The Effect of Distance and Angle of the Measuring Device on Detection of Gamma Rays, Sudan Atomic Energy Center, Khartoum State, Sudan

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Dedication

This work is dedicated with great thanks to my parents, my brothers and sisters.

To my relatives.

To everyone taught me a letter and

My friends and Students

Manhal
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All praise to Allah almighty, is the one and only creator of this whole universe and who helps everyone to complete the work. Thanks University of Gezira and also for all staff of the Department of Electronic Engineering, Faculty of Engineering and Technology.

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Abstract

Radiation is the physical phenomenon which occurs in unstable atomic nuclear, which loses some of its components. Experiments show that there are types of radiation that originate from the nucleus: alpha (α), Beta (β), and Gamma (γ). Radiation effects on human are both harmful or useful. The aim of current study is determination of the distance and angle of inclination effects on the amount of radiation detected of Gamma Rays. It is carried out in Institute of Radiation Safety, Sudan Atomic Energy Center. This study concerns the amount of radiation doses at a distance from the source and the angle of measuring device. RADOS was used to measure the emitted Gamma energy of cesium 137 isotop with 3.7MBq radio-activity. Readings were taken 5, 10, 15 and 20 cm in 30 minutes. It was found that at angle zero and distance 5, 10, 15 and 20 cm the dose equals to 18.3, 9.16, 5.45 and 3.89 μsv/h respectively. Then at the angle 45° and distance 5, 10, 15 and 20 cm the dose equals to 12.3, 7.8, 5.35 5.3 μsv/h respectively. And angle 60° and distance 5, 10, 15 and 20 cm the dose equal to 12.6, 7.13, 5.3 and 4.47, respectively. And angle 90° and distance 5, 10, 15 and 20 cm the dose equal to 4.14, 4.18, 4.7 and 4.44, respectively. So radiation quantity decreases with increasing distance from the source while radiation dose decrease with increasing the angle of measuring device. This study resulted that when increasing distance decreases radiation quantity that is exposed to workers and decrease with increasing angle of incident radiation.
تأثير المسافة وزاوية جهاز القياس على تحديد أشعة قاما - مركز أبحاث الطاقة الذرية
السودانية، ولاية الخرطوم، السودان
منهل مبارك علي بابكر

ملخص الدراسة

النشاط الإشعاعي ظاهرة فيزيائية تحدث في النواة غير المستقرة، وفيه تفقد النواة بعض مكوناتها. وقد دلت الاختبارات على وجود ثلاثة أنواع مختلفة من الإشعاعات هي جسيمات بيتا ودقائق ألفا وأشعة قاما. للأشعة تأثيرات سلبية وإيجابية على حياة الإنسان ومن الضروري معرفة العوامل التي تؤثر على شدة الأشعة حتى تتمكن من تقليل تعرض الإنسان لها. الهدف من هذه الدراسة معرفة تأثير المسافة وزاوية جهاز قياس الجرعات الإشعاعية (RADOS) على تحديد أشعة قاما. أجريت هذه الدراسة بمعهد السلامة الإشعاعية بجهة الطاقة الذرية السودانية. اهتمت هذه الدراسة بتأثير الجرعة الإشعاعية من المصدر والزاوية التي يصنعها جهاز القياس. تم استخدام جهاز قياس الجرعات الإشعاعية (RADOS) لقياس كمية الأشعة المنبعثة من نظير السيميوم 137 ذو النشاط الإشعاعي M Beq 3.7. اخذت القراءات بين 5، 10، 15 و20 سم في نصف ساعة. وقد وجد أنه عند قياس الأشعة عند زاوية صفر والمسافة 5، 10، 15 و20 سم كانت الجرعة الإشعاعية 18.3، 9.16، 4.4 و3.89 مكرو سيفرت في الساعة على التوالي. عند زاوية 45° والمسافة 5، 10، 15 و20 سم كانت الجرعة الإشعاعية 12.3، 7.8، 5.35 و5.83 مكرو سيفرت في الساعة على التوالي. عند الزاوية 60° والمسافة 5، 10، 15 و20 سم كانت الجرعة الإشعاعية 12.6، 7.13، 5.3 و4.74 مكرو سيفرت في الساعة على التوالي. وعند الزاوية 90° والمسافة 5، 10، 15 و20 سم كانت الجرعة الإشعاعية 14.14، 8.18، 4.7 و4.44 مكرو سيفرت في الساعة على التوالي. أي أن كمية الأشعة تقل كلما زادت المسافة من المصدر في حين تقل الجرعة الإشعاعية عند زيادة زاوية أيضاً. من نتائج هذه الدراسة وجد أنه كلما زادت المسافة قلت كمية الأشعة التي يتعرض لها العامل وكذلك عند زيادة زاوية سقوط الأشعة تقل كمية الأشعة.
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CHAPTER ONE

INTRODUCTION

Gamma rays are energy photons emitted as on the three types of radiation resulting from neutral radioactivity, it’s the most energetic from EM radiation. Electromagnetic radiation includes such diverse phenomena as radio, television, microwaves, infrared radiation, light, ultraviolet radiation, x rays, and gamma rays (NCRP, 2009 and Nick et al., 2009). Gamma rays and X-rays are very similar, but have one significant difference, and that is in where they are produced. X-rays are created in the electron shells when the electron undergoes a deceleration or jump to lower energy levels. Gamma rays are created by energy transition within the nucleus (John, 2002).

