Shendi University

faculty of Graduate

Studies and Scientific Research

Evaluation of ionizing radiation impacts in living cells and tissues (Cow’s blood)

Thesis is Submitted to faculty of Graduate Studies, Shendi University in fulfillment of the Requirement for the Degree of M.Sc.in Physics.

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December, 2019

الاستهلال

بِسْمِ اللَّـهِ الرَّحْمَـٰنِ الرَّحِيمِ

(سَنُرِيهِمْ آيَاتِنَا فِي الْآفَاقِ وَفِي أَنفُسِهِمْ حَتَّىٰ يَتَبَيَّنَ لَهُمْ أَنَّهُ الْحَقُّ ۗ أَوَلَمْ يَكْفِ بِرَبِّكَ أَنَّهُ عَلَىٰ كُلِّ شَيْءٍ شَهِيدٌ(53) أَلَا إِنَّهُمْ فِي مِرْيَةٍ مِّن لِّقَاءِ رَبِّهِمْ ۗ أَلَا إِنَّهُ بِكُلِّ شَيْءٍ مُّحِيطٌ (54))

سورة فصلت

Dedication

I dedicate this thesis to

my family

my husband

my children

The humanity

With The a great love

Acknowledgment

I would like to express my deep appreciation to my supervisor Dr.Abdullah Mohammed Ibrahim for his patience guidance, encouragement, and constructive suggests during the planning and development of this search, his kindness and generous attitudes has been very much appreciated.

Abstract

This study aimed to observe the effect of low and high gamma radiation doses on the blood parameters of cows' blood samples for their relation to the exposure time of the samples is also related to the amount of radiation energy doses such that the research methodology is based on the collection of samples of cattle blood representing living matter, A cbc test before the samples are exposed to ionizing radiation, then Per form a cbc test again after the samples are exposed to radiation. The samples were divided into five groups, each group contains three samples, The first group is the control, three groups exposed to low radiation doses during different time periods by the source of cesium-137, at the Sudanese Atomic Energy Commission, The fifth group exposed to High radiation doses compared with the previous three samples were exposed 100, 200, 300, Gray, by a 60 cobalt source at radiology department of Khartoum teaching hospital ,The results showed a decrease in the number of white blood cells and platelets at doses of 7 mGray and 15 mGray and an increase at 2. mGray and at 200, 300, compared with the control sample. An increase in the number of red blood cells Hemoglobin at doses is 2.5 mGray, 15 mGray, 100, 200, 300, Gray and a decrease in their number at 7 mg gray when compared with control, Hemoglobin decreased at the dose of 100 Gy, and significantly reduced at the dose 300 Gy. There is a decrease in the rate of Hematocrit at 300 Gray, an increase at 2.5, 5, 7 mGray, and 100, 200 Gray compared to the control sample these changes explain that when the radioactive energy of gamma is transmitted from the radioactive source to the living material, and after a very short time after the funeral process, the water atoms inside the cell begin to excite and ionize, forming free radicals. Free radicals are molecules with high susceptibility to interact with each other and with other cell components forming toxic compounds. Other sequential changes occur as a result of the ionization of water that affects the structure of the genetic material, the function of the cell, and its adjacent cells, eventually leading to their death and decreasing number. Ionization is associated with the time of exposure to radiation. The more time increases the Probability of ionization radiation to living matter Also; ionization is related to the amount of radiation energy and increases with its increase. Depending on the results obtained, this is important information for personal safety and protection when dealing with ionizing radiation.

ملخص البحث

تهدف هذه الدراسة إلي ملاحظة مدي أثر الجرعات الإشعاعية المنخفضة والعالية لأشعة جاما علي المكونات الدموية لعينات من دم الأبقار ، منهجية البحث هي جمع عينات من دم الأبقار ، وأجراء فحص cbc قبل تعريضها للإشعاع المؤين ، ثم إجراء فحص cbc مرة أخري بعد تعرض العينات للإشعاع. تم تقسيم العينات الي خمس مجموعات ، كل مجموعة تحوي ثلاث عينات ، المجموعة الأولي هي التحكم ، ثلاث مجموعات تعرضت لجرعات أشعاع منخفضة خلال فترات زمنية مختلفة بواسطة مصدر السيزيوم - 137 ، بمعمل هيئة الطاقة الذرية السودانية، المجموعة الخامسة تعرضت لجرعات أشعاع عالية مقارنة مع العينات الثلاث السابقة ،بواسطة مصدر الكوبالت60 بمستشفي الذرة الخرطوم . أظهرت النتائج تغيرات في مكونات الدم ، حيث تناقص عدد خلايا الدم البيضاء ، عند الجرعات 7 ملي جراي و15 ملي جراي وزاد عند الجرعة 2.5 ملي جراي ، تناقص عدد كبير من خلايا الدم البيضاء عند الجرعات 100 200 ، 300 جراي مقارنة مع عينة التحكم ، وزيادة بسيطة في عدد كريات الدم الحمراء عند الجرعة 2.5 ملي جراي ، وزيادة طفيفة جدا عند 7 و15 ملي جراي ،و100 ، 200 جراي واختفاء عدد كبير منها عند الجرعة 300 جراي مقارنة بعينة التحكم، و تناقص صغير في عدد الصفائح الدموية عند الجرعة 7و15 ملي جراي و تناقص كبير لها عند الجرعة 200و300جراي وزيادة صغيرة في عدد الصفائح الدموية عند 2.5ملي جراي وزيادة كبيرة لها عند الجرعة100 جراي مقارنة مع عينة التحكم ، زيادة طفيفة للهيموغلبين عند الجرعة 2.5ملي جراي و200جراي وطفيفة جدا عند15 ملي جراي ونقصان طفيف عند الجرعة 100جراي و7ملي جراي ونقصان صغير عند الجرعة 300جراي وزيادة كبيرة في نسبة الهيمتوكرايت عند الجرعة 2.5 جراي و15ملي جراي وكبيرة جدا عند 200جراي وزيادة طفيف عند الجرعة 7ملي جراي وطفيفة جدا عند الجرعة 100 جراي ونقصان كبير له عند الجرعة 300جراي ، مقارنة بعينة التحكم ، تفسر هذه التغيرات بأنه عندما تنتقل الطاقة الإشعاعية من المصدر المشع إلي المادة الحية و بعد مرور زمن قصير جدا من عملية التشييع تبدأ ذرات الماء داخل الخلية بالإثارة والتأين مكونة الجذور الحرة، وهي جزيئات لها القابلية العالية لتفاعل مع بعضها ،ومع مكونات الخلية الأخرى مكونة مركبات سامة ، تحدث تغيرات أخري متسلسلة نتيجة لتأين الماء تمس تركيب المادة الوراثية ، واعداد ووظيفة الخلايا نفسها، مما يؤدي في النهاية إلي موتها. يرتبط التأين بزمن التعرض للإشعاع كل ما زاد الزمن يزيد احتمالات تأين الإشعاع للمادة الحية ، أيضا يرتبط التأين بمقدار الطاقة الإشعاعية ويزيد بزيادتها ،وذلك اعتمادا علي النتائج التي تم الحصول عليها، وهذه معلومات مهم لسلامة الشخصية والحماية عند التعامل مع الإشعاع المؤين.

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Chapter 1

1.Introduction

Radiation is widespread in our daily lives. We are exposed to it from Common sources such as the foods we eat, cosmic rays, rays from the sun, and medical procedures and imaging . One type of radiation, ionizing radiation, is of particular concern because it is high energy and has the ability to free electrons from molecules and cause damage to macromolecules in our body such as nucleic acids in DNA, blood and other tissues. In other word radiation is the emission of electromagnetic energy that is given off in the form of high speed particles that cause ionization, and during ionization radiation hits and knocks electrons from an atom creating charged ions. Due to the electron being stripped away from the atom this break the chemical bond. Living tissue within the human body is damaged and attempts to repair it but sometimes the damage is beyond repair. Radiation can either be ionizing or non-ionizing depending on how the radiation itself affects matter. Non-ionizing radiation includes visible light, heat, microwaves, and radio waves. This particular type of radiation deposits energy in the materials that it passes through but cannot break molecular bonds or remove electrons from atoms. Ionizing radiation on the other hand has enough energy to break molecular bonds and displace atoms. The displaced electron creates two charged particles known as ions which can cause changes in living cells. The amount of radiation and the duration of radiation exposure is what ultimately that causes health issues/effects. There are two types of health effects pertaining to radiation known as stochastic and non-stochastic. Stochastic effects refer to radiation exposure given over long periods of time at low levels referred to as chronic. Non-stochastic is short-term exposure but at high levels which is referred to as acute. Stochastic effects are those that are associated with cancer so the presence of harmful and undesirable effects of nuclear radiation on the environment, human and animal, these health effects are characterized by at hreshold, generally at a high dose, that must be exceeded before the health effect occurs and by an increase in the severity of the health effect with increasing dose. In contrast, stochastic effects are initiated by the modification of the genetic material of only one or perhaps a few cells in a way that is still compatible with cell survival. Examples are solid cancers, leukemia, and heritable diseases. Such a health effect is characterized by a frequency of occurrence in a population that depends on radiation dose, whereas the severity of the health effect, if it occurs, does not. There is some health effects for which it has not been possible to classify them as either deterministic or stochastic effects. Examples are circulatory diseases and cataracts. For the purposes of this annex, they are subsumed under the term tissue reactions, for developing explanations for phenomena; scientific method is an important well-recognized approach. It is based on the assumption that nature follows certain laws, and that by using certain systematic approaches, these laws can often be revealed. Hypotheses about causation are generated from observations and then tested by controlled experiments or careful observational (that is, other than experimental) studies, leading to better understanding. Modern approaches to the scientific method consider multiple plausible hypotheses, all of which are tested with new results of experiments and observations. Hypotheses that with time no longer explain the information are removed or adjusted, gradually reducing the number of Plausible hypotheses. Those that do explain the results may eventually be deemed proven by the larger scientific community as established scientific fact.

In the context of deterministic effects, one can very often observe many characteristics (e.g. damage evolution and severity) in a differential pathological diagnosis, so that a health effect in an individual can be unequivocally attributed to a radiation exposure. In contrast, it is not, at present, possible to unequivocally attribute a stochastic effect in an individual to radiation exposure; based on current scientific knowledge, Such a health effect is not distinguishable from one that arises from other causes. Up to now, no marker has been found that beyond doubt identifies a cancer or a hereditary disease in an individual as being caused by ionizing radiation, irrespective of dose. Even if a biomarker could be found that identified a radiation-induced cancer, it would not be able to indicate whether it was induced by radiation from natural or artificial sources. At low and, now even, very low levels of dose, there are biological in dicators of radiation exposure, such as hematological or cytogenetic modifications, but these modifications in themselves are not health effects and may notne cessarily result in health effects. For acute exposure* to high doses above the relevant thresholds, there is sufficient evidence, knowledge and scientific consensus regarding causal relationships to be able to pre dictr elatively accurately whether or not there will be a deterministic effect in an exposed individual and, if so, the likely severity of that health effect. For exposures at moderate or high doses (or more strictly, at doses at which an increased frequency of occurrence of certain health effects in a population can be confidently attributed to radiation exposure), there is also sufficient evidence, knowledge and scientific consensus on caus alrelation ships to be able to predict with some confidence an increased risk of stochastic effects in an exposed population similar to that for which evidence exists. There are various obstacles to precisely quantifying risks of stochastic effects after exposure. These include extrapolating from studies of populations exposed at moderate and high doses, often delivered at high dose rates, to estimating risks for other populations with different age and sex compositions and with different baseline rates of cancer, exposed to low or very low doses of radiation of different quality, at low dose rates For such situations, Bayesian inference may provide additional insights and therefore set general rules and regulations that determine the compatibility with the levels of various nuclear energy doses. The effects of high doses of ionizing radiation are well understood from our knowledge of possible to have such a wide array of applications Radiation health effects expanded on more than 100 years of radiation research have provided extensive information on the relationship between radiation exposure and specific health effects, both in the short and long term , and many mechanisms that may be relevant to explain the relationship, for which other more appropriate classifications are used, the internationally accepted framework for radiation protection distinguish hes between so-called “deterministic effects”, now often included under the term “tissue reactions”, and “stochastic effects”. Deterministic effects are those health effects that are caused by extensive cell death and/or cell malfunctioning. Examples are acute radiation syndrome, skin burns, epilation (loss of hair) and sterility. Radiation effects on the human body Such as what we know that the workers in the field of radiation take into account the lack of the number of blood cells to identify the extent of the impact of the body radiation, we find that human blood is composed of a cellular part and a part of the chapel.

