before an 1-131 treatment programme is started, it should be ensured that, All staff involved in planning the programme are properly trained. The facility has a radioactive storage and preparation room with a shielded area under a hood for storage of the material. The room should have walls and floors with surfaces that are easy to clean. The storage room should not be a passageway, or a shared room such that persons not involved with the1-131 treatments spend time in the room. The storage facility should provide secure closure to prevent unauthorized access to the sources, and also maintain acceptable radiation levels, such as 20mSv/h, to persons around the facility. A thick leaded glass window protects the eyes of persons working with the sources. (ICRP,97).

The treatment room could be either a room adjacent to the storage and preparation room or the patient room itself, which should have walls and floors with surfaces that are easy to clean. The facility has an adequate supply of long handled instruments for use in handling the sources, trays with lips and absorbent pads. All persons involved in the programme have and wear personal dosimeters and there are two Geiger counters available: one for use in the storage room, and one outside the storage room for use if a source spills and contaminates the other detector. An accounting system has been established to keep track of the source material. (Radiation protection 97, 98).

A proper system has been established for radio-active waste disposal, especially for urine disposal.Iodine-131 provides effective treatment for some thyroid patients, but can be dangerous if approached casually, or without thorough preparation. . (Radiation protection 97, 98).

2.9 Previous studies

The most commonly used radio-nuclides in ^{131}I. Their applications have been continuously increasing for therapeutic uptake in most of the nuclear medicine facilities in Sudan. Although such an increase is a positive trend for the benefit of patients, the associated risk of radiation exposure of staff needs to be properly evaluated. Generally, occupational workers are routinely monitored for their effective whole body doses by use of the pocket dosimeters. In the following paragraph we will discuss the outcomes of various papers published.

A.Al-Abdulsalam, et al, occupational radiation exposure among the staff of departments of nuclear medicine and diagnostic radiology in Kuwait, they investigated radiation exposure among the staff of departments of nuclear medicine (NM) and diagnostic radiology (DR) during 2008 and 2009 and to compare the mean doses received with the limit of 20 mSv/year of the International Commission of Radiological Protection (ICRP).They using thermoluminescent dosimeter. They studied a total of 1,780 radiation workers, grouped as NM physicians, radiologists, NM technologists, and DR technologists, from 7 departments of NM and 12 departments of DR were included. They found that the annual average Hp(10) and Hp(0.07) were calculated for each group and comparisons were made between the groups and the years. Also t a two-sided Mann-Whitney test was carried out, at the $p = 0.05$ level, to compare the means. The mean Hp(10) was compared with the limits of the ICRP. Of the 16 distributions of Hp(10) and Hp(0.07), 10 were normal, with a mean annual Hp (10) in 2008 of 1.06, 1.03, 1.07, and 1.05 mSv for NM physicians, technologists, and DR technologists, respectively. The corresponding Hp(0.07) values for 2008 were 1.03, 1.00, 1.05, and 1.03 mSv, respectively. Small but significant ($p < 0.001$) reductions in Hp(10) and Hp(0.07) were observed in 2009 for NM technologists and DR technologists. In all other cases, no significant ($p > 0.072$) differences were found. The annual average Hp(10) was well below the limit of the ICRP.

An others authors; KamilSzewczak, et al (2013)(22), Individual dose monitoring of the nuclear medicine departments staff controlled by Central Laboratory for Radiological Protection;. They described the results of the individual doses measurements for ionizing radiation, carried out by the Laboratory of Individual and Environmental Doses Monitoring (PDIS) of the Central Laboratory for Radiological Protection in Warsaw (CLOR) for the medical staff employees in several nuclear medicine (NM) departments across Poland. In total there are 48 NM departments in operation in Poland (consultation in Nuclear Atomic Agency). Presented results were collected over the period from January 2011 to December 2011 at eight NM departments located in Krakow, Warszawa. For radiation monitoring three kinds of thermoluminescence dosimeters (TLD) were used. The first TLD collected information about whole body (C) effective dose, the second dosimeter was mounted in the ring (P) meanwhile the third on the wrist (N) of the tested person. Reading of TLDs was performed in quarterly periods. As a good approximation of effective and equivalent dose assessment of operational quantities both the individual dose equivalent Hp(10) and the Hp(0.07) were used. The analysis of the data was performed using two methods The first method was based on quarterly estimations of Hp(10)q and Hp(0.07)q while the second measured cumulative annual doses Hp(10)a and Hp(0.07)a. The highest recorded value of the radiation dose for quarterly assessments mounted 24.4mSv and was recorded by the wrist type dosimeter worn by a worker involved in source preparation procedure. The mean values of Hp(10)q (C type dosimeter) and Hp(0.07)q (P and N type dosimeter) for all monitored departments were respectively 0.46mSv and 3.29 mSv. There was a strong correlation between the performed job and the value of the received dose. The highest doses always were received by those staff members who were involved in sources preparation. The highest annual cumulative dose for a particular worker in the considered time period was 4.22 mSv for Hp(10)a and 67.7 mSv for Hp(0.07)a. In 2011 no case of exceeding the allowed dose limits was noted.