In reality, Becquerel had found gamma radiation being emitted by radium-226 a nuclide that is part is the uranium decay chain, in 1909, Soddy and Russell resulting that gamma-ray attenuation followed an exponential law and that the ratio of the attenuation coefficient to the density of the attenuating material was nearly constant for all materials (Shao et al., 2012).

1.1 Research problem

The research problem in identification of factors affecting intensity of Gamma rays to reduce susceptibility of man to this injuries rays

1.2 Objectives of this study

The objectives of this research is :

– Identification of different factors affecting Gamma ray intensity.

1.3 Research methodology

Cesium 137 with 30 years half of its lifespan beside RADOS device were used to identify the changes of the ray's density with distance between the source and the measurement device and with Gamma sloping angle (\( \gamma \)). The device is to be put
touching the source \((0 = x)\) them we change the angle of the perpendicular axis on the surface of the device from \(0\) (zero) to 45 degrees them from \(45^0\) to \(60^0\) and finally from 60 to 90 degrees. The measurement device is to be put away to a distance of 5cm, then we repeat the aforementioned steps. After that we take other three observations by adding a distance of 5cm in each.

### 1.4 Thesis layout

Thesis includes four chapters, chapter one is introduction. Chapter two is theoretical background and previous Studies, chapter three is material and method, chapter four is results and discussion.
CHAPTER TWO

THEORETICAL BACKGROUND

2.1 Introduction

Gamma rays are forms of radiant energy, like light or radio waves. Gamma rays can penetrate the body, which allows a radiologist to produce pictures of internal structures. The radiologist can view these on photographic film or on a TV or computer monitor. Gamma ray examinations provide valuable information about your health and play an important role in helping your doctor makes an accurate diagnosis. In some cases Gamma rays are used to assist with the placement of tubes or other devices in the body or with other therapeutic procedures. See the gamma ray, Interventional Radiology and Nuclear Medicine and Radiation Safety page for more information.

2.2 Atom

The atomic nucleus is assumed to be a bound configuration of protons and neutrons. Protons and neutrons have nearly the same mass and differ principally in charge: protons have a positive charge and neutrons are electrically neutral, different elements have nuclei with different numbers of neutrons and protons. The number of Protons in the nucleus is called the atomic number and given the symbol Z. In the neutral atom, the number of protons is equal to the number of electrons. The number of neutrons in the nucleus is given the symbol N. The total number of nucleons (protons and neutrons) in the nucleus is called the atomic mass number and given the symbol A (A = Z + N).

By the early 20th century, there was rather compelling evidence that matter could be described by an atomic theory. That is, matter is composed of relatively few building blocks that we refer to as atoms. This theory provided a consistent and unified picture for all known chemical processes at that time. However, some mysteries could not be explained by this atomic theory. In 1896, A.H. Becquerel discovered penetrating radiation. In 1897, J.J. Thomson showed that electrons have negative electric charge and come from ordinary matter. For matter to be electrically
neutral, there must also be positive charges lurking somewhere. Where are and what
carries these positive charges? A monumental breakthrough came in 1911 when
Ernest Rutherford and his coworkers conducted an experiment intended to determine
the angles through which a beam of alpha particles (helium nuclei) would scatter after
passing through a thin foil of gold. What results would be expected for such an
experiment? It depends on how the atom is organized. A prevailing model of the atom
at the time (the Thomson, or “plum pudding,” atom) proposed that the negatively
charged electrons (the plums) were mixed with smeared-out positive charges (the
pudding). This model explained the neutrality of bulk material, yet still allowed the
description of the flow of electric charges. In this model, it would be very unlikely for
an alpha particle to scatter through an angle greater than a small fraction of a degree,
and the vast majority should undergo almost no scattering at all (Mahr and Lynch,
2004).

2.2.1 The nucleus

The nucleus depicted in Fig. (2.2) is now understood to be a quantum system
composed of protons and neutrons, particles of nearly equal mass and the same
intrinsic angular momentum (spin) of \(\frac{1}{2}\). The proton carries one unit of positive
electric charge while the neutron has no electric charge. The term nucleon is used for
either a proton or a neutron. The simplest nucleus is that of hydrogen, which is just a
single proton, while the largest nucleus studied has nearly 300 nucleons. A nucleus is
identified as in the example of Fig. 2-3 by its atomic number \(Z\) (i.e., the number of
protons), the neutron number, \(N\), and the mass number, \(A\), where \(A = Z + N\) (Mahr
and Lynch, 2004).
As the center of the atom is a nucleus formed from nucleons: protons and neutrons. Each nucleon is made from three quarks held together by their strong interactions which are mediated by gluons. In turn, the nucleus is held together by the strong interactions between the gluons and quarks constituting of neighboring nucleons. Nuclear physicists often use the exchange of mesons—particles which consist of a quark and an antiquark, such as the pion—to describe interactions among the nucleons.

