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Research Article

Advantages and disadvantages of X-rays

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ABSTRACT

Despite the fact that X-rays are used in a variety of fields, their application in medicine is of the utmost importance because of the substantial function they play in recognizing some ailments and in making therapy more accessible for others. Researchers make it their mission to make the most of every new scientific discovery by making use of the characteristics that have been uncovered by it.
In the first chapter of this investigation, the formation of these rays, as well as their primary characteristics and their location within the electromagnetic spectrum, were the primary topics of discussion.
The influence of radiation on human organs, such as the brain and the spleen, is discussed in the second chapter, which also identifies the indications that indicate possible dangerous exposure levels to the body. There is a possibility that the effects will be chemical or biological. The third chapter takes a look at the most common applications of .

1. INTRODUCTION

The wavelength of X-rays falls somewhere in the range of 0.01 to 10 nanometers, making them a component of the electromagnetic spectrum. While their wavelength is less than that of the visible spectrum, they have a higher frequency than that of the visible spectrum at ($16^{-3}\times10^{19}$ 10×3). Due of this, it falls within the spectrum that encompasses both ultraviolet light and gamma rays. On the basis of its wavelength or frequency, it may be differentiated from gamma rays. Additionally, electrons are responsible for the emission of X-rays.
Wilhelm Rontgen, a German scientist, was the first person to investigate this particular category of rays in the year 1895. However, he was not the first person to find it, since these rays were originated from Crookes tubes, which were originally developed in the year 1875.
During that period of time, they were referred to as X-rays, and later on, they were referred to as Röntgen rays. At the current day, any of these two names may be used to refer to them. In addition, in the Arabic language, they are referred to as X-rays, which is an Arabization of it. Because the letter x is often used to denote the unknown in algebraic equations, and because the rays are of an unknown nature, he decided to name them X-rays. For this reason, he termed them X-rays.[1]
The discovery of X-rays occurred in a period of less than a month, and several individuals in this industry endeavored to acquire them in order to investigate them and provide an explanation for the phenomena that they saw. [1]

2. INVESTIGATION AND ANALYSIS OF X-RAYS:

In 1895, the German physicist Roentgen inadvertently discovered rays with significant penetrating power. He designated them as X-rays. These rays are sometimes referred to as Roentgen rays, in honor of their discoverer. This finding was significant and contributed substantially to the advancement of contemporary science. Approximately three months after their discovery, these rays were used by Austrian surgeons at several hospitals in Vienna. These rays continue to be extensively used in medicine and in other domains. Roentgen received the first Nobel Prize in Physics in 1901 for this significant discovery. [1]
X-rays are a segment of the electromagnetic radiation spectrum, positioned between high-energy gamma rays and low-energy ultraviolet rays. Consequently, they are imperceptible rays, since the energy of their photons much exceeds that of visible rays, indicating a high frequency and a short wavelength.

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X-rays possess wavelengths ranging from 10^-8 cm, so their wavelengths are denoted in angstroms (Å). X-rays are generated when an electromagnetic beam interacts with a material, causing the material's molecules to absorb the X-rays, resulting in electronic transitions between energy levels within the constituent atoms, similar to the absorption of ultraviolet or visible light. [2]

X-rays are imperceptible to human senses. They are imperceptible to sight, touch, smell, taste, or sound. Their linear trajectory in a vacuum cannot be altered by conventional electric or magnetic fields. Nonetheless, they may diverge from their trajectory at the boundary between two distinct materials or upon collision with fundamental particles, such as electrons. Consequently, the rays may deviate from their trajectory when incident at an angle on crystals.

