

THE HISTORY OF THE DEVELOPMENT OF KNOWLEDGE ON IONIZING RADIATION AND ITS APPLICATIONS

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Abstract: *Ionizing radiation refers to high-energy electromagnetic or particle radiation that has the ability to completely eject electrons from atoms or molecules, thus ionizing them. These radiations, depending on whether they originate from natural sources or are artificially produced, are utilized in numerous scientific and technological fields. The discovery of ionizing radiation and its development for various applications have provided humanity with new opportunities, leading to positive changes in crucial sectors such as medicine, industry, ecology, and safety.*

Furthermore, ionizing radiation has biological effects and, if used incorrectly or with excessive exposure, can harm human health. Therefore, ensuring safety when working with these radiations and developing both scientific and practical knowledge is crucial. Today, new and innovative methods of utilizing ionizing radiation are being explored, with ongoing scientific research aimed at improving its effectiveness and ensuring its safety.

This article discusses the study of ionizing radiation, its potential applications, and the associated risks, as well as the scientific research conducted in this field and the prospects for future development.

Keywords: *ionizing radiation, medicine, industry, innovative methods, X-rays, gamma rays, ultraviolet radiation, radioactive decay, nuclear reactors, cosmic rays.*

INTRODUCTION

Ionizing radiation consists of high-energy, short-wavelength rays in the electromagnetic spectrum that produce an ionization effect. Ionizing radiation has the ability to impart energy to substances, ionizing them by ejecting electrons.

Ionizing radiation refers to processes associated with high-energy rays that have the ability to ionize atoms and molecules, such as X-rays, gamma rays, and particle radiation (alpha, beta, and protons). These radiations affect the structure of materials by ionizing them and altering their energy levels. Studying the effects of ionizing radiation on materials is particularly important for materials used in high-energy devices.

Types of ionizing radiation

Gamma rays - are a form of electromagnetic radiation with very high energy. They have the shortest wavelength and the highest frequency, making them even more powerful than X-rays.

The main characteristics of gamma rays are as follows:

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Wavelength and frequency: Gamma rays have an extremely short wavelength, ranging from approximately 10^{-12} to 10^{-16} meters. They have a shorter wavelength than ultraviolet rays and X-rays. Their frequency can be as high as 10^{19} Hz or even higher.

Energy: Gamma rays possess very high energy, with photon energies often exceeding 100 keV (kiloelectronvolts). When interacting with matter, they cause a high level of ionization.

Their sources:

Natural sources: Gamma rays naturally occur in nuclear reactions, cosmic radiation, solar studies, and other astronomical events. For example, supernova explosions and the unique processes of black holes can serve as sources of gamma rays.

Artificial sources: Gamma rays can also be produced in nuclear reactors or during the explosion of nuclear weapons.

Applications of gamma rays in medicine and industry:

In Medicine: Gamma rays, similar to X-rays but with higher energy, are used in the field of oncology. They are applied in the treatment of cancer (radiotherapy).

In Industry: Gamma rays are used to inspect the quality of materials, enhance reliability, and in certain fields such as safety or measuring radiation levels.

The risks of gamma rays: Gamma rays are a form of ionizing radiation, meaning they can strike atoms and molecules, knocking electrons out of them and ionizing them. This, in turn, can damage the DNA structure of cells, leading to tumor formation and other harmful effects.

X-rays (or X-radiation) - X-rays are a type of electromagnetic radiation, with wavelengths shorter than ultraviolet rays but longer than gamma rays. They are widely used in various fields, including medicine, industry, and scientific research.

The main characteristics of X-rays:

Wavelength and frequency: The wavelength of X-rays ranges from 0.01 nm (nanometer) to 10 nm, with a frequency range of 10^{16} Hz to 10^{18} Hz. Their energy can vary from 100 eV (electron volts) to 100 keV (kiloelectron volts), making them less energetic than gamma rays.

History: X-rays were discovered in 1895 by the German scientist Wilhelm Röntgen. He named his discovery "X-rays" because they were a new and unknown form of radiation. This discovery was made on November 8, 1895, and led to Röntgen being awarded the Nobel Prize in Physics in 1901.

Their sources:

Natural sources: Some X-rays can originate from space, such as cosmic radiation, and from the Sun. However, they are not very powerful.

Artificial sources: The main source of X-rays is X-ray machines (X-ray tubes), where high-energy electrons strike special materials to produce X-rays. This process is called Bremsstrahlung (the emission of electromagnetic radiation by accelerated charged particles).