Figure (2.1): The nucleus
Figure (2.2): Atomic numbers

\[ A_{mass}^{14} \quad Z_{atomic\ number}^{6} \quad N_{neutron\ number}^{ } = A - Z \]
2.3 Detector

Experiments in Nuclear and Particle Physics depend upon the detection of primary radiation/particle and that of the product particles if any. The detection is made possible by the interaction of nuclear radiation with atomic electrons directly or indirectly. We may conveniently classify the detectors into two classes

(i) Electrical
(ii) Optical,

The same detector may be used to study different types of radiation according to different phenomena. Thus, G.M. counters register all sorts of charged particles through ionization effects. Scintillation counters detect gamma rays by photoelectric effect, Compton scattering or pair production depending on gamma ray energy. Cerenkov counters detect a charged particle moving with speed exceeding that of light in a medium. Neutrons of high energy can be detected indirectly by the ionization caused by the recoil protons, and slow neutrons through the alpha particles produced in boron or by the fission of U-235 nuclei (Kamal, 2014).

2.3.1 RADOS

The RDS-200 utilizes field-proven measurement electronics and also the TIM (Time Interval Method) measuring principle, known from RADOS AAM environmental monitoring system. The RDS-200 Meter is an excellent multipurpose radiation meter for a wide range of applications. Especially it was designed for situations where accurate measurements at low dose rate levels are of import naturally occurring radioactive nuclei undergo a combination of $\alpha$, $\beta$ and $\gamma$ emission. Artificially produced nuclei may also decay by spontaneous fission, neutron emission and even proton and heavy-ion emission. Any decay process is subject to the same basic law data Storage: the data logging interval of the instrument can be set from 1 to 99 minutes and it will memorize the 864 last measurement results in its internal memory power supply: 3 alkaline batteries (IEC LR6 / AA), +12 V DC external battery adapter (optional) or AC adapter (optional) battery life: 200 h in background field (+ 25°C- 77°F) battery alarm: 15 h before battery power-out.
2.4 Radioactive decay

An emitted gamma ray from any type of excited state may transfer its energy directly to any electrons, but most probably to one of the K shell electrons of the atom, causing (external gamma rays and ultraviolet rays may also cause this effect). The photoelectric effect should not be confused with the internal conversion process, in which a gamma ray photon is not produced as an intermediate particle (rather, a "virtual gamma ray" may be thought to mediate the process).

Gamma rays, X-rays, visible light, and radio waves are all forms of electromagnetic radiation. The only difference is the frequency and hence the energy of those photons. Gamma rays are generally the most energetic of these, although a broad overlap with X-ray energies occurs. An example of gamma ray production follows:

First $^{60}$Co decays to excited $^{60}$Ni by beta decay emission of an electron of 0.31 MeV. Then the excited $^{60}$Ni decays to the ground state (see nuclear shell model) by emitting gamma rays in succession of 1.17 MeV followed by 1.33 MeV. This path is followed 99.88% of the time:

\[
\begin{align*}
^{58}\text{Co} & \rightarrow 0.31 \text{ MeV } ^{58}\text{Ni} + ^{58}\text{Co} \\
& \rightarrow 1.17 \text{ MeV } ^{60}\text{Ni} + ^{58}\text{Co} \\
& \rightarrow 1.33 \text{ MeV } ^{60}\text{Ni} + ^{58}\text{Co} \\
\end{align*}
\]

Figure (2.3): Decay scheme of 60Co

\[ ^{60}\text{Co} \rightarrow ^{60}\text{Ni} + ^{58}\text{Co} + ^{58}\text{Ni} + 1.17 \text{ MeV} \]

\[ ^{60}\text{Ni} \rightarrow ^{60}\text{Ni} + 1.33 \text{ MeV} \]
Another example is the alpha decay of $^{241}\text{Am}$ to form $^{237}\text{Np}$; which is followed by gamma emission. In some cases, the gamma emission spectrum of the daughter nucleus is quite simple, (e.g. $^{60}\text{Co}/^{60}\text{Ni}$) while in other cases, such as with ($^{241}\text{Am}/^{237}\text{Np}$ and $^{192}\text{Ir}/^{192}\text{Pt}$), the gamma emission spectrum is complex, revealing that a series of nuclear energy levels exist.