1.1.Cellular segment contains

White blood cells, red blood cells, hemoglobin and platelets. This cell in the human body is composed of two genes, the nucleus and Cytoplasm, containing chromosomes containing the genes. The function of the nucleus is to control cell proliferation and cytoplasm activity in which lunch is converted into energy, the cell plant. When ionizing radiation passes through the body or cell, the following occurs: Radiation may destroy the nucleus of the cell, lose it, weaken its Fragility, or lead to cell death. Radiation may also cause alteration or deformation of the gene with cell Retention on division Because the mechanism of repair of cells in the human body, it tries to Repair itself if possible Radiation damage depends on the rate of absorption of the body of this radiation dose and the damage and damage to the body tissues by radiation exposure affects the structure and functions of body cells The biological effect of this ionization does not depend on the amount of energy Which is absorbed by the fabric only, but also depends on the method of ionization, the nature of the type of radiation and the effect of individuals to the amount of radiation rates more than others are heading to the difference of sensitivity of the members so it uses a efficient of quality or factor relative biological impact and units of measurement as mentioned earlier effect of radiation on the blood composition device: (Hematopoietic System) as bone marrow is the most sensitive part of radiation, leading to changes in blood at a dose of one to Jerry according to a scientific study (Bond et al., 1965). The acute dose that kills 50 percent of people exposed within 60 days is not known,(Gy 5 - 2.5), according to a previous scientific study .The acute dose (Gy10 - 7) is 100 per cent fatal to exposed persons and the effect of radiation dose on humans is damaged or damaged But consistent and effective information in radiation events and radiation therapy for full-body exposure applied to the blood composition device can potentially dose of (Gy10 - 3) The dose was distributed to different sessions for several different months In order to better understand how low & high -dose ionizing radiation can impact animal populations, Current empirical studies and experiments have begun to examine the potential for significant benefit; Of blood components transferred from the cows of the Veterinary College Farm at the Sudan University of Science and Technology The samples were examined microscopically and were scanned in the blood bank medical laboratories, the same blood tests and tests were usually performed when donated to be transferred or stored, such as measurements of the number, size and hemoglobin count of red blood cells and others, and gave positive results this makes the research under study very important and opens the way for further study research and investigation, for ionizing beam applications and their effect on blood, in terms of changing properties Detection of gamma radiation is based on the interaction between the radiation and the detector material. The photon scatters from the electrons of the material (so called Compton scattering), and in each scattering process it loses a part of its energy. If the piece of material is large enough and the scatterings take place suitably, all the energy of the initial gamma ray is absorbed in the material. Thus, the energy of the photon is found by measuring the energy absorbed by the material. How this energy is determined, depends on the detector type and its functioning so when radiation is absorbed in living matter, a biological effect may be observed. However, equal absorbed doses will not necessarily produce equal biological effects. The effect depends on the type of radiation (e.g., alpha, beta or gamma). For example, 1 Gy of alpha radiation is more harmful to a given tissue than 1 Gy of beta radiation. To obtain the equivalent dose, the absorbed dose is multiplied by a specified radiation weighting factor (WR). A radiation weighting factor (WR) is used to equate different types of radiation with different biological effectiveness. The equivalent dose is expressed in a measure called the sievert (SV). This means that 1 sv of alpha radiation will have the same biological effect as 1Sv of beta radiation. In other words, the equivalent dose provides a single unit that accounts for the degree of harm that different types of radiation would cause to the same tissue.

1.2 Research problem

This humble research deals with the problem of damage caused by nucle a radiation emitted from radioactive materials, and other sources such as the effects it causes to the biosphere (Plant kingdom as animal life) including human where this is the subject of the important topics that address an environment such as interactions between components natural compound in the environment. The interaction of ionizing radiation with living matter leads to the appearance of some undesirable changes in the components of the living matter, especially the damage of the weak microscopic structure and it stranslation into changes in the appearance and capabilities of the entire organism. The results of this change did not find many studies to accurately determine the limits of the Effective doses, and the factors on which the interaction depends.

1.3 Research Hypotheses

The hypothesis of research is that humans play a large role and make an effective contribution to increasing the proportion of nuclear radiation especially after the establishment of nuclear reactors, such as the development of nuclear weapons, such as medical devices and the development of industries power plants and desalination plants.

Therefore, the question of self-accusation is whether it has developed nuclear industrial activities by human in the momentum of radiological activities? the nuclear explosions of many nuclear reactors, including the Chernobyl and Fukushima reactors exploding the spread of many radiations to many areas of the world, resulting in the emergence of many diseases Such as congenital malformations and others? The storage of radioactive waste in unsafe ways has played a major role in the spread of radiological activities harmful?

1.4 Research importance

This research is a step on the path of environmental awareness, such as awareness of the dangers caused by radioactive materials. Research on environmental protection programs is useful for identifying the causes of environmental pollution radiation and how to reduce it. Alert energy professionals to the dangers of nuclear radiation and its effects on the natural environment and population.

1.5 Research Methodology

This project is focused to, the descriptive approach and the experimental approach were used. Blood samples were taken from cows ages 6 to 7 years، and then blood samples were examined. The samples were then subjected to different doses of gamma radiation of 2.5 - 7-15 mGy, from a fixed distance of 1 meter ,also each blood sample was exposed to one dose of 100 Gray, 200 Gray and 300 Gray radiation, respectively using the Cobalt Co 60 source at the Khartoum Corn Hospital. And then re-examined again after exposure to gamma rays ، and then Note the results of the examination and discussed and evaluated.

1.6 Research objectives

The purpose of this research is to evaluate the effect of ionizing radiation on the living cell by identifying the factors that influence the interaction of gamma radiation with the living cell and the limits of itseffect with in the cell. And its relationship to the time of exposure to radiation and then its relationship to the amount of radiation energy Identify the damage caused by nuclear radiation from radioactive material sand the extent of their impact on the environment including the human.

1.7 Search content

The thesis dealt with in the first chapter an introduction to radiation, the health effect of ionizing radiation on living matter, and the factors on which the extent of damage depends on tissues and living cells, The second chapter presents the most important previous studies that dealt with the effect of radiation on living matter, especially on blood cells, where a sufficient number of studies were reviewed. The most important theoretical concepts that were presented during the research were discussed in the third chapter, where gamma-ray interactions with matter and with living matter were reviewed, then the absorbed doses were calculated, radiation protection, Chapter Four, experiment steps, results, and discussion, chapter five the conclusions were presented, Recommendations and then search references.

Chapter 2

Literature Review

Ionizing radiation (IR) is defined as radiation with the ability to remove tightly bound electrons from their atomic orbit, effectively charging the matter upon interaction [1]Gamma rays and X-rays have essentially the same physical properties, as both are mass less and carry no net charge [1]. However, the distinction between gamma rays and X-rays lies in their origin. Gamma rays originate from the nucleus and X-rays originate from electrons. Gamma rays and X-ray are dangerous to the body because they have a long penetration range. Thick layers of dense materials like lead and steel are required to provide sufficient shielding against gamma rays and X-rays[2] , Gamma rays are produced as radioactive isotopes such as 137Cs and 60Conaturally decay. Cesium isotopes are produced in nuclear fuel as a result of fission of uranium. They are recoverable as a waste product during reprocessing of reactor spent-fuel rods. There are only a few nuclear fuel-reprocessing plants in the world and the capacity for exacting 137Cs is very limited. As a consequence quantities of 137Csare limited and are rarely used in commercial gamma facilities[3],Maintaining an appropriate safety culture, which includes radiation protection, requires commitment from all members of an organization—the veterinarians, technologists, students, etc., all share in the responsibility of promoting and maintaining a safe work environment [1],the use of real-time dosimetry enables personnel to be aware of their exposures instantaneously; personnel can appropriately adjust their behavior with immediate knowledge of radiation exposure. The transfusion of red blood cellular components is considered a vital treatment for patients suffering anemia triggered by haemorrhage due to surgery or trauma injury, various haemoglobinopathies or malignancy[4],the administration of red blood cellular products is to enhance the intravascular oxygen-carrying capacity and subsequent improvement of tissue oxygenation. Approximately 108 million units of whole blood (WB) donations were collected globally in 2014 of which 76% of transfusions in high-income countries were patients over the age of 65 years whereas children under the age of 5 years accounted for 65% of blood transfusions in low-income countries. It is also reported that more than half of all the WB donations collected were from donors in high-income countries and a growth of 8, 6 million WB donations from voluntary non-remunerated donors recorded from 2004 to 2012 [5], A study in 2009 reported significant differences in the potassium, plasma haemolysis, ATP and 2, 3 DPG concentrations when irradiated and non-irradiated leucocyte-reduced RBCC were compared. These variances were observed whether the leucocyte-reduced RBCC were prepared after component separation or prepared from filtered WB. Differences were also observed in the mean cell volume results although the percentage plasma aemolysis rate for both groups did not exceed 0, 8 percent [6], how ever, while a recent study indicated similar biochemistry results, the concentrations for percentage plasma haemolysis were higher than the recommended 0, 8% [7], al though filtration of RBC products considerably reduces the number of viable lymphocytes, a few leucocytes still remain in the pack. While these remaining leucocytes would normally not be problematic for immunocompetent recipients unless they are receiving family directed/designated donations, the outcome of transfusing the viable leucocytes to immunocompromised recipients may cause TA-GvHD as the eligible patients in this category are increasing [8, 9], It is also imperative that recipients receiving bone marrow transplants, undergoing chemotherapy or in uterine transfusions receive irradiated blood[10],Irradiation causes the inactivation of T lymphocytes as proliferation is inhibited once the nucleated cells are penetrated by ionizing gamma rays, causing damage to the lymphocyte deoxyribonucleic acid (DNA) and therefore, leucocyte reduction via filtration is not the same as irradiation. irradiation as this damage mainly affects RBC components. Red blood cells Granulocyte and platelet function are not impaired as a result of gamma require an efficient metabolism in order to maintain the biconcave shape and membrane permeability of the RBC during storage. It has been reported that gamma irradiation impacts negatively on the potassium/sodium-ion gradient as it changes the intracellular nucleotide levels which may be due to degeneration of the RBC lipid bilayer caused by irradiation instead of the inactive potassium/sodium pump [10, 11], RBC membrane impairment due to irradiation causes an increase in supernatant potassium ions, plasma haemoglobin and lactate dehydrogenase levels and a decrease in pH concentration. The elevated potassium concentration post irradiation is inversely proportional to sodium ion levels and this ion exchange causes the ATP levels to decrease. These factors indicate that gamma irradiation exacerbates storage lesions[8, 9], When storage lesions occur as a result of irradiation, it causes the levels of free hemoglobin to increase but is disregarded as being clinically significant unless patients present with renal failure or hyperkalemia. A recent study has indicated similar cellular damage was observed whether RBCC was irradiated on Day +14 or Day+3. It was also recommended that the transfusion of irradiated blood should be completed at the earliest opportunity to patients with increased potassium sensitivity such as premature infants or renal failure patients while those less sensitive may be transfused with stored blood for up to 28 days post irradiation date [12], While clinicians are aware that irradiation and storage cause cellular degeneration and a subsequent increase in percentage haemolysis, they should also be aware that even “fresh” blood consists of an assortment of RBC at different stages of maturity. The oldest RBC will haemolysis due to shear stress while the more flexible younger RBC may remain undamaged and thus, the storing of irradiated blood for 28 days post irradiation may not be best clinical practice for the recipient[13],It has been established that as a result of metabolic pathologies resulting in hyperkalemia, children are more prone to cardiovascular diseases[14] ,Hyperkalemia may be reduced by washing the irradiated RBC cellular product by using a cell saver for neonates undergoing cardiopulmonary bypass surgery although it is ineffective in reducing hyperlactaemia associated with postoperative morbidity and mortality [15], However, if the neonate is hyperkalaemic then the guidelines also stipulate that blood used for either an exchange or intrauterine transfusion be less than 5 days old and infused within 24 hours after irradiation [16, 17],According to the Japanese national guidelines, blood for transfusion may optimally be irradiated up to 14 days post donation with irradiated dosage prescribed between 15Gy to 50Gy and as their usual expiry period post WB collection is 21 days, the irradiated blood may be used for other patients provided the elevated potassium level will not harm the recipient. Caution is advised against irradiating blood fresher than 3days old because the risk of TAGvHD is higher. Due to the limited haplotypes present, the Japanese also irradiate a wider range of blood components compared to other national guidelines[18] .

Studies have also established that, radiation exposure above certain threshold limits can damage living cells, causing death in some of them and modifying others[19],However, in the case of low doses, studies are inconclusive as to the effect from the exposure to low background doses.