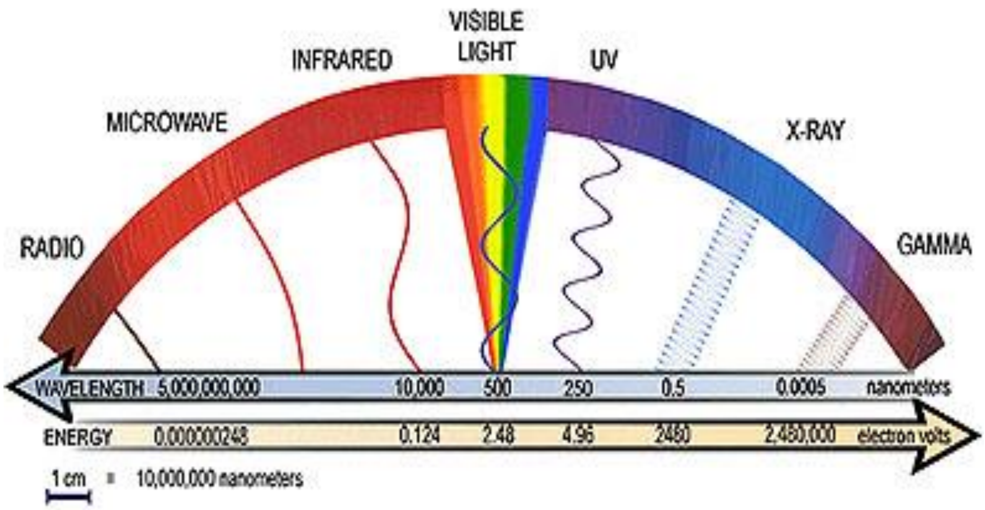

Fig .1. Electromagnetic spectrum and the location of X-rays in it

X-rays possess a dual nature, exhibiting wave characteristics in some contexts and behaving as a collection of energy particles in others, which may eject one or more electrons from certain solid materials, therefore generating an electric current. The energy of X-rays (E) is ascertained based on their wavelength by the following equation: [3]

Were:

- H: is Planck's constant
- c: speed of light in a vacuum
- λ: wavelength of X-rays

$$E = h\nu = \frac{hc}{\lambda}$$

$$E\ (eV) = \frac{1240}{\lambda\ (nm)}$$

3. MAIN CHARACTERISTICS OF X-RAYS:

- Invisible electromagnetic rays. [4]
- Can penetrate metal materials and living cells.
- Penetrate thick materials according to the intensity of the wavelength of X-rays
- Travel in straight lines
- Chemically affect photographic emulsions, therefore photographic films are used to detect the interior of objects and defects in metals after exposure to X-rays
- Ionize the gases through which they pass and are not affected by electric and magnetic fields.
- Travel at a speed of (10 * 3) raised to the power (10) cm/s.
- Release photoelectrons (photoelectrons) when they fall on an element.
- X-rays are not deflected by lenses or prisms, although they can be diffracted when they pass through a small opening. [4]
- X-rays are generated when cathode rays in a discharge tube collide with any solid object, and heavy elements such as platinum are more efficient than light elements such as aluminum.
- X-rays affect the damage of living cells.

4. X-RAY PRODUCTION:

4.1 Electricity production: [4]

X-rays are produced by the collision of fast electrons and their interaction with solid materials. Therefore, the device used to produce X-rays contains the following:

- Sustained electrical energy source: It produces a significant electrical potential difference between the tube's terminals throughout operation, contingent upon the anode being positively charged in relation to the cathode, with the potential difference reaching values in the tens of thousands of volts. The design of contemporary devices mostly relies on the attributes of the tube developed by Coolidge in 1913, which bears his name and is seen in Figure (2). This tube mostly comprises the following elements:
- A hermetically sealed glass tube: It is devoid of air and encased in a substantial lead shield, designed to absorb the majority of the produced X-rays in various directions, permitting only selective egress via a designated window in the lead barrier. The X-ray tube has the following components: The filament, a source of electrons, is a tungsten wire heated to a high temperature by electrical energy, resulting in the emission of electrons. [5]
- The cathode encases the electron source and is selected from a material with a high melting point. Its geometric configuration is engineered to direct the electrons from the source towards the target (anode) in a tight beam, therefore minimizing their dispersion inside the tube.
- The anode, referred to as the target material, must possess a high atomic number; tungsten, with an atomic number of 74 and a melting point of 3422°C, is typically employed in industrial applications and radiology. Molybdenum or rhodium is utilized in breast diagnostic devices, such as mammograms. [5]