Because a beta decay is accompanied by the emission of a neutrino that also carries a varying amount of energy away, the beta emission spectrum does not have sharp lines, but instead is broad. Hence, it is not possible to describe the different energy levels found in the nucleus using beta decay energies alone (Hubbel, ’1969).

2.5 Decay

Since we shall consider a number of basic decay mechanisms. They are: alpha decay; beta decay ($\beta^-, \beta^+$ and electron capture); gamma decay and internal conversion; spontaneous fission (Bock, 2008).

2.5.1 Alpha decay

A radioactive substance becomes more stable by: alpha decay (helium nucleus $^4_2\text{He}$), or beta decay (electron $e^-$ or positron $e^+$) or gamma decay (high energy photon). If a radioactive substance at time $t = 0$ contains $N_0$ radioactive nuclei, then the number of nuclei $N$ remaining after a time interval $t$ is

$$N = N_0e^{-\gamma t} \quad (2.5.1)$$

Where $\gamma$ is the decay constant which is the probability per unit time interval that a nucleus will decay. The half-life $t_{1/2}$ is defined as the time required for half of a given number of nuclei to decay. The decay constant and half-life are related by

$$t_{1/2} = \frac{\ln(2)}{\gamma} \quad (2.5.2)$$
In alpha decay, a nucleus emits a helium nucleus \(^4\text{He}_2\) which consists of 2 protons and 2 neutrons. Therefore, the atomic number \(Z\) decreases by 2 and the mass number \(A\) decreases by 4. If \(X\) is the parent nucleus and \(Y\) is the daughter nucleus then the decay can be written as

\[ ^AX_z \rightarrow ^{A-4}Y_{Z-2} + ^4\text{He}_2 \] (2.5.3)

The attractive forces binding the nucleons together within the nucleus are of short range and the total binding force is approximately proportional to its mass number \(A\). The repulsive electrostatic force between the protons is of an unlimited range and the disruptive force in a nucleus is approximately proportional to the square of the atomic number. Nuclei with \(A > 210\) are so large that the short range strong nuclear force barely balances the mutual repulsion of their protons. Alpha decay occurs in such nuclei as a means of reducing their size and increasing the stability of the resulting nuclei after the decay has occurred. A simple model for the potential energy \(U(r)\) of the alpha particle as a function of distance \(r\) from the centre of the heavy nucleus (Bock, 2008).

### 2.5.2 Beta decay

In the beta decay process the atomic number \((Z)\) increases or decreases by one unit and the atomic mass number \((A)\) stays constant. In effect, neutrons and protons change state. The three types of beta decay are \(\beta^-\), \(\beta^+\) and electron capture.

Beta-minus decay \((\beta^-)\) was the first detected process; the \(\text{\textit{f}}\) particle was found to be a normal electron. During the decay process the nucleus changes state according to the following formula:

\[ ^AX_Z \rightarrow ^AX_{Z+1} + e + \text{ve} \] (2.5.4)

proton, an electron, and an electron antineutrino. The decay is energetically possible for a free neutron and occurs with a half-life of 12.8 min. This is the common
beta-decay process for nuclei with high atomic number and for fission-product nuclei, which usually have significantly more neutrons than protons.

During $B^+$ decay the nucleus changes state according to the following for

$$B^+$$

\[ \Lambda X_z \rightarrow ^4 X_{z-1} + e^+ + \nu e \]  \hspace{1cm} (2.5.5)

Electron capture competes with the $B^+$ decay process. The nucleus interacts with an inner atomic electron and, in effect, captures it, changing a proton into a neutron with the emission of a positron and an electron neutrino. The formula for this process is

$$B^-$$

\[ \Lambda X_z \rightarrow ^4 X_{z+1} + \bar{e} + \nu \bar{e} \]  \hspace{1cm} (2.5.6)

All unstable nuclei with atomic number less than 82 decay by at least one of the three processes and sometimes by all three. Beta decay occurs whenever it is energetically possible. It is energetically possible if the following conditions are met for the masses of the neutral parent atoms ($p$) and the potential daughter atom

$B^-$ decay : $M_p > M_d$

$B^+$ decay : $M_p > M_d + 2me$

**Electron capture:**

Beta decay can be to the ground state or to an excited state in the daughter nucleus. In the latter case the excited state decays by gamma-ray emission or internal conversion.
2.5.3 Gamma decay

As we have seen γ-decay is often observed in conjunction with α- or β-decay when the daughter nucleus is formed in an excited state and then makes one or more transitions to its ground state, emitting a photon whose energy is equal to the energy difference between the initial and final nuclear state. These energy differences are usually of order 100 KeV so the photon is well in the γ-ray region of the electromagnetic spectrum.

The lifetime of excited nuclear states is usually of the order of $10^{-3} - 10^{-12}$ s., so the lifetime is far too short to be measured.

The decay rate (inverse of the mean lifetime) depends on the energy of the photon emitted and the ‘type’ of radiation.