It is also important to add that much of the studies on the effect of exposure to radiation have been based on the studies of the health records of survivors of the Atomic Bombing in Hiroshima and Nagasaki and also based on studies on animals [20]. There are experimental evidences from animal studies that show that exposure to high levels of radiation could cause genetic effects. However, in the case of the low doses, it is assumed that exposure to background levels of natural radiation may lead to an additional risk of cancer, even though this has not yet been established [20]. This is now a subject of debate and controversy. Some of the known effects resulting from radiation exposure are either damage to cells that are killed or modified. If the repair of the damage or modified cells is not perfect, the resulting modification will be transmitted to further cells and may eventually lead to cancer. The biological damage due to radiation exposure could lead to somatic stochastic effect or here ditary stochastic effects. Stochastic effect is radiation effects, generally occurring without a threshold level of dose, whose probability is proportional to the dose and whose severity is independent of the dose[21]. Radiation exposure has also been associated with most forms of leukaemia and other types of cancers affecting various organs such as lungs, breast and thyroid glands. It is also worth noting that radiation-induced cancer may manifest itself decades after exposure. The major long-term evaluation of populations exposed to radiation was based on studies of approximately 86,500 survivors of the atomic bombings of Hiroshima and Nagasaki, Japan [19]. This study revealed an excess of hundred cancer deaths in the population studied. Radiation exposure also has the potential to cause hereditary effects in the offspring of persons exposed to radiation. Studies on this effect have been based on animal species and it is yet to be detected in human populations [19]. There are several pathways by which the radioactive material can reach humans. The pathway largely depends on the processes involved and can be broadly categorised into; on-site, off-site, airborne, waterborne, food products, etc[22]. For on-site pathways, the exposures tend to be direct from external gamma radiation or internal exposure resulting from inhalation of radioactive dust or radon progeny. Due to the presence of NORM in most soils and rocks, underground mining activities can lead to enhanced levels of radioactive dust, and radon isotopes and other radioactive isotopes[22]. On-site external exposures in industrial or mining situations could be due to the presence of NORM in stockpiles, waste piles, storage tanks, build-up of surface contamination on equipment, in pipes and storage tanks. External exposures to members of the public (off-site) can result from exposure to gamma radiation from passage of cloud shine or exposure to gamma radiation from material deposited on the ground (ground shine) [22]. The dominant exposure pathways in most situations are external gamma radiation, inhalation of radon gas and its decay products, ingestion of contaminated food and/or water[22] . The guiding principle in controlling the radiological impact of NORM in all these situations is the ALARA principle[22] ,which states that all exposures should be kept as low as reasonably achievable (ALARA), social and economic factors taken into account. The damage that may arise as a result of interaction of radiation with the human body may be death or modification of cells that will affect the function of organs or tissues resulting in deterministic or stochastic effect. The damage to the deoxyribonucleic acid (DNA) in the nucleus is the main initiating event by which radiation causes long-term harm to organs and tissues in the body[19].It has been reported that double strand breaks in DNA are responsible for causing critical damage. Disrepair and radiation damage could also lead to potential for progression to cancer induction or hereditary disease[19]. The mechanism of the biological effect arising from exposure to ionizing radiation is a result of direct and indirect actions. When the body is overexposed to ionizing radiation, a series of long and complex events are initiated through ionization or excitation of relatively few molecules in the body. The effects of radiation in which zero threshold doses are postulated could be thought to be as a result of direct ionization and excitation of molecules with the consequent dissociation of the molecule [23]. The dissociation, due to ionization or excitation of an atom on the DNA molecule prevents the information originally contained in the gene from being transmitted to the next generation. Such point mutations may occur in germinal cells in which the point mutation is passed onto the next individual or it may occur in the somatic cells which results in a point mutation in the daughter cell. Since these point mutations are thereafter transmitted to succeeding generations of cells, it is clear that, for those biological effects of radiation that depend on point mutations, the radiation dose is cumulative, every little dose may result in a change in the gene burden, which is continuously transmitted[23] .About 70-75 % of the human body is made up of water and most of the direction action of radiation is therefore with water molecules. This leads to absorption of energy by water molecules which results in the production of highly reactive free radicals that are chemically toxic[23] .Biological systems are structured in various levels of organization: atoms, molecules, cells, tissues, and organisms. Ionizing radiation primarily interacts with atoms and biological responses may become observable ascending to every level of organization. The probability of such observation largely depends on complex signalling within and between cells at every level of organization controlling homeostasis and adaptation of the whole system[24]. Proteins, cell membranes and DNA are targets of radiation exposure, and effects on these structures can be produced by direct damages well as free radicals, including reactive oxygen and reactive nitrogen species (ROS and RNS, respectively)[25].DNA damage is formed by the ionizations/excitations of DNA or the surrounding material, mostly water within a radical-diffusion distance of 4 nm from the DNA in the cellular environment[26]. Various forms of DNA damage are induced by ionizing radiation. Previous publications allow the rough estimation of the yields of DNA damage in mammalian cells caused by low-LET radiation exposure: for each diploid cell, 1 Gy induces 1000 simple-strand breaks, 10000 base damage, 150 protein-DNA cross-links, 70 bulky lesions (ie, clusters of base damage), and 40 double-strand breaks (DSB)[27]. During recent years, many scholars have conducted a large number of studies on the effect of electromagnetic radiation emitted by many sources. For example, Osepchuk, made a review of the safety of microwave ovens. He has showed that typical leakage values imply exposure values well below the most conservative exposure standards in the world. Microwave ovens are being more accepted and safer than they were in 1973[28]. While evaluating the health risks from exposure to electromagnetic radiation, Matthes investigated the measurements of radiation emitted from microwave ovens and he found that detrimental health effects are not expected to occur as a result of radiation exposure during microwave cooking[29].

Kolodynski and Kolodynska from their experiments on school children living near the Radio Location Station (RLS), they conclude that these children had less developed memory and attention. Their reaction time was slower and their neuromuscular apparatus endurance was lowered [30]. Sieber and his team proved that fears can be neglected concerning the formation of D-amino acids in micro waved milk. A biological experiment showed that no evidence for the hazards of microwave heat treatment of milk [31]. Moreover Inaloz and his group in their study believe that it is not easy to say that microwave ovens have cataract genic effect on human eyes [32]. Alhekail in his study argued that user exposure to RF radiation from microwave ovens is much less than the public exposure limit set by the international standard ICNIRP in 1998 at 2.45 GHz which is 104 mW/m2, and that a detrimental effect on health is an unlikely result of exposure to radiation from microwave ovens[33]. On the other hand microwave ovens greatly affected food stuffs, Song and Milner studied the effect of microwave ovens on garlic. They demonstrated that heating garlic for 60 second in a microwave oven is enough to inactivate its allinase, garlic's principle active ingredient against cancer[34]. Radio frequency signals at an average specific absorption rate (SAR) of at least 5.0 W/kg under extended exposure conditions are capable of inducing chromosomal damage in human lymphocytes. This research has been studied by Tice and his group[35]. Vallejo showed that microwave ovens have serious effects on nutrients in people's food such as broccoli "zapped" in the microwave with a little water lost up to 97 percent of its beneficial antioxidants. By comparison, steamed broccoli lost 11 percent or fewer of its antioxidants. There were also reductions in phenolic compounds and glucosinolates, but mineral levels remained intact[36]. In addition, Kesarik and his team summarized in their research that the regular and long term use of microwave devices (mobile phone, microwave ovens) at domestic level can have negative impact upon biological systems especially on brain[37]. Alto and his group found that the electromagnetic field emitted by a commercial mobile phone affects regional cerebral blood flow in humans[38]. Radiation from a cell phone penetrates deeper into the head of children. Children may be more susceptible to damage from cell phone radiation. Children absorb energy differently than adults because of differences in their anatomies and tissue composition. This has been summarized by

Wiart and his team in 2008[39]. A study done by Mailankot and his team to evaluate the effect of radio frequency electromagnetic radiation(RF-EMR) from mobile phones on free radical metabolism and sperm quality. They summarized that semen quality is negatively affected from RF-EMR emitted. Male fertility may impair by exposure to these radiations [40]. Tacken and his group investigate the idea that after low temperature microwave heating, triglyceride and carotenoid concentration in human milk remained stable. Therefore, mature human milk can be safely heated in a microwave oven without loss of fat or carotenoid [41]. The study conducted by Cinquanta and his team on heating orange juice in microwave ovens showed that there is a slight decrease in vitamin C content after microwave heating[42]. Han and his group in their study demonstrated that watching TV and using a mobile phone during the first term pregnancy may increase risk of embryo growth ceasing significantly[13].A study was done by Mousa to measure the electromagnetic radiation from some cellular base station around the city of Nablus. He summarized that the measured and calculated values of electric field, magnetic field, and the power density were small compared to the international standards[43]. Robinson and his group in their study argued that children as young as 17 month could start microwave ovens, open the door, and remove the contents, but these actions may put them at a significant risk for scald burn injury[44]. People usually think that, there is a dangerous health problem due to radiation leakage from microwave ovens. Several experiments carried out in this field. According to Australian standard it is found that the maximum allowable leakage from a microwave oven is 5 mW/cm2 at 5 cm distance from the surface of a microwave oven. The only danger from the exposure to the radiation emitted by an oven is a thermal effect[45]. The detrimental effects of microwave radiation emitted by mobile phones at students in university are studied in 2012. Mortazavi and his group summarized that the student visual reaction time (VRT) decreased after exposure to electromagnetic fields generated by specific absorption rate mobile phone[46] . Lahham and Sharabati in their study found that the amount of radiation leakage from microwave ovens at a distance 1 m vary from 0.4 to 16.4 µW/cm2 with an average value that equals to 3.64 µW/cm2. They concluded that there is a linear relation between the amount of leakage with both oven age and the operating power[47]. Thambiraj and his group argued that microwave ovens are considered an important source of injury at home especially among young children in the United States[48] The effect of electromagnetic field from mobile phones on fasting blood glucose in Wister Albino rats was determined by Meo and Rubeaan study. They concluded that there is an increment in fasting blood glucose and serum insulin in long-term exposure Albino rats[49]

Chapter 3

Theoretical concepts

Ionizing radiation is radiation that has sufficient energy to remove electrons from atoms ,creating ions. The result of this ionization is the production of negatively charged free electrons and positively charged ionized atoms. Ionizing radiation can be classified in to two groups: photons (gamma and X rays) and particles (alpha, beta, and neutrons).Ionized atoms (free radicals), regardless of how they are formed, are much more active chemically than neutral atoms. These chemically active ions can form compounds that interfere with the processes of cell division and metabolism. The degree of damage suffered during exposure to ionizing radiation depends upon the type, intensity, energy ,duration, and chemical form of radiation so when photons and electrons interact with matter. These are the radiations that are important for diagnostic radiology, and only those interactions which result in their attenuation, absorption and scattering are dealt with the energy range used for diagnostic radiology is generally on the boundary between classical and quantum physics and following the "Complementarity Principle", the numerical details of the interactions will be treated by classical reasoning where that is appropriate and by quantum mechanical considerations where that gives superior results, the probability of a single photon incident on a slab of material of area A, that contains one target of cross-sectional area σ, interacting with the target will be the ratio of the two areas: σ/A If there are Φ photons randomly directed at area A, that contains n targets, each with area σ, the expected number of interactions $\Delta\Phi$ between photons and targets will be $\Delta\Phi = \Phi\, n(\sigma/A)$ Another way of saying this is that the probability of a projectile making a hit is $n\,(\sigma/A)$, which is just the fraction of the area that is blocked off by the targets Changing now the targets to: atoms, their cross-section would be an atomic cross-section ,This wouldn't be an actual area of the atom, but would be an effective area – effective for an interaction between the photon and the atom that is being considered Cross-sections are frequently represented by the symbol σ and conventionally expressed in a unit of area call barn 1 barn = $10^{-28}m^2$.