X-rays in medicine: X-rays are one of the most commonly used forms of ionizing radiation in medicine. They are used to examine the internal structures of the human body, such as bones, organs, and tissues, and are widely applied in imaging (X-ray images).

Radiography – Used to examine bones and other structures.

Computed Tomography (CT) – A method of obtaining high-precision 3D images based on X-ray images taken from multiple angles.

X-ray Therapy – X-rays are used in the treatment of cancer, a process known as "radiotherapy".

X-rays in industry: X-rays can be used to detect hidden defects in materials. For example, they are applied in the inspection of airplane parts or pipes.

In a method called industrial radiography, X-ray images are used to identify internal defects in materials.

Risks of X-rays: X-rays are a type of ionizing radiation, and they can ionize and alter the cells of living organisms, potentially causing mutations. Therefore, they should be used with caution and within controlled limits. Prolonged exposure to high doses of X-rays can lead to cancer or other health problems. For this reason, safety precautions are necessary when using X-rays.

Ultraviolet rays (UV rays) - these rays form the high-energy part of the electromagnetic spectrum that is invisible to the human eye. They lie between blue and violet light but have much less energy than X-rays and gamma rays.

The main characteristics of ultraviolet rays:

Wavelength and frequency: The wavelength of ultraviolet rays ranges from 10 nm to 400 nm. Their frequency ranges from 7.5×10^{14} Hz to 3×10^{16} Hz. The wavelength of ultraviolet rays is shorter than that of blue and violet light, but much longer than that of X-rays.

Ultraviolet rays are divided into the following categories:

UV-A (315–400 nm): This wavelength range is the longest and has the lowest energy. UV-A rays often penetrate the skin, causing long-term effects, and can harm the eyes.

UV-B (280–315 nm): These rays are stronger and can cause ionization processes in the upper layers of the skin (epidermis). UV-B rays are among the most dangerous rays from the Sun.

UV-C (100–280 nm): These rays have the highest energy, but they are rarely encountered in the environment because they are completely absorbed by the ozone layer. Their harmful effects are mainly observed under laboratory conditions or with artificial sources.

Sources of ultraviolet rays:

The Sun – The Sun is the primary source of UV rays. The UV rays emitted by the Sun can affect the environment, but the presence of the ozone layer ensures that they do not cause excessive harm.

Artificial Sources – Ultraviolet rays can also be artificially generated using special lamps, UV devices, or lasers. These sources are used in medicine and industry, for example, in skin treatment, sterilization, or disinfecting liquids.

Biological effects of ultraviolet rays:

Effect on the Skin: UV-B rays can alter the DNA structure of skin cells, leading to mutations. These processes may result in the development of cancer, such as skin cancer. UV-A rays, on the other hand, reduce collagen in the skin, which accelerates the aging process of the skin.

Effect on the Eyes: The intense impact of ultraviolet rays can damage the transparent parts of the eye, such as the cornea. Long-term exposure to UV-A rays can lead to cataracts (changes in the lens) and a decline in vision.

Effect on the Immune System: Prolonged exposure to UV rays can weaken the immune system's function.

Effects of ionizing radiation

Biological Effects: Ionizing radiation can damage biological cells. They can harm DNA, leading to mutations or the development of cancer.

Physical Effects: Ionizing radiation interacts with materials, potentially causing new chemical reactions and changes.

History of the development of initial knowledge on ionizing radiation and its applications⁶⁷: The history of the development of early knowledge about ionizing radiation and its effects holds a very important place in the history of science. These rays were first discovered at the end of the 19th century and the beginning of the 20th century, and later, they began to be widely used in scientific research and practice.

Discovery of ionizing radiation: In 1895, Wilhelm Conrad Roentgen discovered X-rays. During his experiments, he found that when an electric current passed through a vacuum tube, it emitted unknown rays that could pass through materials and create the ability to see objects like wood. He referred to these rays as "X-rays." Later, they came to be known as X-rays. This discovery laid the foundation for the development of the radiographic method in medicine.

The scientific discovery of ionizing radiation and its initial study began with the discovery of X-rays by Wilhelm Conrad Roentgen. X-rays soon found applications in medicine as they allowed for the visualization of the internal structure of bones. However, this discovery did not only lead to advancements in medicine; it also brought about significant breakthroughs in other areas of science.

In 1896, Henri Becquerel discovered the phenomenon of radioactivity. While studying uranium salts, he found that they emitted radiation on their own. Later, Marie Curie and Pierre Curie further investigated this phenomenon and discovered new radioactive elements such as radon and polonium.