As in the case of Atomic Physics the transition amplitude is proportional to the matrix element of the electric field between the initial and final wave functions of the nucleon that makes the transition. This electric field has a space dependence that may be written

$$E = E_0 e^{ik \cdot r} \quad (2.5.4)$$

where $k$ is the wave vector of the emitted photon. For photons of energy 100 KeV and a nucleus of radius a few fm, $k \cdot r$ is much less than $(10^{-3})$ and it is sufficient to expand this exponential to first order.

$$1(kr = \frac{\hbar k}{E} = \frac{E}{h} \cos \theta = \frac{150 \text{eV} \times 1 \text{fm}}{1.973 \times 108 \times 1 \text{fm}}$$

The transition amplitude is therefore proportional to

$$A \propto \int \Psi^* f(r) K \cdot r \Psi_f(r) d^3r \quad (2.5.6)$$

Where $\Psi_i$ and $\Psi_f$ are the initial and final wave functions of the proton that makes the transition. This is called “electric dipole” transition (there is no “electric monopole” transition from the first term in the expansion of the exponential because $\Psi_f(r)$ and $\Psi_i(r)$ are orthogonal wave functions).

The rate for such transition is well approximated by the formula
\[ \lambda = 10^5 E^3 r A^{2/3} \quad (2.5.7) \]

Where \( E^\circ \) is the energy of the photon in KeV. The factor of \( A^{2/3} \) is understood from the fact that the transition amplitude is proportional to the nuclear radius, which is in turn proportional to \( A^{1/3} \) (the transition rate is proportional to the square of the amplitude). For photons with energy of order 100 KeV and \( A \) of order 100 this gives \( 2.5 \times 10^{12} \text{ s}^{-1} \).

However, for the above electric dipole matrix element to be non-zero we require certain conditions on the spin and parity of the initial and final states. As in Atomic Physics, the photon carries away one unit of angular momentum, so that the initial and final nuclear spins have to obey the selection rule

\[ \Delta l = 0, \pm 1 \quad (l=0 \rightarrow 0 \text{ forbidden}) \quad (2.5.8) \]

Furthermore since \( r \) is odd under parity reversal, we require the initial and final states to be of opposite parity, which means that the orbital angular momentum changes by one unit.

If the parity of the initial and final states are the same then the transition is still allowed, but this means that the photon carries away the angular momentum by flipping the spin of the nucleon that makes the transition. For this to happen the magnetic moment of the nucleon interacts with the magnetic field component of the electromagnetic wave associated with the emitted photon. This is called a “magnetic dipole transition” amplitude, and for such a process the transition amplitude is suppressed relative to the amplitude for a typical electric dipole transition by about a factor of \[ \frac{h c}{m_p R} \] which is about 0.1 for a nucleus of radius a few fm. (and therefore .01 suppression of the decay rate).

Transitions between nuclear states in which the photon is required to carry off more than one unit of angular momentum are permitted. This is because the photon can acquire orbital angular momentum relative to the recoiling nucleus. Thus the total angular momentum change, \( L \) in a nuclear transition can take the values

\[ |l_i - l_f| \leq L \leq |l_i + l_f| \quad (2.5.9) \]
Where $I_i$ and $I_f$ are the initial and final nuclear spins. However there is a price to pay in terms of transition rates. For each increase in $L$ there is a suppression in the transition amplitude of $kR$, because these higher multi-pole transitions arise from higher orders in the expansion of $\exp(ik \cdot r)$. For a nucleus of radius a few fm and a photon energy of 100 KeV is a factor of $10^{−3}$ (so a factor of $10^{−6}$ in the rate). There is a further suppression factor for higher values of $L$. A transition will proceed by the lowest allowed value of $L$.

This is also subject to selection rules for the parity difference between initial and final states, namely

$$\Delta P = (-1)^L \quad (2.5.10)$$

$\Delta$ For electric transitions (written $E\{L\}$) with angular momentum $L$, and $P = (-1)^{L−1}$, for the (even further suppressed) magnetic transitions.

Thus from the initial and final nuclear spins and parities we can determine the “multi-polarity” of the transition and whether it is electric or magnetic.

Here are some examples

$$2^+ \rightarrow 1^−, \ E1,$$

$$2^+ \rightarrow 1^+, \ M1,$$

$$3^+ \rightarrow 1^−, \ M2,$$

$$3^+ \rightarrow 1^+, \ E2.$$

Most electromagnetic transitions from an excited state to the ground state have a lifetime which is $+11/2$ too short to be measured (less than 1 μs). However, in the Shell Model the energy levels sometimes arrange themselves such that there is a very high spin excited state next to a low spin ground state or vice versa. Such a transition is only permitted by a high multi-polarity transition and therefore proceeds very slowly. The excited states then live long enough for their lifetime to be measured and can even be as long a several years. An example is the nuclide $^{137}{\text{Ba}}_{56}$ (barium) which has an excited state with spin and parity $-\frac{11}{2}$ next to ground state of $\frac{9}{2}$.
The transition is M4 and the excited state has a mean lifetime of around 200 s. These metastable excited states are called “isomers” and there are regions of the Periodic Table known as “islands of isomers” where such meta stable excited states are quite common.