3.1 Interaction radiation

Radiation either in the form emitter particles such as neutrons, protons, alpha and beta particles, or electromagnetic radiation such as gamma rays and x - rays, has properties of energy ,mass, momentum, and charge which combine to determine who it interacts with matter. [50] [51] Over all the reactions that occur to the radiation with the material whether they lead to the full or partial absorption or dispersion of the radiation energy, are working to ionize the atoms of the material by making them lose a number of orbital electrons to the atom to leave them in a state of ionization as a result of this loss in this case, the atom is positively charged as a result of this loss or by raising it electrons to higher orbits to leave an atom to be excited, or that the radiation is transformed from one form to another such as photons resulting from the electron and positron annihilation process. In general, charged particles lose most of their energy ionization process nitrogen and photons lose their energy by dispersion and absorption **,**there are several ways to express the interaction of radiation with matter, which describes the loss of particles to their energy during the passage of one of these methods is the ability to stop, which is symbolized by the symbol(**S)** (dE) along its path (dX).

which is defined as the amount of the particle's loss In the article where it can be written as the following mathematica

$$s = -\frac{\partial E}{\partial x} \text{........} \quad (3-1)$$

A negative sign in the equation means that there is a decrease in the particle's energy as it passes through the distance (x) in the material and the linear rate for the loss of particles to their energy in the material along their path, or the ability of the medium to stop these particles and using relative quantum the pythian world was able to derive a mathematical relationship to the ability of matter to arrest charged particles Heavy as follows and known as a pythian relationship to the ability to stop

$$-\frac{\partial E}{\partial X} = \frac{4\pi Z^2 e^4 n}{mc^2 \beta^2}\left[\ln\frac{2mc^2\beta^2}{I\left(1-\beta^2\right)} - \beta^2\right] \quad \text{........} \quad (3-2)$$

Where(z) is the atomic number of the particle and(e) is the electron charge and(n) is the number of electrons per unit volume in the material and(m) The electron mass in the dormancy and $\beta = v / c$ the velocity of the electron at the speed of light and (I) the average of the excitation energy of the atoms Subject We find that the ability to stop depends on the charge and the number of protons of the particle and the speed of the particle, all Characteristics of the charged particle and the material depend on the number of electrons in the material and on the average energy[50] [51].The nature of the reaction can also be described by the transfer of energy to the material linearly so the description is similar to the description of the stopping power as the energy transmission to the material linearly equal to the capacity of stopping by the first ,process of mass loss is expressed within a given volume, while the latter describes the particle's energy has been absorbed Also, the second means the rate of energy that has moved locally to the center Within a specific energy - and a certain distance - and locally means the place where the collision took place and the process of transition Energy from the particle to the material or place very close to it, noting that the expression moved locally may return to the distance Of the path or the maximum energy specified for the missing particle energy in the material[50] [51].

3.2 Gamma Rays Reactions with the Material

The interaction of electromagnetic radiation with the material is more complex than the interaction of other types of radiation with the material. The fact that these rays are wave energy, the speed of which is the speed of light, there is no Block stillness and no electric charge. In general, the interaction of the photon with the material is statistically determined by the probability of its interaction in the unit of distance traveled in the material and this probability depends on the type of material and photon energy. When the photon interacts with the material, there is a possibility of absorption and the possibility of being dispersed by changing its path or the loss of part of its energy or even transit without a final interaction. Although its interaction is based on statistical probability, this possibility falls within four main ways of the photon's interaction with the material. These mechanisms are interrelated dispersion, photoelectric effect, dispersion as coupling and binary production[50] [51]

3.2.1 Distant dispersion

This dispersion is known as conventional dispersion and occurs when the photon passes by an orbital electron that oscillates with the photon wave The radiation of energy gained from the original photon and the energy value emitted by this oscillating electron is equal to the absorbed photon energy but is in a different direction from the original direction of the absorbed photon. the photon energy is absorbed and then irradiated again with the same energy absorbed by the In a direction different from the original direction at small angles and the probability of this interaction is higher in materials with a large atomic number and with low-energy photons and practically there is no consideration for this type of interactions as it does not change any energy and a limited change in direction[50] [51] .

3.2.2 Photoelectric Effect

The photoelectric effect is the reaction of the photon with one of the electrons of the atoms of matter. The electron is released from its place. This electron takes the entire energy of the photon in the form of kinetic energy, except for the energy to get rid of the energy of an electron bond in a run with the atom. This process can be characterized mathematically as a photon whose energy is equal to $E = h\nu$ interacts with the material, the energy The freed electron equals Eelc = hv - Eb where E b is the energy of connecting the electron in orbit. In order for this interaction to happen, the photon energy must be greater than the energy of the bond. This interaction can occur for any of the electrons in different orbits in a atom[50] [51] .After the electron is extracted from one of these orbits, it leaves a space in the orbit and an ionizing or excited atom. This vacuum will be filled with one of the electrons from the upper orbits. In this process, the electron coming from the upper orbit of the energy will produce X-rays equal to the energy difference between the two orbits The probability of a photovoltaic effect reaction depends on the photon energy and the atomic number of the material. This reaction is inversely proportional to the photon and Z^5 atomic energy cube and the probability of this reaction being mathematically expressed as follows:

$$\tau = K\frac{Z^5}{E^3}........ \quad (3-2)$$

Where(K) is static

Of the above mathematical relationship shows that this interaction is more when the energy of the photon is few and the atomic number of the material is large and this interaction is the basis for the diagnosis of radiation as the energy used for imaging is low, increasing the likelihood of interaction in addition to the absorption of photons depends on the atomic number of the fifth Exponentiation This makes the distinction between the components of the human body possible, such as distinguishing between the bones with the largest atomic number that absorb these photons more likely and other tissues with low atomic number .This phenomenon is characterized by several characteristics: that this interaction occurs only with one of the orbital electrons associated with the substance of the material. The probability of this reaction is greater when the radiation energy is sufficient to overcome the energy of the bond. This is in low energy photons that are equal or greater than Atomic orbit. In addition, in the case of tissue, the absorption coefficient and the transition factor are almost equal in this reaction[50] [51] .

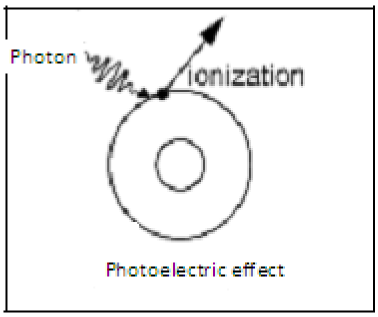


Figure 1: Photoelectric effect

3.2.3 The dispersion of Campton

The dispersion of Campton is very important in gamma rays and medium energy (MeV 1 - 0.5) and materials The atomic number is as little as the tissues present more than other reactions. The dispersion as a mutation is the result of the photon collision With one of the orbital electrons in the atoms of matter leads to the removal of this electron from the position and give it part of energy The photon, called the transformed electron, and the photon, which is lost to a portion of its energy, is dispersed in a different direction and is called the dispersed photon as shown in Fig (2). In the case of dispersion of Campton, the orbital electron associated with the atom can be considered a free electron because of the small value In this case, when the photon collides with the electron, it gives it enough energy to launch in a direction that creates an angle of with the direction of the original photon. The photon is dispersed after losing a value from its energy at the angle .By applying the principle of energy conservation on the x and y axes, The converted electron energy is equal to

$$E = hv\frac{\alpha(1-\cos\theta)}{1+\alpha(1-\cos\theta)} \;.... \quad (3-4)$$

And dispersed photon energy

$$hv = hv\frac{1}{1+\alpha(1-\cos\theta)} \;........ \quad (3-5)$$

Where the energy of the converted electron(hv) is the original photon energy and (hv) is the energy of the dispersed photon $\alpha = hv / m c^2$ The angle at which the electron starts [50] [51] .

$$\cos\phi = (1+\alpha)\tan\left(\frac{\theta}{2}\right) .... \quad (3-6)$$

The difference in the wavelength of the internal photon (λ i) and the dispersion (λf) can be found as follows

$$\Delta\lambda = \lambda_f - \lambda_i = \frac{h(1-\cos\theta)}{m_o c} \quad .... \quad (3-7)$$

The probability of dispersion of Campton increases with the increase of the photon energy and its dependence on the atomic number is small by its direct dependence on the number of electrons in one gram of matter and this ratio is almost equal to all substances except hydrogen[50] [51] .

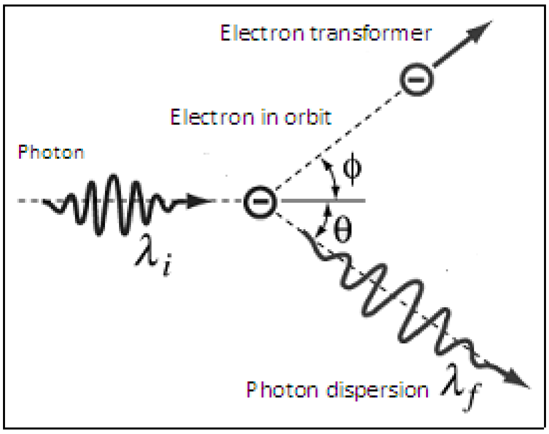


Figure (2) : Dispersion as Kempton

3.2.4 Pairs production

Binary production is one of the strongest clues to the process of transforming energy and mass from one form to another of photonic energy in to a mass If the photon energy inside is greater than1.02 MeV, there is a very high probability of this photon interacting with the electromagnetic field of the nucleus of the material giving its full energy to produce two particles, one electron and the other with Positron**.** Their total idle **e**nergy is equal to 1.02 MeV and the rest of the photon energy These particles are produced in the form of energy movement Of these particles with the possibility that one of these particles take the total of this energy left from the production of particles in the form of kinetic energy while the other remains in the state of sleep and without kinetic energy, and usually *Positron* acquire a greater amount of energy than the electron because the interaction occurs near the nucleus The positive charge leads to the dissociation of the Positron with the nucleus leads to the acquisition of the amount of energy as a result of this contrast and the electron will lose part of its energy to overcome the power of grappling with the nucleus of the atom. For this interaction it is necessary to increase the photon energy from 1.02 MeV and otherwise there is no probability of this reaction and the particles produced tend to go to the same side as the photon[50] [51].

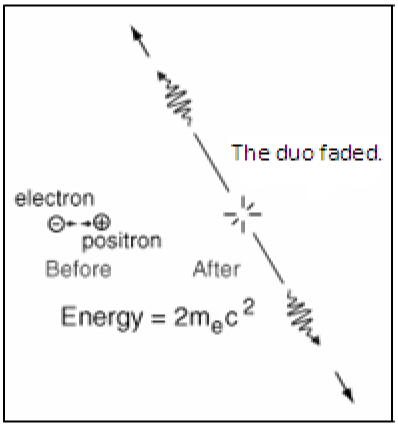


Figure (3): A diagram showing how The duo faded

3.3 absorption and attenuation

The nature of the photons' interaction differs from other types of radiation, such as charged particles. When these photons cross the material, part of it is fully absorbed and the other passes without any interaction and the latter is dispersed after losing part of its energy and direction. (I_0)and the geometrical system that crosses a certain barrier by the thickness of (x), the number of previous interactions between these photons and atoms of the material will result in a change in intensity due to absorption and attenuation of this package. The higher the thickness of the material the greater the attenuation and absorption in the package, so the package Radioactivity The(dI) and the thickness of the subject matter(dx) can be expressed mathematically as follows

$$-\frac{\partial I}{\partial X} = \mu I \,........ \quad (3-8)$$

Where (μ) claims the linear attenuation coefficient of the material and is equal to the slope of the straight line representing the relationship between the thickness of the material and the logarithm of the beam intensity This equation is integrated as follows:

$$\int \frac{\partial I}{I} = \int -\mu \partial x \,........ \quad (3-9)$$

we find that:

$$\ln I(x) - \ln I_O = -\mu x \quad .... \quad (3-10)$$

$$I(x) = I_O e^{-\mu x} \quad .... \quad (3-11)$$

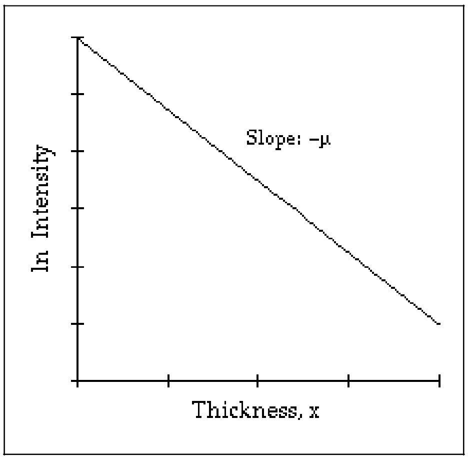


Figure (4): The relationship between the thickness of the material and the intensity

The linear attenuation coefficient (μ) represents in this case the sum of the attenuation coefficients of the reactions that occur to the photon by crossing the thickness of a specific mass. These reactions are the photoelectric reaction, dispersion of the Campton and the binary production.[50] [51]

$$\mu = \tau + \sigma + k .... \quad (3-12)$$

(κ, σ, τ) are the linear coefficients of the Photoelectric effect interaction and are dispersion of the Campton and binary production, respectively. Hence, it is surprising that this parameter is linear since the sum of these reactions, each dependent entirely on photon energy or atomic number and density The material and some of these relationships are nonlinear but when the relationship is graphically represented between the logarithm of the intensity of the beam and the fish we get this linear relationship when we talk about absorption, attenuation and dispersion together. It is worth mentioning here that this laboratory is used for the purposes of radiation protection in the calculations of radiation shields when it is important to express the ability of the photon to move and crossing the absorbed medium In the case of radiation exposure or absorbed dose calculations, which are derived from the energy actually absorbed in the physical medium, another coefficient must be found that illustrates this relationship as energy. For example, the Photoelectric reaction gives full power to the electron that stores this energy in the end In the case of dispersion of the Campton, a part of the energy carried by the converted electron is the one who deposits this energy in the material while the part carried by the scattered photon goes away to put energy elsewhere, and the same happens in the interaction of binary production when the Positron**.** and the electron Thus, another factor is the linear energy absorption coefficient (μ_{en}), which equals the linear attenuation coefficient minus the sum of the other energy loss coefficients that are related to carrying the energy to another location such as the photon Dispersion and photon-induced photons and the resulting a radiation (Brehmsstrahlung) produced by the electrons produced from the reactions, which accelerate in the center, causing the emission of these rays, or x-rays characteristic of the element. In this case, we can rephrase this parameter mathematically as follows

$$\mu_{en} = \mu - \left(\sigma_S + k_{pp} + others\right) \quad .... \quad (1-13)$$

However, another more effective factor is the linear mass energy ($\mu en / \rho$) unit, which is the square centimeter per gram cm^2/g.It is used in the treatment of the absorbed dose or the amount of radiation exposure when the ray stream is known or known, For calculations of absorbed energy and not for attenuation calculations. Therefore, the appropriate laboratory should be checked when used in calculations of radiation prevention and solutions to their problems[50].Most of the work on radiological protection, such as radiation shield calculations, is solved by using the linear attenuation coefficient (μ) and the radioactive dose calculations are performed using the (μ_{en}) mass absorption factor instead of using partial interactions of the reactions But the processing of each interaction is more important when the photon energy is taken into consideration and the atomic number of matter[50].