At the end of the 19th century and the beginning of the 20th century, research on X-rays and the phenomenon of radioactivity advanced rapidly. In 1899, Ernest Rutherford identified the distinct characteristics of radioactive radiation and classified

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them into alpha, beta, and gamma rays. This classification marked the initial stage of a detailed study of ionizing radiation.

In the early 1900s, several studies on the biological effects of ionizing radiation began. During this period, ionizing radiation was first used in medicine. X-ray imaging of bones started, marking the beginning of the use of radiography in medical diagnostics.

In 1913, Max von Laue used X-rays to study the crystal structure of materials, opening a new direction in physics.

During the 1920s and 1930s, methods for using X-rays in medical diagnostics and treatment were developed.

Radiotherapy—the first experimental use of ionizing radiation to treat cancer—also emerged during this period.

In the 1930s, research on the effects of X-rays and gamma rays on biological tissues expanded. It was during this time that initial scientific understanding of the potential risks and hazards of using ionizing radiation began to emerge.

In the Soviet Union, particularly during the 1920s to 1950s, extensive research was conducted on radioactivity and ionizing radiation. The works of scientists such as Henri Becquerel and Marie Curie expanded scientific knowledge about ionizing radiation and its biological and physical effects. During the Soviet era, these scientific studies and practical developments began to advance in the fields of radiology and radiotherapy in Uzbekistan.

In the 1940s and 1950s, atomic energy and nuclear research experienced significant growth. To understand the principles of nuclear reactor operation, knowledge of how ionizing radiation works was crucial. At the same time, the development of nuclear weapons marked the beginning of a new phase in the study of ionizing radiation.

From the 1950s onwards, the use of ionizing radiation expanded into other fields, such as industry, archaeology (carbon dating), ecology, and materials science, leading to innovative applications and technological progress in these areas.

By the mid-20th century, scientific understanding of ionizing radiation became more refined. Scientists like Niels Bohr and Erwin Schrödinger made significant breakthroughs in studying the atomic structure and its energy states. Ionizing radiation affects atomic structures by ejecting electrons from atoms, a process known as ionization. These scientific concepts helped advance our understanding of ionizing radiation and its biological effects.

Ionizing particles such as gamma rays and alpha particles were studied more deeply in the mid-20th century. These rays began to be applied in fields like radiology, architecture, technology, and many others.

In the 1960s and 1970s, a number of scientific studies and legislative measures were introduced to examine the harmful effects of ionizing radiation and ensure its safe use. During this period, safety standards for ionizing radiation in nuclear power plants were also established to protect workers and the environment.

In the 1990s and beyond, scientific research expanded significantly in the fields of ecology and healthcare, particularly focusing on the issues of radiation pollution and its effects. Studies on the environmental impact of radiation, as well as its effects on human health, became more widespread.

The use of ionizing radiation in radiotherapy and radiodiagnostics further expanded. By the end of the 20th century, radiotherapy methods had advanced, and precise, effective treatment methods using X-rays and gamma rays were developed for cancer treatment. At the same time, new technologies such as computed tomography (CT) and magnetic resonance imaging (MRI) became widely used in medicine. Despite the growing use of these advanced imaging techniques, the beneficial effects of ionizing radiation remained important, particularly in specific medical applications.

At the end of the 20th century and the beginning of the 21st century, new safety standards for the use of ionizing radiation were developed. The International Atomic Energy Agency (IAEA) and other organizations established radiation protection standards and began playing a significant role in ensuring safety when working with ionizing radiation. At the same time, scientific research on radiation risk assessment and protection expanded.

Environmental risks associated with the use of ionizing radiation also emerged as important concerns. By the 21st century, technologies aimed at reducing radiation risks and controlling ecological impacts were developed. New methods for managing nuclear waste and minimizing the environmental effects of radiation were introduced, reflecting the increasing awareness of the need for both safety and sustainability in radiation-related fields.

The more precise use of ionizing radiation in medicine has been greatly enhanced by the development of new technologies in radiotherapy and diagnostics. Approaches such as proton therapy and intensified radiotherapy have emerged as advanced methods. These techniques provide more accurate and effective ways to treat cancer by delivering radiation in a targeted manner, which reduces damage to healthy surrounding tissues.

Proton therapy uses protons rather than conventional X-rays, allowing for even more precise treatment, especially for tumors located near critical structures, like the brain or spine. Intensified radiotherapy involves optimizing radiation doses and treatment schedules to improve the efficacy of cancer treatment, making it possible to achieve better outcomes with fewer side effects. These innovations have made cancer treatment more effective, offering a more focused approach that increases the precision and efficiency of radiation therapy.