2.6 Gamma ray characteristics

Gamma rays are the highest-energy form of electromagnetic radiation, being physically the same as all other forms (e.g., X rays, visible light, infrared, radio) but having higher photon energy due to their shorter wavelength. Because of this, the energy of gamma-ray photons can be visible light is emitted during changes in the chemical state of elements and compounds. resolved individually, and a gamma ray spectrometer can measure and display the energies of the gamma-ray photons detected.

Radioactive nuclei (radionuclides) commonly emit gamma rays in the energy range from a few keV to ~10 MeV, corresponding to the typical energy levels in nuclei with reasonably long lifetimes. Such sources typically produce gamma-ray "line spectra" (i.e., many photons emitted at discrete energies), whereas much higher energies (upwards of 1 TeV) may occur in the continuum spectra observed in astrophysics and elementary particle physics boundary between gamma rays and X rays is somewhat blurred, as X rays typically refer to the high energy electronic emission of atoms, which may extend to over 100 keV, whereas the lowest energy emissions of nuclei are typically termed gamma rays, even though their energies may be below 20 keV (Nick, 2009).
2.7 Caesium-137

Caesium-137 (Cs-137), is a radioactive isotope of cesium which is formed as one of the more common fission products by the nuclear fission of uranium-235 and other fissionable isotopes in nuclear reactors and nuclear weapons. It is among the most problematic of the short-to-medium-lifetime fission products because it easily moves and spreads in nature due to the high water solubility of cesium's most common chemical compounds, which are salts.

In gamma decay, resulted a nucleus changes from a higher energy state to a lower energy state through the emission of electromagnetic radiation (photons). The number of protons (and neutrons) in the nucleus does not change in this process, so the parent and daughter atoms are the same chemical element. In the gamma decay of a nucleus, the emitted photon and recoiling nucleus each have a well-defined energy after the decay. The characteristic energy is divided between only two particles.

Cs-137 atom emits radiation in the form of medium energy gamma rays, and to a lesser extent, high-energy beta particles, which disrupt molecules in cells and deposits energy in tissues, causing damage. Cs-137 is used in medical therapy for oncology, industrial radiography, radiation gauges, food irradiators and soil testing. It is also a potential plume component following a nuclear power plant incident. Significant external dose results from prolonged, close proximity to a Cs-137 source,
or being immersed in a plume of airborne radioisotopes from a nuclear power plant release. External exposure stops when the person leaves the impacted area and is decontaminated. Inhalation and ingestion are the most likely routes for internal contamination from Cs-137 (Bock, 2008).

2.7.1 Properties of cesium

Cesium is a soft, shiny, gold-colored metal. It reacts rapidly with oxygen or water. Its melting point is 301.55°K (28.4°C or 83.1°F) and boiling point is 951.6°K (678.5°C or 1253.2°F). Cesium-133 is the only naturally occurring isotope and is non-radioactive; all other isotopes, including cesium-137, are produced by human activity. Among these other isotopes, cesium-137 is the most common and was discovered by Glenn Seaborg and Margaret Melhase in the 1930s. Cesium-137 has a half-life of 30.17 years. It emits beta particles and gamma rays when it decays to barium-137m, which then decays to non-radioactive barium Exposure to cesium-137 will increase the risk of cancer. Avery high exposure will bring serious burns and can be fatal (Emsley, 1998).

2.7.2 Cesium-137 cycle

Cesium-137 does not exist in the natural environment and is always produced by human activity. Cesium-137 is produced by reactors as a fission byproduct. As a result of fission, a uranium atom splits into two atoms. Figure (2.4) shows the yield of atoms resulting from the fission of uranium. There are many possible fission fragments produced corresponding to different mass numbers, but the largest yields occur at mass numbers 95 and 137. Therefore, cesium-137 is considered one of the major fission byproducts and remains in spent nuclear fuel. In some cases, cesium-137 is extracted from spent nuclear fuel and treated as a commercial product, while the rest is treated as waste (USPA, 2012).
2.7.3 Cs-137 Uses

Caesium-137 has a number of practical uses. In small amounts, it is used to calibrate radiation-detection equipment. In medicine, it is used in radiation therapy. In industry, it is used in flow meters, thickness gauges, moisture-density gauges (For density readings, Americium-241-Beryllium providing the moisture reading an Caesium-137 is not widely used for industrial radiography because it is quite chemically reactive, and hence, difficult to handle. The salts of cesium are also soluble in water, and this complicates the safe handling of cesium. Cobalt-60, \( Co^{60} \), is preferred for radiography, since it is chemically a rather non reactive metal offering higher energy gamma-ray used in gamma ray well logging devices. As a man-made isotope it has been used to date wine and detect counterfeits and as a relative-dating material for assessing the age of sedimentation occurring after 1954 (Michael, 2012).