3.4 Effects of gamma rays on living organisms

Radiation effects on living organisms are mainly associated with the chemical changes but are also dependent on physical an physiological factors. Dose rate,] dose distribution, radiation quality are the physical parameters. The most important physiological and, environmental parameters are temperature, moisture content and oxygen concentration

.An action of radiation on living organisms can be divided into direct and indirect effects normally, the indirect effects occur as an important part of the total action of radiation on it. The Figure 2 shows that radiolytic products of water are mainly formed by indirect action on water molecules yielding radicals OH•e- aq and H•. The action , of the hydroxyl radical(OH•) must be responsible for an important part of the indirect effects. Drying or freezing of living organisms can reduce these indirect effects. If we consider pure water, each 100 eV of energy absorbed will generate: 2.7radicals OH•, 2.6 e- aq, 0.6 radicals H•, 0.45 H2 molecules and 0.7molecules H2O2.

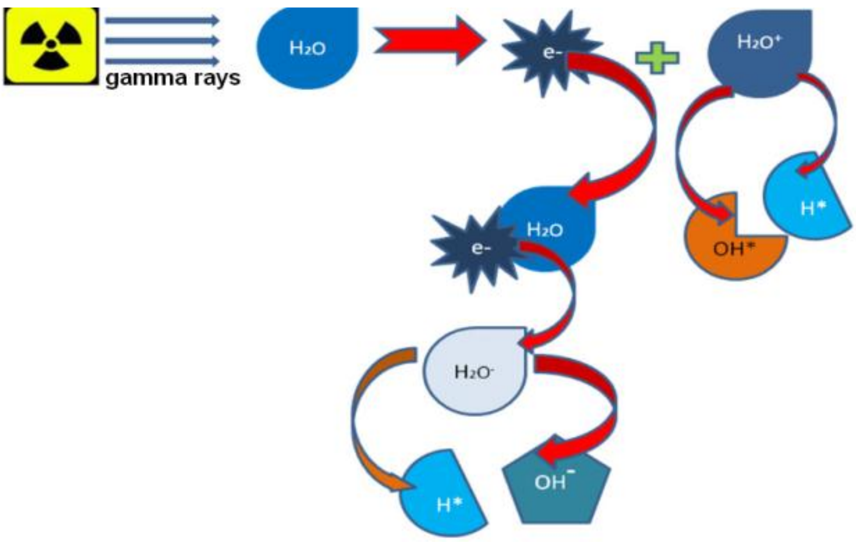


Figure (5) Effects of gamma rays on water molecules

So in general and most of the In direct effects of radiation will occur in the water molecules, which constitute 70-80% of the organism causing disintegration and produces free radicals with high reactivity, forming toxic compounds that affect toxins on living cells Partial water will be decomposed by equation [50] [52].

$$H_2O \rightarrow H_2o^+ + e^-$$

The water ion will then decompose immediately as follows

$$H_2O^+ \rightarrow H^+ + OH$$

The free electron will be taken by non-decomposed water to dissolve directly, according to the following equations

$$H_2\,\mathrm{O} + e^- \rightarrow H_2\,\mathrm{O}^-$$

$$H_2 0^- \rightarrow H + OH^-$$

The time required for these reactions begins with the physical stage of the ionization and excitation phase (10^{-14}) second, in the pre-chemical stage,during which decomposition is (10^{-11}) seconds, Free with each other or with other molecules if they spread in their time(10^{-6}- 10^{-11} seconds) [50] [52] The following equations

$$H + O_2 \rightarrow H\mathrm{O}_2$$

That the parts of the water in the original has an excess of the charge of the hydrogen atoms and a small increase in the negative charge at the atom of oxygen and therefore the electron is a free pure root and claims the water electron as shown in the following equation

$$e^-{}_{\mathrm{sub}} \rightarrow \mathrm{nH}_2O \rightarrow e^-{}_{aq}$$

The compound $\mathrm{H_2\,O_2}$ has a high oxidation capacity that indirectly affects the cells, and in the presence of $\mathrm{O_2}$ will interact with the free root H free water peroxide is formed which is toxic Thus, the direct biological effect of radiation is most often in the formation, transmission or evolution of these mutations into other mutations [50] [52].The effects include small doses that are constantly exposed to humans, where this effect can occur and thus have a cumulative effect of radiation and potentially in the doses of radiation up to 250 milligrams. This effect then starts increasing in proportion to the dose Several studies have confirmed that these changes occur at high doses of radiation due to the potential of binary effect of radiation, which occurs when the amount and energy at two different sites in the genetic chain (which is known Theory of dual radiation action) between DNA atoms, the cell loses its ability to reform itself and the repair process is easier when the fraction of the bond is from a single site Two sites close to the genetic chain, causing the destruction of the nucleus of the cell as a result of the loss of its ability to reform itself, in contrast, the possibility that the cell repair itself will be greater when the break in the bond is monolithic [50] [52]. Radiation affects both the structure of DNA and its synthesis. An effects on the structure were shown initially in bacterial cells by the elegant experiments of McGrath and Williams (1966), and in mammalian cells by Lett and co-workers (1967). Both investigations involved the centrifugation of DNA in an alkaline sucrose gradient. The high pH caused a separation of strands to the single-strand state. Any change in the sedimentation rate was related to a change in the size of the DNA molecule. Both groups showed a decrease in the size of DNA with radiation. In the mammalian cell system, this decrease can be seen at 1000 rad or less for several hours after irradiation and the DNA then analyzed, the sedimentation rates return to normal (see following text for repair mechanisms). It is important to distinguish between structural integrity and functional soundness: although the DNA may appear as a continuous strand, the correct order of bases may not have been maintained [50] [52] .There for the spread of these free radicals and compounds are carried out in all directions and randomly for a distance of x over time t, the amount of propagation constant D *equals*

$$D = \frac{x^2}{6t} \ldots\ldots\ldots \quad (3-14)$$

3.5 Gamma radiation interaction with blood

Blood, lymph and tissue fluid form the internal environment of the organism. Blood is the fluid constituent of the cardiovascular system, comprising both plasma and cellular components. Fifty-five percent of total blood volume is composed of plasma. Red blood cells, white blood cells and platelets form the cellular component. Blood has many essential homeostatic functions including the transport of oxygen and carbon dioxide, nutrients and waste products, immune function, buffering and hemostasis. As blood has such an important role in the maintenance of homeostasis. Problems with blood composition or circulation can lead to downstream tissue malfunction. Blood is also involved in maintaining homeostasis by acting as a medium for transferring heat to the skin and by acting as a buffer system for bodily pH.[53].

3.5.1 Composition of Blood

Blood contains plasma and formed elements. If blood is collected from an individual and its coagulation prevented by adding anticoagulants to it and then centrifuged sufficiently, the blood is separated into two layers, an upper clear (i.e. free from formed elements) layer, called the plasma and a lower layer, where the formed elements are packed up. On the other hand, if blood is collected without anticoagulant and is allowed to clot and some further time be allowed so that the clot is allowed to shrink, a fluid separates out. The fluid can be centrifuged further and the clear supernatant part can be collected. This is serum. Basically, serum is plasma minus fibrin. Formed elements are so called because under microscope they have definite forms. Formed elements are (i) red blood corpuscles (RBC) or erythrocytes, (ii) white blood corpuscle (WBC) or leucocytes (also spelt as leukocytes), (iii) platelets or thrombocyt [53].

3.5 .2 Effect of ionizing radiation on blood

The change in the composition of blood, such as the number of red blood cells and white blood cells and other components of the most important symptoms of radiation exposure as the blood cells of the most sensitive cells of radiation, and thus serve as a biological detector of radiation exposure in cases of acute exposure to radiation as it is likely to note These changes after exposure to doses greater than 140 milligrams and it is possible that no changes to 250 - 500 milligrams, according to some studies After this dose, these changes are almost certain to occur. After acute radiation exposure, there is a sharp increase in the number of granulocytes followed by a decrease after one day until the minimum reaches back to normal after several weeks to several months while lymphocytes decrease sharply after exposure and remain for several months. These changes are considered one Indicators of acute radiation exposure, red blood cells do not show this for up to a week after exposure and then decrease and continue to decline until reaching a minimum in a month to two months to begin a slow recovery may take several months. In the case of exposure to doses of radiation greater than 2 Gry, the destruction of bone marrow cells producing blood corpuscles and this immediately causes the body to attack diseases due to loss of defense in the body for its functions, the effect is seen after several hours of exposure and in the form of nausea and vomiting and imbalance followed by Less than one month of hair loss. If not followed and treated, the possibility of death occurs within one to two months of exposure, and when exposed to doses greater than 4-6 Gry, the destruction of bone marrow completely or uncertain[50].It was found that the radiation effects on the red cell membrane from three different but correlated properties: electrical, mechanical and chemical, and to derive useful parameters for the evaluation of radiation effects. AC conductivity of cell suspension was measured in the frequency range 40 kHz to 5 MHz, the osmotic fragility of the membrane and solubilization of the membrane by detergent were also measured. Adult male rats were exposed to 1, 2 .5, 3.5, 5, 7 and 9Gy gamma radiation from Cs137 source. The results showed decrease in the AC conductivity, average osmotic fragility and average membrane concluded that exposures to low doses of gamma and X-rays showed a high sensitivity of characteristics of the lipid metabolism in erythrocyte. [54]. Studied the effects of γ-rays in the dose rate range 0 Gy on RBCs membrane solubilization, of rats erythrocytes using sodium dodecyl sulfate (5.6 SDS). The results showed that shift in the detergent critical concentration of irradiated dose Blood films for in-vivo rats showed irregular shaped red blood cells[55],Gamma irradiation of red blood cells induces alterations at three different function al units of the membrane: lipid bilayer, protein components and cytoskeleton at the membrane surface([56].In addition, radiation induces shortening in the lipid fatty acid chains by lipid per oxidation[57] .The production of hydro peroxides and cross-linkages in the membrane lipids can disorder the upper region of the bilayer favoring penetration of water and ending by hemolysis[58].