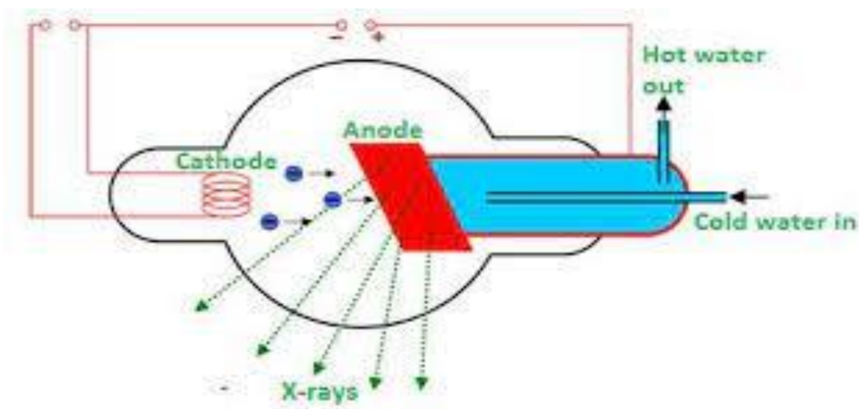

Fig .2. Basic x-ray production process.

4.2 High frequency machines:

We have previously mentioned the necessity of having a cathode permanently charged with a negative charge, and an anode also charged with a positive charge. It is therefore not possible to use alternating current, as the nature of the tube poles changes many times per second (50 or 60 times per second) >

On the other hand, a high frequency must be obtained, which cannot be obtained by connecting the tube poles to a battery or a reasonable number of batteries. Therefore, the users of X-rays in the period following their discovery thought of using an induction machine with direct current after equipping it with a device to cut off the electricity and connect it many times. [5]

5. MEASURING THE INTENSITY OF X-RAYS:

The X-ray beam is determined by two factors: the first is quantitative, which is the intensity of the beam, and the second is qualitative and relates to the spectral distribution of the intensity of the rays, i.e. the energy. The intensity is the amount of energy carried by a certain radiation per second and through a unit of measurement of an area located in a plane perpendicular to the straight path of the rays. We will define the unit of measurement later.

In some cases, it may be difficult to measure this intensity directly, so scientists usually measure it indirectly in most measurements, i.e. by measuring the results of the penetration of X-rays into the material. Thus, after linking the intensity of the beam to the physical, chemical or biological effects, it is indicated to determine the methods of measurement. [5]

5.1 Thermal technique:

When an X-ray beam interacts with a metal item that permits almost perfect absorption (97% or more), the absorbed energy is transformed into heat energy. The outcome is a rise in the metal's temperature. This technique has been precisely used in several measures pertaining to X-rays, including:

- Quantifying the energy intensity of the X-ray beam. ● Analyzing the energy distribution within the X-ray spectrum.
- Assessing the variation in beam intensity corresponding to changes in the frequency voltage supplied to the X-ray tube
- Quantifying the correlation between the energy emitted by the X-ray tube and the electrical energy supplied to it.

5.2 Ionization:

When X-rays traverse a certain atmosphere, they eject electrons from some molecules with substantial kinetic energy, making it challenging for the molecules to reabsorb them. The infiltration of these electrons into the gas results in the degradation of some molecules and their dissociation into negative and positive ions. The energy required to disintegrate the molecule is derived from the kinetic energy of the electron, resulting in a reduction of the latter's value and therefore allowing for the potential reabsorption of the electron by one of the ions present in the gas. The high frequency voltage must be elevated and enough to attract all the ions generated by the X-rays in the gas. It is essential to implement sufficient precautions to prevent X-rays from impacting the metals of the poles, as exposure to X-ray beams will liberate electrons with kinetic energy, potentially leading to the ionization of gas and introducing errors into the measurements. They have successfully created gas-filled tubes including a cathode and an anode. The cathode has a cylindrical configuration, whereas the anode is a metallic strip situated along the axis of the cylinder. Three categories may be derived based on the frequency voltage given to the poles: [6]

- Ionization tube: a meter functioning at a low voltage of under 200 volts.
- Relative meter: a meter operating at a medium voltage frequency (below one thousand volts).
- Geiger counter: a device that functions at high voltage.