2.8 Dose

The unshielded gamma-ray dose equivalent rate at 1 meter from a point source, i.e., the specific gamma-ray dose constant, is a useful quantity in radiation protection applications. Recently, an extensive compilation of the nuclear data required to compute this constant has become available for approximately 500 nuclides important to dosimetry and radiological assessment applications, and it has been used to compute a table of the specific gamma-ray dose constant. In addition, the half-life,
mean attenuation coefficient and thickness for 9594 attenuation with a lead shield have been computed.

The data were computed on a different basis from earlier tabulations. The dose equivalent rate is given in Si units as mSv/ti for a unit source of 1 μBq. To convert to the previous common normalization, one may note that 1 rmCi is equal to 37 μBq and 1 Sv is equal to 100 rem. That is, to convert data in units of (μESv·h)/μBq to (mrern·ti)/pC·i, multiply by 3.7 (Ungar and Trubey, 1982).
CHAPTER THREE

MATERIALS AND METHODS

3.1 Introduction

This experiment was done in the Sudan Atomic energy commission at the Institutes of radiation Safety (IRS) on Wednesday the fifteenth of April 2015 AD.

The aim of this experiment is to identify the effect of distance and sloping angle of Gamma ray. Besides, identifying the effective factors on safety in order to prevent the danger of the radiation.

Cesium 137 radiant isotope that generates Gamma ray and formed from nuclear fusion and carrying 662 ker energy with 30 years half of its lifespan. The cesium isotope was placed inside anti-radiant box. Radio-active for cesium isotope 137 equals 3.7 MB. The serial number of this device OL 219. To measure radiation intensity and the doses, RADOS device with serial number 990372 was used. the observations were taken between 0.02 and 0.05 during half an hour from inside a room with 4x4 dimensions. The factor titration of the device is 0.96. since the source size is small compared with the distance up to the point we need to measure, its density, the source can be considered.

3.2 Experimental techniques

To identify the changes of the ray's density with distance between the source and the measurement device x and the angle, the device is to be placed touching the source (0=x), then we change the sloping angle of the perpendicular axis on the device with the perpendicular axis on the surface of the device from 0(zero) degree to 45 degrees, then from 45 degrees to 60 degrees and finally from 60 degrees to 90 degrees. The measurement device is to be put away to a distance of 5cm, then we repeat the aforementioned steps. After that we take other three observations by adding a distance of 5 cm in each.
To check the results, they should be compared with square inverse law which shows the relation between light intensity with distance $x$ and the angle in the following formula.

$$I = \frac{I_o \cos \theta}{r^2}$$  \hspace{1cm} (3.3.1)

When exposure time is fixed at $(1 = t)$ s dose will be as follows:

$$S = \pm I = \frac{I_o \cos \theta}{r^2}$$  \hspace{1cm} (3.3.2)
CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter includes the data analysis that collected to achieve the objective of the research, beside the most important findings of the study.

4.2 Results

Table: (4.1): The relation between radiation dose $S$ with the distance $X$ at angle zero

<table>
<thead>
<tr>
<th>$x \pm 0.01$m</th>
<th>$S \pm 10^{-6} \mu$ sv/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>116</td>
</tr>
<tr>
<td>5</td>
<td>18.3</td>
</tr>
<tr>
<td>10</td>
<td>9.16</td>
</tr>
<tr>
<td>15</td>
<td>5.45</td>
</tr>
<tr>
<td>20</td>
<td>3.89</td>
</tr>
</tbody>
</table>

Figure (4.1): The relation between radiation dose $S$ with distance $X$ at angle zero
Table: (4.2): The relation between radiation dose $S$ with the distance at angle 45

<table>
<thead>
<tr>
<th>$x \pm 0.01m$</th>
<th>$S \pm 10^6 \mu \text{sv/h}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>61.2</td>
</tr>
<tr>
<td>5</td>
<td>12.3</td>
</tr>
<tr>
<td>10</td>
<td>7.80</td>
</tr>
<tr>
<td>15</td>
<td>5.35</td>
</tr>
<tr>
<td>20</td>
<td>5.30</td>
</tr>
</tbody>
</table>

Figure (4.2): The relation between radiation dose $S$ with distance $X$ at angle 45
Table (4.3): The relation between radiation dose $S$ with the distance $X$ at angle $60^\circ$

<table>
<thead>
<tr>
<th>$x \pm 0.01m$</th>
<th>$S \pm 10^6 \mu sv/h$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>187</td>
</tr>
<tr>
<td>5</td>
<td>12.6</td>
</tr>
<tr>
<td>10</td>
<td>7.13</td>
</tr>
<tr>
<td>15</td>
<td>5.30</td>
</tr>
<tr>
<td>20</td>
<td>7.47</td>
</tr>
</tbody>
</table>