3.6 Radiation prevention

Radiation prevention is the protection against radiation and radiation exposure or the reduction of the amount of exposure To the extent that it minimizes the risk of radiation, exposure to ionizing radiation is either through radiation exposure from an outside radiation source and a card capable of penetrating the body and claiming external radiation or exposure to radiation from within the body as a result of the entry of radioactive material into the body through the digestive or respiratory system or Through the skin. Radiation exposure from an external source of radiation may be from a device for the production of radiation or it may be radioactive material depends on the type and energy of the radiation. Radiation from the x-ray tube or sources of gamma rays or neutrons is usually capable of penetrating and influencing the body. In addition to some radioactive sources of high-energy beta particles, they can penetrate the body and enter internal tissues when the maximum beta energy exceeds 300 keV In the case of beta particles emitted from nuclei

H^3 C^{14} P^{33} S^{35} $Ca^{45}Ni^{63}$have a capacity of less than 300 keV, thus their ability to penetrate the body is limited to a very short range of 0.1 mm in the skin tissue. Pose a risk to the body as an external source of radiation[50] .The basic principle of radiological protection is to limit or minimize exposure to radiation exposure. The application of this principle is to develop methods and bases for dealing with radioactive sources in radiological practice and to take the necessary measures and reserves to reduce exposure from natural sources of radiation to reduce the exposure value Radiation, it is possible to adopt three important principles to reduce the amount of radiation exposure resulting from an external radiation source. These principles are :

1- Increase the distance from the radiation source

2 - Reduce the amount of time during which sources of radiation are dealt with

3 - the use of radiation shields

3.6.1 Distance and Radiation

The greater the distance from the source of the radiation the greater the amount of radiation exposure whenever the distance from the source of radiation the lower the intensity and thus the amount of radiation exposure photons from this. The source, which represents the intensity of the source and therefore the amount of radiation exposureR_0 will spread and distributed in all directions evenly with a certain intensity If we assume a ball around this source, the radius of this ball is equal to the default distance and the surface area of this ball will be equal to

$$A = 4\pi r^2 \ldots\ldots\ldots \quad (3-15)$$

At this distance, the amount of exposure (R_0)will be distributed over the entire surface of the virtual ball and the amount of radiation exposure at this distance(R) will be equal to the original exposure amount distributed on the surface of the ball as follows

$$R = \frac{R_O}{4\pi r^2} \ldots. \quad (3-16)$$

From the above equation we find that the amount of exposure or radiation dose is inversely proportional to the square of distance from the source of radiation This proportionality is called the reverse quadratic law. This means that if the distance from the source is double the radiation exposure will fall by four times its value at the first distance as shown in Figure (8)

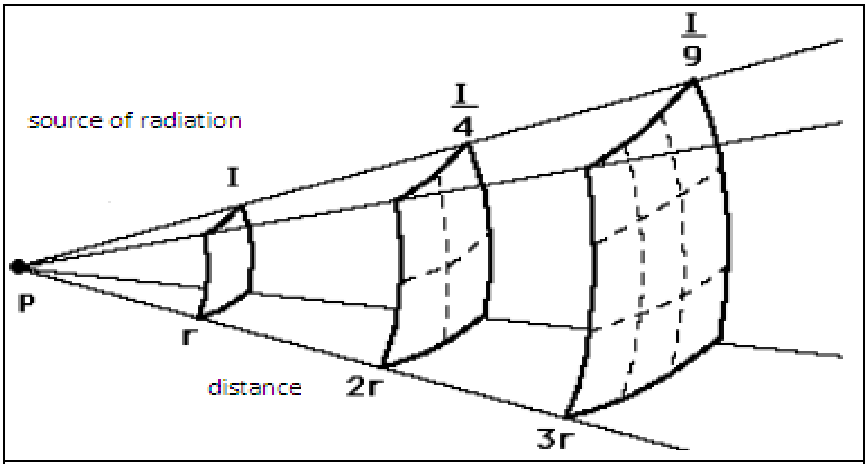


Figure (6) How to reduce exposure as distance increases by reverse squared law

3.6.2 Time and Radiation

Is an important factor in all scientific applications. In the field of radiation, exposure time is a key factor in radiation protection, in the case of exposure to an external radiation source or during the period of taking radionuclide's for patients exposed to internal radiation, and to avoid this harmful effect to increase the period of dealing with the source of radiation and its consequences of the consequences requires the development of appropriate methods to reduce the period of dealing with the radioactive source is employing this factor in several ways, the most important professional or professional in dealing with the radioactive source to accomplish the work in a short period of time and through rehabilitation and training appropriate and raise the level of professional radiologist[50].The amount of radioactive doses resulting from radiation exposure shall be calculated so that the permissible limits do not exceed the most appropriate time to deal with the source of radiation as follows

$$Time\lim it = \frac{DoesLimit}{DoesRate} \ldots\ldots.. \quad (3-17)$$

Attention should be paid to the units during the evaluation of the most appropriate time, which results in a reduction of the dose, for example, the dose rate equivalent to the unit of Sivert per hour. Therefore, the permissible dose limits should be in the Sivert unit[50].

3.6.3 Radiation shields

When the radiation passes through the material then it deposits its energy in the material through the production of charged ions as mentioned earlier Previously, the material works to absorb or attenuate the radiation energy The absorption capacity of the material depends on several factors, including the type , energy, and type of radiation. Depending on this order, different types of materials have been used to make them shields from radiation or to reduce their level[50].

3.7 Radiation exposure

When radiation interacts with matter, it results in ionization and irritation of matter atoms and thus electrons Secondary, which in turn may produce other electrons as a result of their interaction with matter Lead to chemical and biological changes in the material that has been exposed to radiation through the process of transferring energy from The main radiation is absorbed by matter[50] [51].Exposure is defined as the amount of ionization due to gamma or X-rays in the air and is measured in the resin unit (R) Exposure by the International Committee for Radiological Protection is defined as the amount of charge resulting from ionization of atoms as a result of exposure to gamma or X-rays per unit of weight and can be expressed mathematically as follows

$$R = \frac{\Delta Q}{\Delta m} \ldots. \quad (3-18)$$

(Q) The amount of ionization charges in the weight of matter is m, from the photons fully absorbed in this Weight so the one roentgen is equal to

$$1R = 2.58 \times 10^{-4} C/kg$$

3.7.1 Radiation exposure units

And radiation exposure units can be applied only to electromagnetic radiation photons in the air The energy absorbed in the air due to exposure to one resin is equal to 87.6 erg per one gram of air In this case, it is necessary to find a larger concept to include other types of radiation and other materials, especially living tissue It was found from the calculations that the exposure of one resin leads to the absorption of energy of 85 erg per gram of living tissue has been used for this amount called unit of reproduction (rep), which means the physical equivalent of roentgen This unit was used initially in the field of radiation protection and no longer use this unit now where a new definition has been found to include all types of radiation, which is called the absorbed dose is known as the absorbed dose is the amount of energy absorbed joule in the unit weight of the material in kilograms and measured in the running unit where:

$$D = \frac{E}{m} = \frac{J}{kg} \ldots\ldots.. \quad (3-19)$$

(D) absorbed dose and (E) absorbed energy in the substance, (m) weight of the material.

$$1Gy = \frac{J}{kg} = \frac{10^7 erg}{10^3 g} = 10^4 \frac{erg}{g} = 100 rad$$

The absorbed dose is the basic physical quantity for the measurement of radiation doses, but this unit is insufficient for the purposes of radiation protection because the damage to the biological tissue differs from one type of radiation to another. The biological effect of neutrons had to be correlated between these effects and the absorbed dose to evaluate these effects، So he found the so-called equivalent dose The equivalent dose is equal to the absorbed dose multiplied by the quality coefficient of radiation Q (also called the weighted coefficient of radiation W_R according to ICBB Circular 60 of 1991) where there is a specific coefficient for each type of radiation depending on the amount of effect it causes in the biological tissue due to the amount of transmission. Linear energy depending on the ability of each type of radiation to ionize events in the material, [50] [51].The equivalent dose is denoted by the symbol H

$$H = Q \times D ..... \quad (3-20)$$

Or by the new definition

$$H = Q \times W .... \quad (3-21)$$

It is measured in units of Sivert as Sivert is equal to the amount of energy in joules per unit weight in kilograms, which is the same unit of absorbed dose running but was given this name to avoid confusion between them and distinguish them from the absorbed dose

$$1sev = \frac{1J}{kg} = 100rem$$

There is a table showing the different values of the quality coefficient for different types of radiation according to the different energies and the linear energy transfer value Note that the quality coefficient is equal to gamma rays, X-rays and electrons because the linear transmission value of these types does not exceed 3.5 Kilo-electron volts per micrometer, because on this value and without it is constant, the dependence on biological effects is little and limited ‹Because these changes are limited[50].These changes begin to emerge effectively after this value up to 175 Kilo-electron volts per micrometer The value of the coefficient of quality has reached 20, and after this value begins the process of stability in value because the effect in living tissue has reached the saturation limit of the intensity of radiation concentration.

3.7.2 Calculation of radiation exposure

The amount of exposure or dose is calculated directly if the flow rate is known to the photon radiation source or the energy flow rate, which is measured by the number of photons or particles passing through an area of 1cm^{2}per second. Pedestrians per unit area according to the following equation

$$\varphi = \frac{\partial N}{\partial a} \ldots\ldots.. \quad (3-22)$$

$$\varphi_E = \frac{\partial N \times h\nu}{\partial a} = \frac{\partial E}{\partial a} \ldots\ldots.. \quad (3-23)$$

Where(φ) flow,(φ_E) the amount of energy flow, (da) area

The flow rate in a given time period is equal

$$\varphi = \frac{N}{t \times a} \ldots\ldots.. \quad (3-24)$$

The amount of energy flow in a given time period is equal

$$\varphi_E = \frac{E}{t \times a} \ldots\ldots.. \quad (3-25)$$

Each type of radioactive material is defined by a constant coefficient that distinguishes it from other materials This coefficient is called a constant

Gamma rays (Γ) It is measured in units of resin per hour resulting from one Korean amount of radioactive material within one meter, and the energy emitted is constant for each element[50] [51].The energy of the emitted radiation plays a key role In the process of granting energy to the absorbent material, these fixed parameters can then be found mathematically or from a table showing gamma ray constant resin values per hour , It is easy to calculate the radiation exposure value of any radioactive element at any distance (d) measured in meters if it knows the amount of its radioactivity (A)*Curie* Where each radioactive material the amount of radioactivity In mm *Curie* or *Curie* Of the following equation

$$R = \frac{\Gamma \times A}{d^2} \text{........} \quad (3-26)$$

The amount of absorbed dose is calculated indirectly by the value of radiation exposure in the air and in the body by knowing the value of the relative stopping capacity between air and living tissue S_{rel} Which is valued at 1.12 through the relationship

$$D_{tissus} = S_{rel} \frac{R \times 87.6 erg}{100 erg / gs} \text{........} (3-27)$$

Directly the absorbed dose can be calculated directly in the living tissue by the rate of energy deposition in the material using the energy absorption coefficient of the living tissue μ_{en}/ρ on the appropriate energy of the photon and find the amount of radiation flow, It is worth mentioning here that when talking about the absorbed dose we mean in this case the amount of energy absorbed by radiation This energy is deposited in matter through the interaction of charged particles Such as electrons, protons and alpha minutes due to an inelastic collision with orbital electrons in matter atoms Which results in ionization and excitation of these atoms. In the case of photons, the energy absorption process is carried out through the interaction of the photon with the material and the production of a charged secondary particle (electron) which in turn deposits energy, If we assume that one of these electrons entering the material is high energy and produces Regressive rays These rays will carry part of the main energy and move it to another place to be deposited there, In this case, the energy carried to the other place does not account for energy absorbed from the main particle, only the energy absorbed will be absorbed in the same place، This is equal to the energy of the main particle minus the energy carried to the other place[50] [51].

3.8 Radiation processing

Radiation processing refers to the use of radiation to change the properties of materials on an industrial scale. The term 'ionizing radiation' relates to all radiation capable of producing ionization cascades in matter. The energy range characteristic of ionizing radiation begins at about 1000 eV and reaches its upper limit at about 30 MeV. To avoid induced radioactivity, which may appear if the gamma ray energy is higher than 5 MeV or the energy of the fast electrons exceeds 10 MeV, it is prohibited to use for sterilization radiation characterized by energy higher than these values. On the other hand, the application of lower energy radiation (below 0.2 MeV) is not rational. Commercial gamma ray irradiation facilities are typically loaded with 60Co of total activity from 0.3 to 3.0 MCi1, while commercial e-beam facilities are equipped with one or two electron accelerators generating high power (10– 100kW) beams of 8–10 MeV electrons. When radiation passes through materials it breaks chemical bonds. Radiation processing has been used commercially for almost forty years. Gamma radiation from 60Co. Implants, artificial joints, syringes, blood-bags, gowns, bottle teats for premature baby units and dressings are all sterilized using radiation. The surgical gloves are sterilized using gamma radiation from 60Co. Other industries that benefit from radiation .processing include the food, pharmaceutical, cosmetic, horticultural, and automotive industries. In the horticultural industry, growing-mats, fleeces and pots may be reused after irradiation-reducing waste and cost and saving the environment from unnecessary waste .Similarly, commercial egg trays may be recycled after irradiation without risk of proliferating salmonella.

Gamma rays are formed with the self disintegration of Cobalt-60 (60Co) or Cesium-137(137Cs) sources. Among thousands of gamma emitters only 137Cs and 60Co are indicated for radiation processing. The energy of gamma rays, as electromagnetic quantum waves, is similar to light, but with higher photon energy and shorter wavelength. The 60Coradionuclide can be produced in a nuclear power reactor by the irradiation of 59Co (metal),with fast neutrons. The radioactive isotope is formed by neutron capture as showed equation 27Co59 + 0n1 → 27Co60 (1) The unstable nucleus of 60Co emits photons of 1.17 and 1.33 MeV, decaying with a half-life of 5.2714 years to stable 60Ni .The radioactive 60Cosource is composed of small pellets of cobalt that are loaded into stainless steel or zirconium alloy sealed tubes (pencil arrays).Radiation is the unique source of energy which can initiate chemical reactions at any temperature, including ambient, under any pressure, in any phase (gas, liquid or solid),without use of catalysts. Thus, radiation processing uses highly penetrating gamma radiation from sealed radiation sources travelling at almost the speed of light.