6. TYPES OF X-RAYS:

1. First: White X-rays or the uninterrupted spectrum. The word white here does not mean the color white, but rather means that this spectrum contains X-rays of different frequencies and wavelengths. That is, we find in this spectrum all the waves that can be imagined within two lower or higher limits of wavelength.
2. Second: X-rays specific to each metal, which are composed of several lights, each of which has a single wavelength, gathered in several groups. The wavelength of each light is related, according to a law that we will see later, to the atomic number of the material element that generated it. The "white spectrum" can be obtained by subjecting the X-ray tube to a relatively low frequency. [5]

7. EXPOSURE TO RADIATION:

Prolonged exposure to radiation may result in consequences that manifest clinically in individuals immediately after exposure, including nausea or erythema, and in extreme instances, acute symptoms. These effects are termed "deterministic effects" since they occur unavoidably when the dosage beyond the threshold level. Radiation may have physical consequences, including malignant tumors that manifest after a certain duration and can be identified in populations by epidemiological approaches. This is presumed to transpire over the whole spectrum of dosages without a threshold level. Genetic changes resulting from radiation exposure have been shown in other species and are presumed to occur in humans as well . The impacts identifiable using epidemiological techniques, such as malignant tumors and genetic influences, are referred to as random effects. Conclusive effects arise from many mechanisms, namely cell death and postponed cell division owing to exposure to elevated radiation levels. Concentrated radiation may impair the functionality of the exposed tissue. The intensity of the decisive impact in the exposed person escalates as the dosage above the threshold level for its manifestation. Random consequences may manifest if a mutation arises in the irradiated cell without resulting in its demise [6] . Mutated cells may arise over an extended period, and one might envision the emergence of diverse genetic consequences in the progeny of the individual subjected to radiation.

7.1 Effects of the chemical stage:

The use of X-rays in chemistry is now limited to two specific fields. The first field is related to the use of X-rays for the purpose of examining the composition of a substance without causing any changes in it, specifically as a means of chemical analysis with the aim of achieving success. Without changing the inherent properties of the substance by inducing chemical processes. The second part is related to the interaction between X-rays and the substance, which leads to changes in its chemical composition. The silver salt present in the sensitive plate, which is intended for imaging purposes, undergoes changes when exposed to the X-ray beam [6] . The importance of studying the chemical effects emerged after the atomic bombs were dropped on Japan in 1945 at the end of World War II after the deadly biological effects of atomic radiation appeared. Knowing these effects is important for every person on Earth. Since that time, some governments have begun to direct scientific research in this direction in order to provide every citizen with a small and easy-to-use device capable of providing information about the intensity of radiation in a specific place.

Because of the relatively high amount of energy carried by the X-ray photon, the chemical reactions generated by traditional rays differ fundamentally from those caused by X-rays. When a photon hits a substance, the substance absorbs the photon. Therefore, the absorption of a photon comes before any physical or chemical event that occurs in the substance. As we have seen, the absorption of the energy of a photon can sometimes lead to the ionization of an atom, which is the removal of one electron from an atom. [6]

In contrast to the gradual absorption of the energy carried by a (large) X-ray photon, the energy carried by a normal X-ray photon is absorbed all at once, which places the molecule in a higher energy level. Using conventional radiation of a single wavelength results in a large number of molecules occupying the same high energy level, but using X-rays results in multiple high energy levels due to the difference in energy absorption between molecules.

The excited molecules undergo a chain reaction, as in the case of chloroform, which leads to the formation of chloroform, which in turn produces chloroformic acid. The importance of X-ray reactions in water lies in their profound implications for understanding the biological effects of X-rays. Exposing water containing oxygen gas to an X-ray beam results in the formation of oxidized water.

7.2 Impacts of the biological phase:

- The comparative biological impact: Ionizing radiation, such as gamma rays, X-rays, beta rays, alpha rays, and neutrons, can ionize matter and have different biological effects on the body from the same dose. It represents the ratio of the absorbed dose of gamma radiation at a certain energy to the absorbed dose of the other type of radiation so that their biological effects are the same and the relative biological effects of any type of radiation vary with energy and human organ. Two kinds of X-ray radiation poisoning exist: [7]