Figure (4.3) The relation between radiation dose $S$ with distance $X$ at angle $60^\circ$
Table (4.4): The relation between radiation dose $S$ with the distance $X$ at angle 90

<table>
<thead>
<tr>
<th>$x \pm 0.01m$</th>
<th>$S \pm 10^4 \mu \text{sv/h}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>3.99</td>
</tr>
<tr>
<td>5</td>
<td>4.14</td>
</tr>
<tr>
<td>10</td>
<td>4.18</td>
</tr>
<tr>
<td>15</td>
<td>4.7</td>
</tr>
<tr>
<td>20</td>
<td>4.44</td>
</tr>
</tbody>
</table>

Figure (4.4): The relation between radiation dose $S$ with distance $X$ at angle 90
Table: (4.5): The relation between radiation dose S with the angle θ at distance zero

<table>
<thead>
<tr>
<th>θ ±</th>
<th>S±10^6μ sv/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>116</td>
</tr>
<tr>
<td>45</td>
<td>61.2</td>
</tr>
<tr>
<td>60</td>
<td>18.7</td>
</tr>
<tr>
<td>90</td>
<td>3.99</td>
</tr>
</tbody>
</table>

Figure (4.5): The relation between radiation dose S with angle θ at distance 0.
Table (4.6): The relation between radiation dose $S$ with the angle $\theta$ at distance 5

<table>
<thead>
<tr>
<th>$\theta$ ±</th>
<th>$S\pm 10^6 \mu$ sv/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>18.3</td>
</tr>
<tr>
<td>45</td>
<td>12.3</td>
</tr>
<tr>
<td>60</td>
<td>12.6</td>
</tr>
<tr>
<td>90</td>
<td>4.14</td>
</tr>
</tbody>
</table>

Figure (4.6): The relation between radiation dose $S$ with angle $\theta$ at distance 5
Table (4.7): The relation between radiation dose $S$ with the angle $\theta$ at distance 10

<table>
<thead>
<tr>
<th>$\theta \pm$</th>
<th>$S \pm 10^6 \mu$ sv/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>9.16</td>
</tr>
<tr>
<td>45</td>
<td>7.8</td>
</tr>
<tr>
<td>60</td>
<td>7.13</td>
</tr>
<tr>
<td>90</td>
<td>4.18</td>
</tr>
</tbody>
</table>

Figure (4.7): The relation between radiation dose $S$ with angle $\theta$ at distance 10
Table (4.8): The relation between radiation dose $S$ with the angle $\theta$ at distance 15

<table>
<thead>
<tr>
<th>$\theta \pm$</th>
<th>$S \pm 10^6 \mu$ sv/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>5.45</td>
</tr>
<tr>
<td>45</td>
<td>5.35</td>
</tr>
<tr>
<td>60</td>
<td>5.30</td>
</tr>
<tr>
<td>90</td>
<td>4.70</td>
</tr>
</tbody>
</table>

Figure (4.8): The relation between radiation dose $S$ with angle $\theta$ at distance 15
Table (4.9): The relation between radiation dose $S$ with the angle $\theta$ at distance 20

<table>
<thead>
<tr>
<th>$\theta \pm$</th>
<th>$S \pm 10^6 \mu$ sv/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>3.89</td>
</tr>
<tr>
<td>45</td>
<td>5.30</td>
</tr>
<tr>
<td>60</td>
<td>7.47</td>
</tr>
<tr>
<td>90</td>
<td>4.44</td>
</tr>
</tbody>
</table>

Figure (4.9): The relation between radiation dose $S$ with angle $\theta$ at distance 20
4.3 Discussion

As showing at the tables and figures (4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 4.9) it is clear that the radiation dose(s) decreases by the increase of distance x and this is consistent with inverse square law in the equation (3.3.1).

This means the radiation safety procedures entail controlling the distance between the source and the exposed people for the dose to be below the (20 μSv/Y).

The figures (4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 4.9) shows that radiation dose(s) decreases with the increase of angle and this is also in consistent with square inverse law in the equation (3.3.2).

There is a significant observation concerning tables and figures (4.4) according to angle 90 degrees where the dose does not decrease with the distance.

This is attributed to the fact that, when the source axis and the device axis are orthogonal, it is difficult for the radiation to fully reach the device. This is clear from the small amount of the dose compared with other angles. This small amount which increases radiation dispersion as the distance increases from the device, gives irregular and imprecise observations.
CONCLUSIONS

Conclusions drawn from this study can be summarized as follows:

– Radiation security and safety requires approximate limits for radiation dose.
– Radiate measuring device should be adjusted at zero angle so as it can measure for the highest dose.
– The space between the source of radiation and the exposed people should be adjusted to reduce the dose to the minimum level.
REFERENCES

Andres pokes “Attenuation of Gamma ray. Department of Solid state Electronic of atomic and nuclear physics (Email: Andres –poskus@ff.vnlt)