3.9 The energy carried by gamma rays

Radiation is transferred to the product being irradiated by collisions between the radiation and the atoms of the product. In these collisions atoms lose their bound electrons in a process called ionization. It is this process that results in irreparable damage to the life sustaining chemistry of living organisms and the initiation of crosslink king chemistry or main chair scission in polymeric materials, during use of this type of radiation, high-energy photons bombard the product, causing electron displacement within. These reactions, in turn, generate free radicals, which haid in breaking chemical bonds. Disrupting microbial DNA renders any organisms that survive the process nonviable or unable.

Chapter 4

Results & Discusion

Gamma rays are the most influential types of radiation with high penetration and ionization of matter .The extent of the effect of ionizing radiation depends on a number of factors including exposure time, distance from the radioactive source, type and energy of the source, and other factors .The aim of this study is to observe the effect of low doses of gamma radiation on living material (cows blood samples), And its relationship to the time of exposure to radiation and then its relationship to the amount of radiation energy .Through the experimental steps described in this chapter, and then discuss and interpret the results of the treadmill, to the conclusion and recommendations.

4.1 Experimental Setup

4.1.1 Experimental Animals and Irradiation

Cows blood samples were divided into five groups, each group three samples, the first group is the control group, the second, third and fourth were exposed to radiation dose of 2.5 mGray, 7 mGray, 15 mGray respectively using the source of cesium-137 at Sudan Atomic Energy Commission Laboratory, Each blood sample was exposed to one dose of 100 Gray, 200 Gray and 300 Gray radiations, respectively using the Cobalt Co 60 source at the Department of radiology Khartoum teaching hospital. In all groups the distance between the samples and the source was 1 Metter The exposure time for radiation was different between each sample and in the three groups that used the cesium-137 source,5, 15, 30 minutes, respectively. The groups that used the cobalt source 60 had a very small exposure time and the source energy was greater compared to cesium-137.

Image(1) cows from which blood samples were taken

4.1.2Blood sample collection

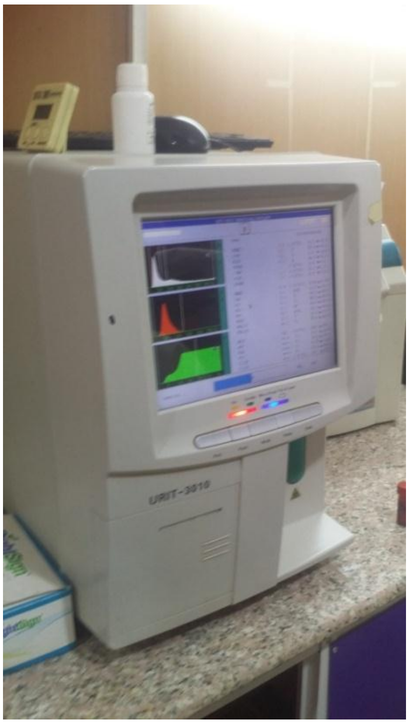
Blood samples were taken from the vein by injection from cows at the College of Animal Production Science and Technology - Sudan University of Science and Technology ,in a container containing anticoagulant (EDTA).

Image(2) Inject for blood sampling

Image(3) The blood container containing the anticoagulant (EDT)

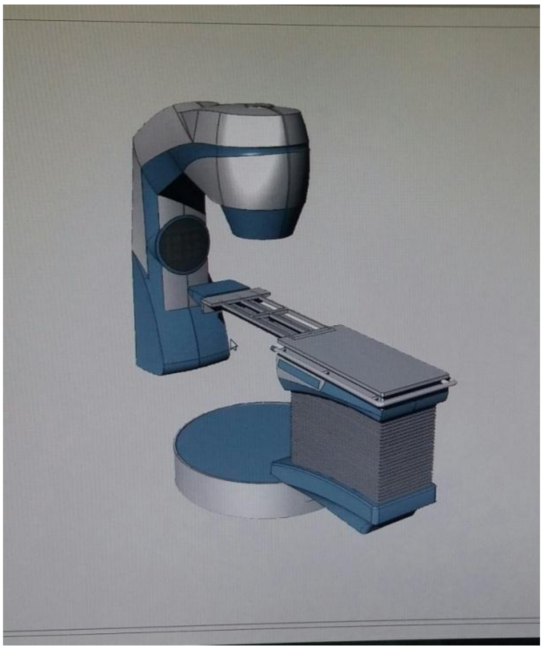
4.1.3 Determination of Hematological Parameters

The number of white blood cells, red blood cells, hemoglobin, platelet count, and hematocrit is taken from by device complete blood analysis



Image(4) of a complete blood counting and analysis device

CBC URIT 3010



Image(5) of the cobalt unit used in the treatment

Image (6) of the Caesium137 Unit

4.1.4 Calculations and graph

The arithmetic mean of blood parameters was taken for the first four groups, The results are shown in Table 1, and the graphical relationships of each parameter with time are shown in Figures 1-5, The fifth group, each of the three samples taken one dose different from the other, the results are recorded in Table 2, the graphical relationships of each parameter with the radiation dose shown in Figures 6-10.

4.2 The effect of low doses of gamma rays on living matter in different times

Table(1) The results of four groups, each group three samples, the first group is the control or control group, the second, third and fourth were exposed to radiation dose of 2.5 mGray, 7 mGray, 15 mGray respectively using the source of cesium-137 at the Atomic Energy Commission Diagrams 1 to 5 show the relationship of the change of blood parameters when exposed to different energy doses with time.There was a simple decrease in the number of white blood cells, platelet doses at 7 and 15 mGray , an simple increase at 2.5 mGray dose compared to the control sample, an simple increase in the number of Red blood cell count and hemoglobin at 2.5 and 15 mGray doses When compared with the control, The number was sample decrease at 7 mGray when compared with control we notice an increase in the proportion of hematocrit compared to the control sample.

Blood Indices	WBC $\times \mathbf{10^3} /\boldsymbol{\mu L}$	RBC $\times \mathbf{10^6} /\boldsymbol{\mu L}$	HGB g /dl	PLT $\times \mathbf{10^3} /\boldsymbol{\mu L}$	HCT %
control	7.79 ± 0.30	6.28 ± 0.42	10.2 ± 0.93	174 ± 30	25.1 % ± 0.73
$\mathbf{2.5}$ $(\boldsymbol{m\,Gray})$	8.62 ± 0.88	7.25 ± 0.65	11.73 ± 0.43	198 ± 15.33	29.13 % $\pm 1,98$
$\mathbf{7}$ $(\boldsymbol{m\,Gray})$	6.39 ± 0.78	6.24 ± 040	9.83 ± 0.24	142 ± 40.66	26.33 % ± 0.59
$\mathbf{15}$ $(\boldsymbol{m\,Gray})$	7.63 ± 0.85	6.32 ± 0.86	10.6 ± 1.066	153.66 ± 30.88	28.1 ± 2.86

Table (1)

Results of the first group, the control group, and the results of the second, third and fourth group were exposed to radiation dose of 2.5 mGray, 7 mGray and 15 mGray respectively using the cesium-137source at Atomic Energy Commissio

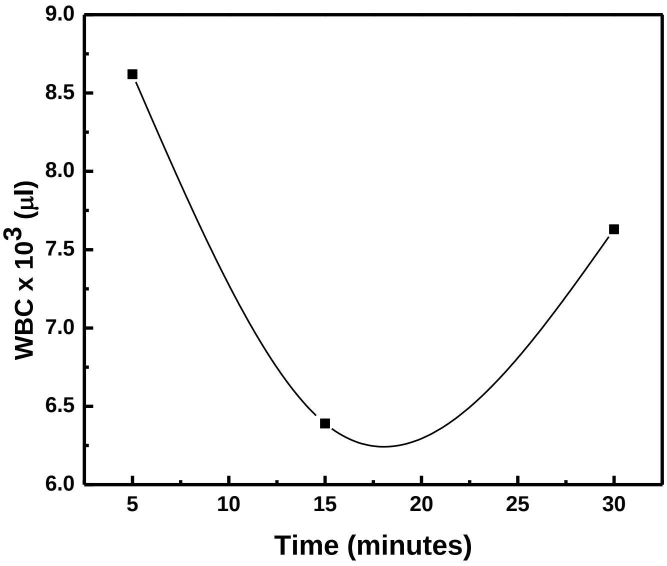


Figure (1)

The relationship between the number of white blood cells(WBC) and time

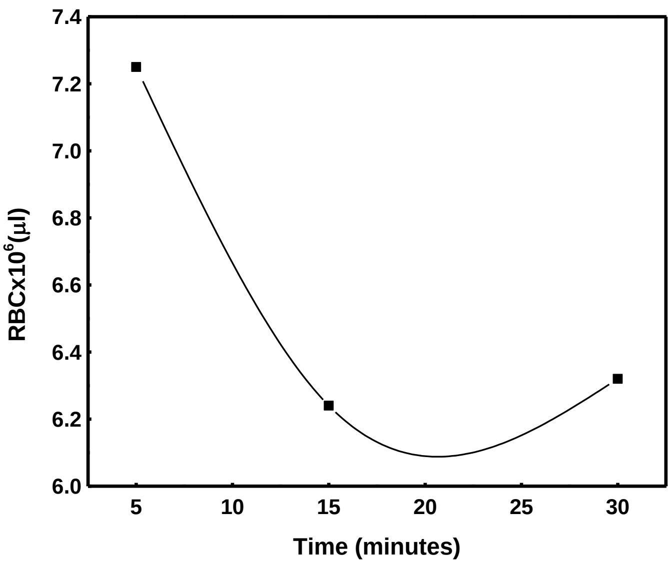


Figure (2)

The relationship between the number of red blood cells (RBC) and time

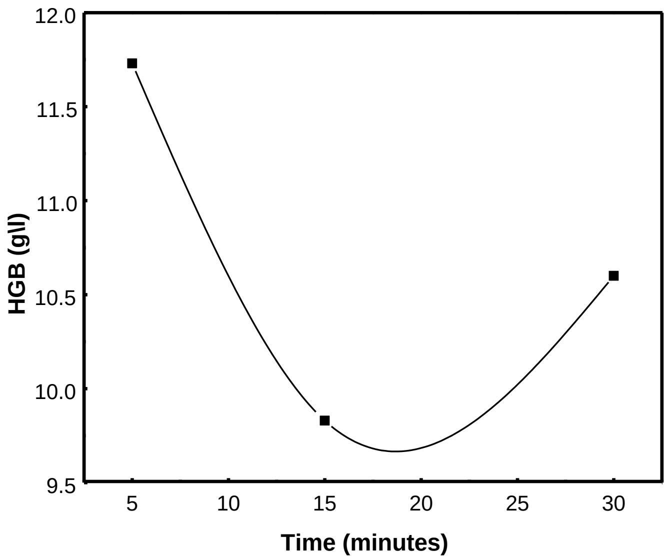


Figure (3)

The relationship between hemoglobin(HGB) and time

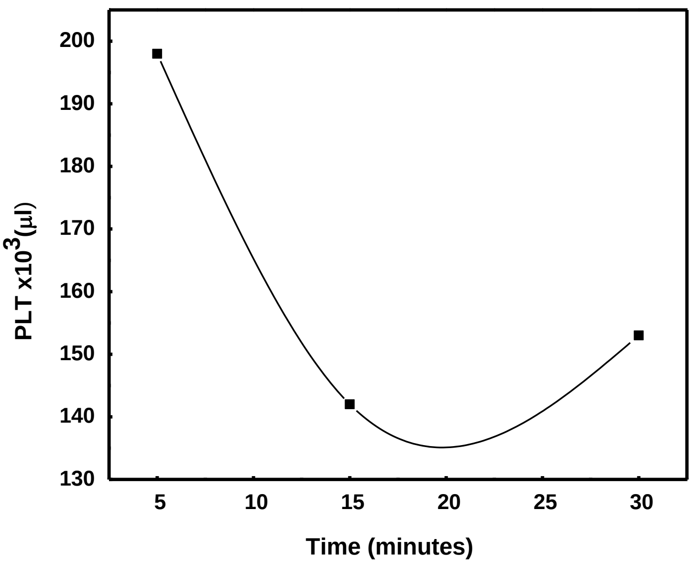


Figure (4)