1. First: Acute poisoning: - This type of poisoning usually occurs in sudden nuclear explosions or radiation leakage from nuclear reactors. The following symptoms occur: -
   a. Nausea and vomiting.
   b. Redness of the skin and the appearance of burns similar to second-degree burns and serous blisters.
   c. Weight loss, loss of appetite and lack of concentration.
   d. Inhibition of the functions of the bone marrow that produces red blood cells and platelets, which leads to loss of appetite, inflammation of the mucous membranes, the appearance of bleeding spots under the skin, ulcers in the nose and mouth, hair loss, bloody vomiting and diarrhea, and severe internal bleeding may occur that threatens the patient's life.
2. Chronic poisoning: - This type occurs when exposed to radiation in small doses for long periods, as happens to radiologists, those dealing with radioactive elements, and those living in radioactively contaminated areas. Symptoms appear after a long period of exposure and affect various body systems depending on the nature of the tissues and the dose. The following symptoms occur: -[7]
   1- Severe anemia and a decrease in the number of white blood cells, which reduces the body's immunity to diseases.
   2- A decrease in the number of platelets, which makes the patient susceptible to bleeding.
   3- The incidence of leukemia increases.
   4- Recurrent pneumonia occurs, leading to pulmonary fibrosis and then lung cancer.
   5- Skin atrophy occurs, its color changes, ulcers and cracks occur, fingerprints are destroyed, and tumors of all kinds appear on the skin.
   6- A deficiency in calcium deposition occurs in the bones, which causes osteoporosis
   7- It is exposed to fractures and may cause bone cancer
   8- Infertility occurs in men and women, miscarriage of pregnant women, and fetal deformities.

9- The lens of the eye is affected by what is known as cataracts. The effects of genes affect men and women of childbearing age, leading to the birth of deformed children. The type of effects that the body is exposed to are divided into random and non-random effects, .

7.3 Effect of X-rays on the bone marrow

When the whole body is exposed to a radiation dose of the level of the lethal dose for a period of half an hour, we find the following changes in the body:

1. Cessation of division in bone marrow cells.
2. Increase in the number of fully developed red blood cells and a decrease in the number of red blood cells containing nuclides and immature ones in the blood fluid.
3. A clear increase in the number of atrophied red blood cells in the bone marrow.
4. A slight decrease in the number of granulocytes.
5. The bone marrow becomes filled with a gelatinous substance that replaces the cells that have been destroyed.

7.4 Impact of radiation on lymph nodes: [8]

The lymph node tissue cells exhibit considerable variability in their radiation sensitivity, resulting in a progressive cessation of glandular function. Radiation alters their composition; yet, the lymphatic fluid flow persists. Within three weeks of radiation treatment, lymphocytes start formation in the adjacent cortical region, and after four months, their levels recover to baseline. Exposure to radiation dosages results in cellular destruction and alteration.

7.5 Impact of radiation on the spleen:

Exposure to radiation results in the destruction and severe shrinkage of spleen cells, adversely affecting the spleen's functions related to red blood cell storage, flow rate, erythropoiesis, iron storage, and the production of harmful antibodies. [8]

7.6 The impact of radiation on blood constituents:

The impact of radiation on blood components is contingent upon three factors: the degree of radiation's influence on the tissues responsible for blood cell production and the susceptibility of those cells to radiation.

- The degree of proliferation and differentiation of hematopoietic cells.
- The age of the cells suspended in the blood plasma
- The impact of radiation on white blood cell components in the bloodstream stabilizes at a typical rate of 4000 cells per cubic millimeter, with the effects contingent upon the exposure dosage and the specific cell types affected. Upon exposure to a non-lethal radiation dosage, the whole body experiences an instantaneous although transient decrease in white blood cell count, followed by a subsequent rise within a few hours. This is subsequently succeeded by a pronounced decline on the second day of exposure. It is important to note that not all leukocytes are impacted by radiation at the same rate. Red blood cells, similar to other blood components suspended in plasma, are cells that withstand direct radiation damage. Their age is 120 days, and the daily cell turnover rate is 83%. Exposure to radiation doses utilized in treatment results in a gradual decrease in red blood cells, while doses exceeding those employed in radiation therapy enhance the capacity to permeate the blood vessel wall, facilitating the exit of red blood cells from the bloodstream and their subsequent degradation outside the vessel.