Also TuncayBayram, et al. (2011), Radiation Dose to Technologists per Nuclear Medicine Examination and Estimation of Annual Dose they measured deep-dose equivalent to technologists per procedure and reported doses within the range of 0.13 ± 0.05 to 0.43 ±0.17 µSv using a lead shield and 0.21 ± 0.07 to1.01 ± 0.46 µSv without a lead shield. Also, the annual individual dose to a technologist performing only a particular scintigraphic procedure throughout a year was estimated. For a total of 95 clinical cases (71 patients), effective external radiation doses to technologists were found to be within the permissible levels. This study showed that a 2-mm lead shield markedly reduced the external dose to technologists.

The doses to technologists varied significantly for different diagnostic applications. Consequently, the estimated annual dose to a technologist performing only a particular scintigraphic procedure is very different from one type of procedure to another. The results of this study should help in determining the rotation time of technologists in different procedures and differences in their individual techniques.

Other authors Opio Peter, et al (2015), Assessment of Radiation doses of Staff of Nuclear Medicine Unit at Mulago National Referral and Teaching Hospital, they assessed of radiation doses of staff in the Nuclear Medicine Unit of Mulago National Referral and Teaching Hospital. The doses received by staff are compared with the dose limits recommended by the International Atomic Energy Agency (IAEA), World Health Organization (WHO) and International Commission on Radiological Protection (ICRP). Doses of occupational workers in the Nuclear Medicine unit were monitored for a period of 5 months. Personal radiation doses were determined using two chip LiF TLD-100 dosimeter badges. The TLD badges and reader were calibrated using a standard 90-Strontium radiation source. The mean monthly effective radiation doses for the staff ranged from 0.78± 0.05mSv/month for nursing officers to 0.08± 0.05mSv/month for the nuclear medicine physician. These mean monthly effective radiation doses were projected to the annual effective radiation doses received by staff. The mean annual radiation doses were 9.29±0.60mSv/yr for Nursing Officers, 2.79± 0.60mSv/yr for Medical Physicist and Radiographer, 6.46 ±0.60mSv/yrfor Radioimmunoassay Technologists, 1.71 ± 0.60mSv/yr for Nuclear Medicine Technologist and 0.91±0.60 mSv/y for Nuclear Medicine Physician. The results of this study show that effective radiation doses received by the Nuclear Medicine staff of Mulago National Referral and Teaching Hospital are within the recommended dose limits for occupational workers.

The next ones A. Sadremomtaz, et al (2011), occupational Exposures in Nuclear Medicine Clinics in Guilanthey assessed the occupational exposures involved in these practices, few clinics were selected for the sake of personnel dosimeter in the capital city of Rasht. Application of radioisotopes for diagnostic and therapeutic purposes has been widely increased in Iran during recent years. Numerous nuclear medicine centers have been established in the northern Iranian province of Guilan during this period.. On the basis of collected information, target groups were chosen and specially designed badges, consisting three LiF: MCP TLD chips each, have been distributed among them for measurement periods of two months. The TL dosimeters are going to be analyzed by Harshaw 3500 TLD reader using WinREMS software. average whole-body dose to specialists was(0.05-0.09)mSv/yr, average whole-body dose to nurses was(0.08-0.72) mSv/yr, average whole-body dose to technologists was(0.05-0.16) mSv/yr, average whole-body dose to receptionists was(0.05-0.16) mSv/yr, average whole-body dose to health physics was(0.07-0.12) mSv/yr and average whole-body dose to employee was(0.06-0.18) mSv/yr The result on occupational radiation doses will be compared with the relevant national as well as international standards and guidelines.

T.M.Taha ,et al (2008), Hand Dose in Nuclear Medicine Staff Members In Egypt 2008, they measured of the hand dose during preparation and injection of radiopharmaceuticals is useful in the assessment of the extremity doses received by nuclear medicine personnel. Hand radiation doses to the occupational workers that handling m Tc^{99m}-labeled compounds,I^{131} for diagnostic in nuclear medicine were measured by thermo luminescence dosimeters.