The relationship between platelets (PLT) and time

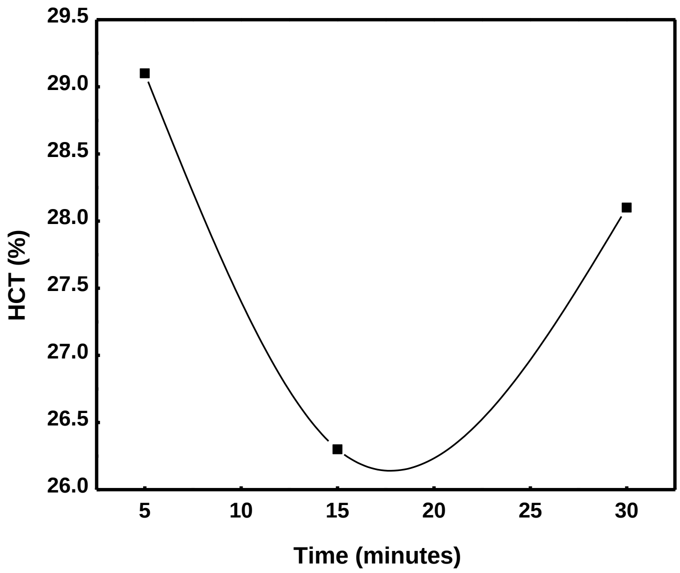


Figure (5)

The relationship between hematocrit (HCT) and time

4.3 The effect of high doses of gamma rays on living matter

Table(2)The results of the fifth group consisted of three samples, each of which was subjected to a single blood sample to a radiation dose made by 100 Gray, 200 Gray and 300 Gray, respectively, using the cobalt source Co 60 at the radiology department Khartoum teaching hospital, Graphs 6 to 10 show the relationship of the change of blood parameters when exposed to different Greater radiation energy Compared to cesium-137. Note that there is a significant reduction in the number of white blood cells at doses 100, 200, 300 Gray, compared with control, as well as platelets have a significant reduction at doses 200, 300 Gray when compared to control The number of red blood cells increased slightly at all doses compared to the control sample, Hemoglobin decreased at the dose of 100 Gray, a significant decrease at the dose of 300 Gray, and a small increase at the dose of 200 Gray, We find a decrease in the proportion of hematocrit at 300 Gray, and a small increase at 100, and 200 Gray

Blood Indices	WBC $\times 10^3 /\mu L$	RBC $\times 10^6 /\mu L$	HGB g /dl	PLT $\times 10^3 /\mu L$	HCT %
control	7.79 ± 0.30	6.28 ± 0.42	10.2 ± 0.93	174 ± 30	25.1 % ± 0.73
100 (Gray)	4.24	6.39	9.8	300	25.2%
200 (Gray)	3.86	6.48	11.6	98	31.8%
300 (Gray)	4.92	4.63	8.8	69	22.6%

Table (2)

The results of the fifth group contain three samples each one blood sample was exposed to one dose of radiation made by 100 Gray, 200 Gray and 300 Gray, respectively, using the cobalt source Co 60 at the radiology department Khartoum teaching hospital.

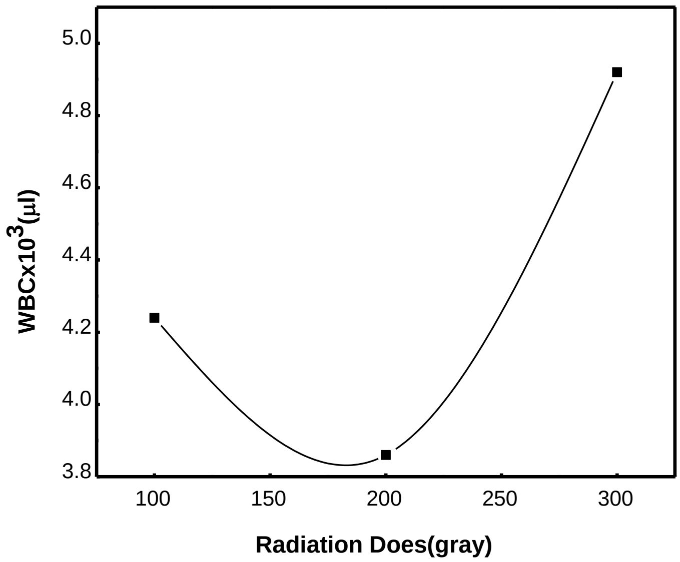


Figure (6)

The relationship between the number of white blood cells (WBC) and radiation dose

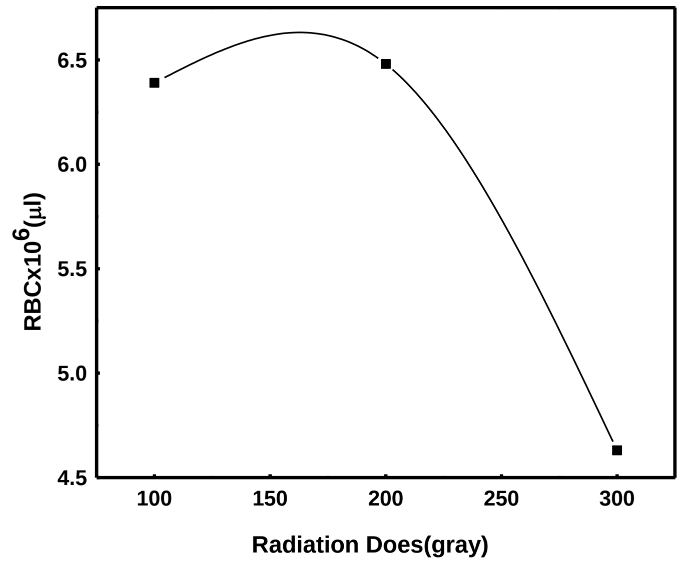


Figure (7)

The relationship between the number of red blood cells (RBC) and radiation dose

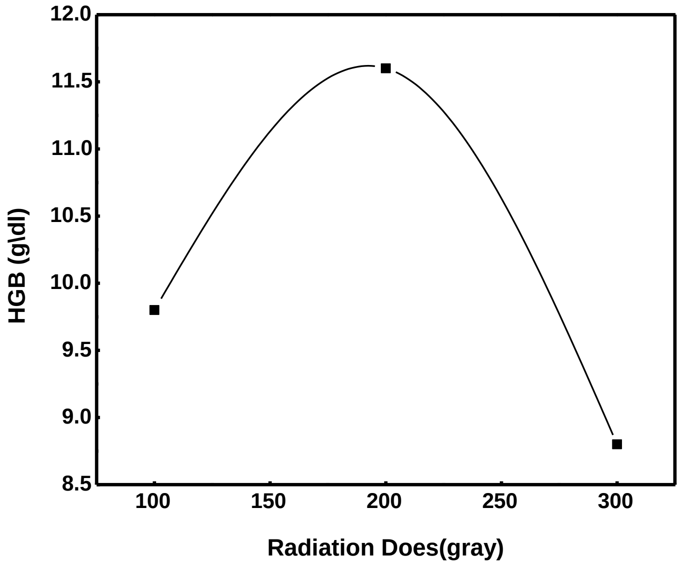


Figure (8)

The relationship between hemoglobin(HGB) and radiation dose

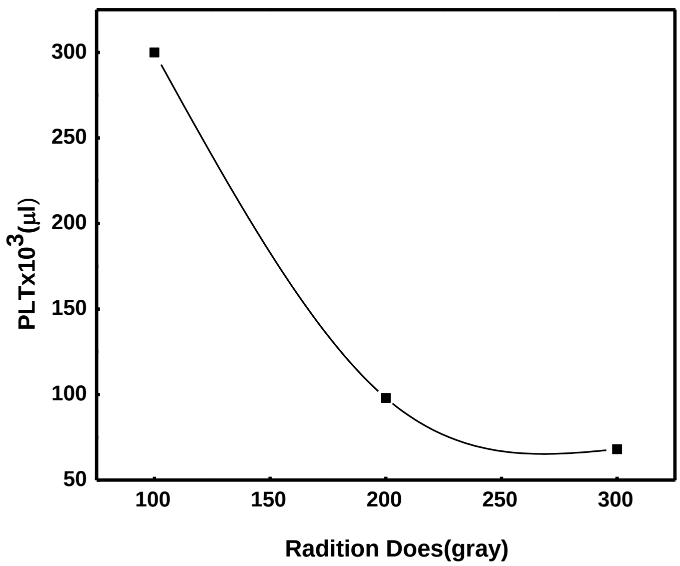


Figure (9)

The relationship between platelets (PLT) and radiation dose

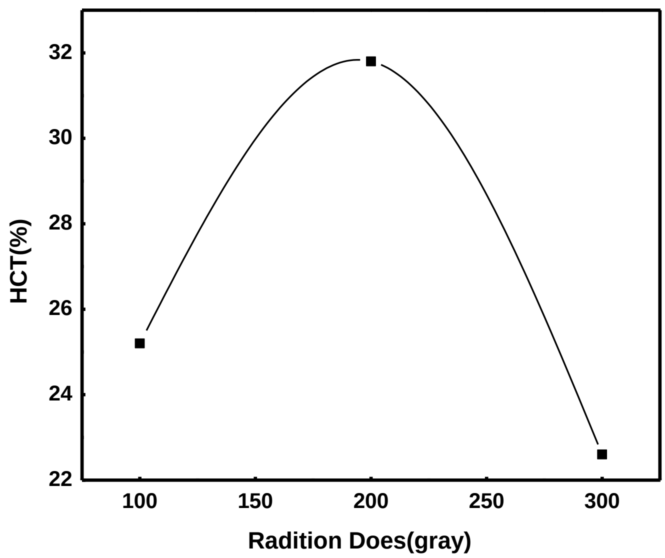


Figure (10)

The relationship between hematocrit (HCT) and radiation dose

The radiative energy of gamma is transmitted from the radioactive source to the living matter during time, At 10^{-14} seconds of the Radiation exposure process , the water atoms within the cell begin to excite and ionize, forming free radicals. Are molecules that are highly reactive to each other and with other cell components to form toxic compounds, Since water is the largest component of the cell, chemical changes occur as a result of free radical reactions caused by ionization of water molecules within the cell of the genetic material and the function of the cell and adjacent cells leading to death and decrease ,or Increase in number, The results in Table 1 and graphs 1 to 5 show that the changes in blood parameters are small compared to the control sample due to the low dose used. We also note that the small decrease in parameters was mostly associated with samples that were exposed for a longer period of time ،This change explains that the ionization that occurred in the blood cells and its components and the reason for the changes was more in the samples exposed To the radiation In longer time than others. Table 2 and graphs 6 through 10 show changes in most parameters compared to the control sample Due to the high doses and the exposure time is very small compared to the previous doses in Table (1), low white blood cell count, and platelets at doses 7 mg gray and 15 mm gray, consistent with the results of previous studies[59].Gamma irradiation also results in a decrease in the total number of white blood cells[60].observed at doses 100, 200, 300, compared with control, The increase in the release of hemoglobin from erythrocytes occurs when the number of erythrocytes increases or with a decrease, concomitant concentration in hemoglobin with increased dose[61].The hematocrit ratio decreases not only with the total number of red blood cells, In contrast, the increase in the number of red blood cells due to lack of oxygen, severe dehydration due to exposure to gamma rays and plasma volume decreases, blood viscosity increases rapidly with the increase of hematocrit, and lack of anemia index[53] This change explains that the ionization that occurred in the blood cells and its components and the reason for the changes was more in the samples that were exposed to higher doses of radiation energy than others.

Chapter 5

Recommendations& Remarks

5.1 Conclusions

This study showed that low energy gamma rays can be dangerous to some blood parameters, especially when the exposure time increases as the absorbed dose increases causing many changes in blood parameters, as well as the amount of radiation energy is a very important factor in ionizing radiation reactions with blood. The ionization of living matter due to radiation is related to the time of exposure of the material to radiation. The more time The probability is increasing of radiation ionization of living material, and increases the extent of biological damage، ionization is also related to the amount of radioactive energy, When energy increases the probability is increasing ionization of living matter, as well as the probability of biological damage.

5.2 Recommendations

- Expand the study by increasing the exposure time and the amount of radiation energy or changing the distance between the radioactive source and the target sample.

- Using an electron microscope to observe the effect of ionizing radiation on the microstructure of the living cell.

- The rats may be exposed to radiation, and then blood samples taken after exposure to radiation to study the impact of ionizing radiation on blood parameters.

-Providing more safety tools within the laboratory to prevent radiation hazards.

-Attention to the periodic maintenance of laboratory equipment.

-An importance of using the necessary means of protection, when dealing with radiation.

- Pay attention to the effect of low doses of ionizing radiation, especially for those exposed to radiation for long periods.

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