8. X-RAY APPLICATIONS:

X-ray applications are many and varied, but the most common application of X-rays used is X-ray radiography. In addition to medicine, these rays play an important role in industry to study the crystal structure of different materials and also to know the thickness of some materials or detect defects in them. They are used in aviation, for example, to detect defects in important parts of aircraft before using them to ensure safe flight and prevent accidents that could have occurred had such defects not been addressed. The following are some of these applications. [8]

8.1 investigation of the crystalline structure of substances:

X-ray crystallography is a technique used to elucidate the atomic arrangement inside crystals by directing X-rays at the crystal, which are then scattered in several precise directions. The X-ray diffraction apparatus generates a three-dimensional representation of atomic density inside the crystal, determined by the angles and intensity of the deflected rays.

The X-ray wavelengths used must range from 1.0 to 10 angstroms, since they need to be equal to or shorter than the interatomic distances, which average around 1 angstrom in the solid state.

8.2 In the medical field:

Medical radiography is utilized in medicine to identify dental and skeletal fractures, ascertain the positions of solid foreign objects such as shrapnel or bullets within the body, and detect tumors. These rays enable the precise visualization of bone fractures due to their ability to penetrate soft tissues like skin while being obstructed by bones, resulting in the depicted image in Figure 3. Radiography has become an essential method for identifying the location of contaminants inside the human body, with several applications evident since its integration into routine clinical and hospital practices. To see the digestive system, it must be transformed into an opaque entity that obstructs the transmission of rays, hence generating disparities in the absorp tion coefficient between various points. The same is true for imaging the gallbladder, bronchi, kidneys, uterus, liver, arteries, and veins. The opaque material varies depending on the anatomical structure being photographed, as the substance used for kidney imaging differs from that employed for stomach or intestinal imaging. The selection of this opaque material has evolved into a specialized discipline necessitating sophisticated approaches in some instances. This category encompasses spinal cord imaging, vascular imaging, lymphatic imaging, cardiac imaging, and renal imaging. [8]

Fig .3. Fracture of the fifth metatarsal bone of the hand near the joint

8.3 Dental and molar x-rays:

Individuals place significant emphasis on the health and aesthetics of their teeth due to both cosmetic factors and the crucial function of the mouth in supplying essential nutrients for bodily development. To preserve dental health, individuals must confront many ailments impacting the oral cavity and teeth, including gum abscesses, dental caries, and calcium deficiencies [7]. Dentists now use x-rays to scan the damaged region for the diagnosis of various disorders. This diagnostic outcome enables the physician to choose the optimal course of action for achieving the greatest outcomes. X-rays often assist the treating physician in determining the requirement of molar extraction or the feasibility of preserving it once the afflicted area has been excavated and filled with specialized, non-toxic solid materials. Figure (4) displays x-rays of many adult molars and teeth. [8]

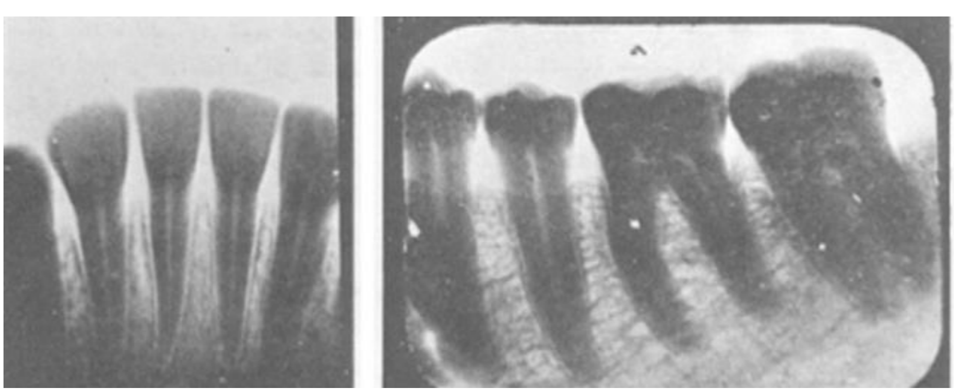

Fig .4. A picture representing teeth taken by X-ray.