The history of the development of early knowledge about ionizing radiation and its use in Uzbekistan: The development of early knowledge about ionizing radiation is closely linked to changes in global science and includes unique historical processes. Scientific research and practical applications related to ionizing radiation, especially from the mid-20th century, began to actively evolve. In Uzbekistan, the formation and development of knowledge in this field went through several stages.

The early development of knowledge about ionizing radiation in Uzbekistan was directly linked to the scientific potential of the Russian Empire and later the Soviet Union. The study of X-rays and their use in medicine in Uzbekistan began in the 1900s to 1920s.

1910s - The study of X-rays for medical use and the establishment of the first X-ray laboratories in Uzbekistan. As a result, the first educational courses and research in radiology and radiography began in Uzbekistan.

1920s - The development of radiology in medicine. In Uzbekistan, particularly in Tashkent, the first X-ray machines were installed and began to be used for patient diagnostics.

The scientific and technological development of the Soviet Union had a significant impact on the study of ionizing radiation in Uzbekistan. During the 1930s to 1950s, scientific research on ionizing radiation and radioactivity actively expanded.

1930s - Scientific research in the field of ionizing radiation broadened. During this period, Uzbekistan began scientific and practical work in the fields of radiology and radiotherapy.

1940s-1950s - Along with the development of nuclear technologies and the handling of radioactive materials in the Soviet Union, nuclear research centers and laboratories were established in Uzbekistan. During this time, many scientists, including those from Tashkent State University and the Tashkent Institute of Physics and Technology, became engaged in the study of ionizing radiation.

1950s - The Tashkent Radiological Research Institute was established, and extensive research on the use of X-rays and gamma rays began. This scientific institute focused on studying the use of ionizing radiation in medicine, including its application in cancer treatment (radiotherapy).

1960s-1980s - The use of ionizing radiation expanded in Uzbekistan, not only in medicine but also in industry and ecology.

1960s-1970s - Scientific research aimed at radiation measurement and ensuring radiological safety expanded in Uzbekistan. At Tashkent State University, physicists and radiologists conducted numerous studies on measuring ionizing radiation and ensuring its safe use.

1980s - Expanded scientific research in the fields of physics and atomic energy helped develop atomic energy and nuclear technologies in Uzbekistan. Additionally, research on radioactive contamination and its environmental impact began to be conducted.

After Uzbekistan gained independence, scientific research and practical applications in the field of ionizing radiation expanded further. This period opened new opportunities for the development of science and technology.

1990s-2000s - In Uzbekistan, numerous scientific studies on radiation safety and radiological monitoring were conducted. Special attention was given to ensuring the safe application of ionizing radiation in industry, ecology, and medicine.

Since the 2010s – New scientific centers have been established in Uzbekistan in the fields of nuclear energy and radiological technologies. Practical research on the use of ionizing radiation continues, including applications in radiotherapy, radiological diagnostics, materials science, and nuclear technologies. These advancements have strengthened Uzbekistan's capacity to develop and apply nuclear and radiation technologies across various sectors.

CONCLUSIONS

The development of early knowledge about ionizing radiation opened new frontiers in science and technology, leading to revolutionary changes in fields such as medicine, industry, and ecology. This historical process began in the late 20th century and, through discoveries and scientific research, created opportunities to understand ionizing radiation and use it safely and effectively.

The discovery of X-rays and the study of radioactivity (by Becquerel and Curie) formed the initial knowledge of ionizing radiation. These discoveries not only had a significant impact on medicine but also found wide applications in industry, nuclear technologies, and ecology. During the Soviet era, scientific research and practical applications based on ionizing radiation, particularly in the fields of radiology and radiotherapy, developed in Uzbekistan.

After gaining independence, the scientific and practical use of ionizing radiation in Uzbekistan expanded further, with the establishment of new scientific centers and numerous studies in radiation safety and ecological monitoring. However, it is crucial to recognize the potential risks associated with ionizing radiation. Deepening research on its biological and ecological impacts, ensuring safe usage, and strengthening scientific oversight are essential tasks in today's world.

Thus, the initial scientific research and practical applications of ionizing radiation have significantly contributed to the development of Uzbek science. Today, these applications are not only important in scientific fields but also in healthcare, energy, and ecology, opening up new prospects in line with changing technological and social conditions.

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