A convenient method is to use a TLD ring dosimeter for measuring doses of the diagnostic units of different nuclear medicine facilities. Their doses were reported in millisieverts that accumulated in 4 weeks. The radiation doses to the hands of nuclear medicine staff at the hospitals under study were measured. The maximum expected annual dose to the extremities appeared to be less than the annual limit (500 mSv/y) because all of these workers are on rotation and do not constantly handle radioactivity throughout the year **.**

Also EUR JornalNucl Med 1997 Dec,24(12):1545, Radiation dose rate from patient receiving iodine-131 therapy for carcinoma of thyroid they had combined whole-body dose rate measurements taken from 86 thyroid cancer patient after radioiodine administration with published data on nursing and social contact times to calculate the accumulate dose that maybe received by the patient . These dose estimates have been used to calculate restrictions to patient behavior to limit received doses to less than 1msv .The acclumative dose to the nursing staff for the week after the treatment was depend on the patient mobility and was estimated at 0.08mSv for self-caring patient to 6.3mSv for totally helpless patient(9). In the other hand a team of International Journal of Radiation Research ،April 2016 ،Y. Lahfi* and O. Anjak; Protection and Safety Department, Atomic Energy Commission, estimation the radiation dose during emergency. The yaimedto exposure to patients treated with iodine-131 during the isolationperiod. They usedThe dose rate from a sample of 192 patients administrated by three different radioactivity of 131I (3.7, 5.55 and 7.4 GBq)was measured, at 1 meter after 1, 24 and 48 hours post dose administration,at three different levels from the patient body (thyroid glands, abdomen andknee). The average of decay curve of the measured radiation dose rate was poled and their values were filed. The medical emergency exposure was estimated in the form of an equation to take into account the duration and the position of the intervention. They result that The estimated radiation doses received during 10 minutes of intervention emergency at a distance of 20, 40and 60 cm from patient after different times post dose administration were in the range of 72.2 to 1207.5, 18.1 to 301.9 and 8.0 to 134.2 μSv, respectively.

They conclude that during the first ten hours following patient dose administration, the estimated emergency dose could be considered as high occupational dose value compared to the dose limit recommended by ICRP.

S.A. Alramlawi1, et, al, assessment the occupational ionizing radiation in medical uses, they objective to assess the occupational ionizing radiation doses in medical uses based on job categories and level of radiation doses exposure. Radiation survey has been carried out in Cairo University Hospital in 3 main places that use radionuclide's for various diagnostic and therapeutic purposes, Nuclear Medicine Department (Exposed to high doses of Tc99m and I131), Cardiology Center (Exposed to medium doses of Tc99m) and Gamma Camera Center in King Fahd Unit and Radiotherapy Center (Exposed to low doses of Tc99m). Each level of exposure is divided into three subgroups according to job category, Physicians, Physicists and Technologists (Technicians and Nurses) groups. the equivalent dose of hand per year "mSv" was measured for radiation workers in nuclear medicine only, while the equivalent dose per year "mSv" and the accumulated doses over ten years "mSv" (2002-2012) of whole body were measured for the all groups. The results revealed that the Physicists in nuclear medicine were exposed to the highest equivalent dose of hand (36.5±1.86) mSv followed by Physicians (21.7±1.96) mSv and Technologists (6.23±1.72) mSv. The statistical analysis of these results showed a considerable significant difference among each group. The maximum expected annual dose of fingers appeared to be less than the annual limit (500 mSv/y). For the whole-body, the results of equivalent and accumulated doses indicated that, there was no significant difference among each group in each level of radiation also revealed that these doses were lower than the international recommended dose limits (20 mSv)

Soliman K, et, al Estimation of patient attenuation factor for iodine-131 based on direct dose rate measurements from radioiodine therapy patients, They aimed to measure the actual dose at 1 m from the patients per unit activity with the aim of providing a more accurate prediction of the dose levels around radioiodine patients in the hospital, as well as to compare our results with the literature. In this work the demonstration of a patient body tissue attenuation factor is verified by comparing the dose rates measured from the patients with those measured from the unshielded radioiodine capsules immediately after administration of the radioactivity. The normalized dose rate per unit activity is therefore proposed as an operational quantity that can be used to predict exposure rates to staff and patients' relatives. The average dose rate measured from our patient per unit activity was 38.4±11.8 μSv/h/GBq. The calculated attenuation correction factor based on our measurements was 0.55±0.17. The calculated dose rate from a radioiodine therapy patient should normally include a factor accounting for patient body tissue attenuation and scatter. The attenuation factor is currently neglected and not applied in operational radiation protection. Realistic estimation of radiation dose levels from radioiodine therapy patients when properly performed will reduce the operational cost and optimize institutional radiation protection practice. It is recommended to include patient attenuation factors in risk assessment exercises - in particular, when accurate estimates of total effective doses to exposed individuals are required when direct measurements are not possible. The information provided about patient attenuation might benefit radiation protection specialists and regulators.