8.4 X-ray therapy:

X-rays can be used to treat diseases if this treatment is done by obtaining the following phenomena:

- Inhibiting the activity of glands and cells, especially glandular cells, and those that are preparing to divide, in other words, inhibiting the activity of glands that are highly affected by X-rays, for example, by treating some skin diseases caused by high activity in the glands and reducing the severity of infections such as chest infections, for example.
- Healing gas gangrene, because X-rays help in the formation of oxygenated water or some substances that contribute to healing.
- Treating various internal infections. There was a period of time when X-rays were used to treat all imaginable diseases, meningitis, polio, asthma, severe cough, tonsillitis, excessive insulin secretion, and leukemia. [5]
- Killing and destroying malignant tumors, and nuclear radiation has begun to replace X-rays in this field. A general study of forty types of X-ray therapy for ninety cases of internal diseases showed that the results ranged from complete recovery to no change in the condition of the disease.

8.5 X-rays and Oncology:

Comparisons between the contributions of X-rays and those of other sciences are inadequate when evaluating the role of X-rays in cancer treatment. Treatment with X-rays or gamma rays has successfully saved the lives of tens of thousands and alleviated the suffering of those diagnosed with cancer after a certain duration post-onset. Despite this, cancer continues to be a predominant enigma in the minds of many medical professionals. In the domain of X-ray therapy, a differentiation must be established between two critical phases:

1- Locally excising malignant tissue and thereafter cleaning the damaged region by removing the debris of the necrotic cells following their destruction with radiation. [5]

2- Restoring the affected tissue by replacing necrotic cells with healthy cells that migrate to repair a wound or that have been damaged by X-rays, cancer, and its poisons. Diseased cells have more sensitivity to X-rays than normal cells, enabling the eradication of a malignant tumor while preserving the adjacent normal cells. Nonetheless, therapy cannot be completed without inflicting damage to healthy tissue. This presents a novel designation for X-ray treatment, which is based not on the efficacy of the dosage in eradicating the malignant tumor, but rather on the resilience of healthy cells to the dosage administered to the afflicted organ or region. Some research is being conducted to determine whether the dose should be given all at once or in batches, and whether the effectiveness is related to the wavelength used or the value of the high frequency directed at the two ends of the X-ray tube.

8.6 Military domain:

Identifying mines several meters subterranean and locating assailants inside structures without jeopardizing life. Significant uses exist in catastrophe scenarios for detecting individuals trapped beneath debris or during a fire. X-rays are used at airports and public venues to inspect luggage for the presence of guns, explosives, or other questionable items. [8]

9. RECOMMENDATIONS

The process of removing electrons from certain atoms of a material and the ensuing ionization of its component molecules, resulting in the substance's breakdown and imbalance, has been previously documented in connection with X-ray absorption. This event results in the degradation of the material and the disruption of its equilibrium, posing substantial hazards to human health upon exposure to X-rays.

This danger has compelled researchers to devise strategies to safeguard the physical safety of workers in a domain necessitating the use of an X-ray generator. The laws regulating X-ray absorption by a substance enable the calculation of the material thickness required to shield the human body from the possible hazards of X-rays, including severe physiological effects such as anemia or burns. Lead has been recognized as the most efficient substance for X-ray absorption to provide excellent protection. Ensuring adequate protection against X-rays is a vital consideration when acquiring or deploying an X-ray equipment.

Individuals using an X-ray machine should refrain from extended exposure to the operation room, since the X-ray radiation may result in anemia or burns. The penetration of the X-ray beam ionizes the air, resulting in secondary reactions that may minimally impact the human body. The human body can endure around 0.5 x-rays each week without experiencing adverse effects. A weekly dosage of 1.5 x-rays is permissible when just the hands and feet are exposed. Health specialists believe that just one-tenth of this quantity may be tolerated without incurring detrimental consequences.

10. CONCLUSION

The primary function of the x-ray tube is to convert accelerated electrons into usable radiation beams. This generates both bremsstrahlung and conventional x-rays. X-ray generation is a very inefficient process, and the generated heat regulates both system components and the tube. The primary components of an X-ray machine are the cathode, anode, rotor, spinning stator, and tube assembly. These factors affect the characteristics of the X-ray beam, such as the energy spectrum and the effective focal spot size. Tubes designed for swift exposure in cardiovascular or vascular imaging, as well as tubes segmented for various targets and filtering products used in cancer screening, are essential components in x-ray tubing design.

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Conflicts of Interest:

The authors declare that they have no conflicts of interest.

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