Short Communication

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Impact of X-Rays on Patients in Radiological Applications

Issoufou Arzika Alio[1,2]* and Almoustapha Aboubacar[1]

[1]*Climate, Environment, and Materials Radiation Laboratory (LCEMR), Faculty of Science and Technology, Abdou Moumouni University, Niger*

[2]*International School of Advanced Studies (SISSA), Italy*

***Corresponding author:** Issoufou Arzika Alio, International School of Advanced Studies (SISSA), Via Bonomea, 265 34136 Trieste, Italy

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ABSTRACT

Medical X-rays and CT scans are very useful nowadays. They offer the means to obtain a diagnosis to optimize the treatment of patients. But these techniques expose our bodies to large doses of X-rays. The latter affect living things at an atomic level by ionizing the molecules inside the microscopic cells that make up our body, and this could have adverse consequences on human health such as mutation, cell death, and skin cancer. We will study in this article, the effects induced by X-rays on the water molecule (the majority component of the human body) such as energy deposits and therefore the distribution of dose deposited in a considered interaction medium. A comparative study of our results obtained by a numerical calculation with the results of an analytical calculation on the coefficient of mass absorption of X-rays in liquid water was made for an energy range between 1keV to 1000keV. Good agreement was observed following this comparison.

Introduction

X-rays are electromagnetic waves whose energy range is between ultraviolet and gamma rays. They are used in various fields of application, including medical physics. These energies are of the order of magnitude of the electron bonding energies of the inner layers of atoms (of the order of keV) and are therefore likely to ionize matter. During propagation through a medium, X-rays can be scattered or absorbed by atoms in the medium. It is this phenomenon of absorption that is involved in the medical applications of radiology. The principle of medical imaging is to send an X-ray beam produced by an X-ray tube in the direction of the area of the human body to be examined. Its intensity is modulated by the differential absorption of the organs crossed. The image is collected as an output on a detector. The coefficient of mass absorption in energy relative to the notion of kerma, depends on the chemical composition of the tissues crossed. Although the use of X-rays is of great interest in medical imaging, it nevertheless presents a great danger to patients. Indeed, when an X-ray is exposed to organs or tissues, it loses part of its energy according to the intensity of the incident radiation. This loss of energy can ionize the atoms in the cell, destroying the normal chemical balance of the cell and eventually leading to cell death. Therefore, to protect personnel to be examined, medical imaging equipment must be rigorously controlled, to ensure that each X-ray or CT scan uses the smallest possible dose of radiation. This study will aim to study the effects induced by the passage of X-rays in liquid water. The choice of liquid water comes from the fact that the latter is the majority constituent of living cells. So, the damage that X-ray can cause during its passage through liquid water is like that which it can cause during its passage through the human body if we consider that the latter consists mainly of liquid water. In the section entitled Method and Materials, a brief overview of the method used as well as the numerical modeling calculation were presented. The results and discussions section provides the results obtained by a numerical simulation calculation. Then it provides a comparative study between our results obtained by numerical simulation with the results of an analytical calculation. Then we will conclude this work with a discussion followed by a conclusion and recommendations.

Method and Materials

The method used is to model the passage of X-rays through liquid water, using the GEANT4 simulation software. The latter is a simulation software designed by CERN (European Center for Nuclear Research) that allows to accurately simulate the passage of particles through matter. It is based on the Monte Carlos particle transport code which is a statistical method used to achieve numerical integrations [1]. It offers good precision in numerical simulation and modeling of radiation transport. Full information about GEANT4 is available online. Four documents of interest to users can be cited: the GEANT4 Source Code; the GEANT4 Installation Guide [2]; the Guide for Application Developers [3] and the Reference Manual that describes Physics [4].

Calculation of the Interaction Process

In GEANT4, the process of interaction of a particle in each medium is calculated using the density of atoms and the macroscopic effective cross-section of the physical process considered [3].

Numerical Modeling

Geometry: It consists of a homogeneous box surrounded by air whose target is represented by a cube filled with liquid water.

Physical Processes: Only standard electromagnetic physical processes are considered in this modeling. Multiple scattering is not instantiated, and all processes are recorded as discrete: there is no continuous loss of energy.

Kinematics of the Problem: The projectile is a point source of unidirectional X-rays of -energy placed near the target and fired in the center of the cube.

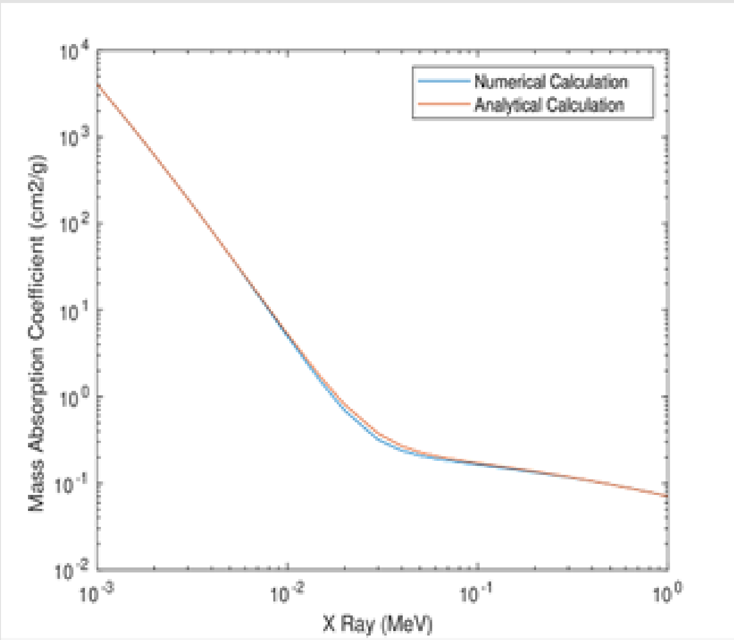

Figure 1: Coefficient of absorption of mass energy by X-rays in liquid water.

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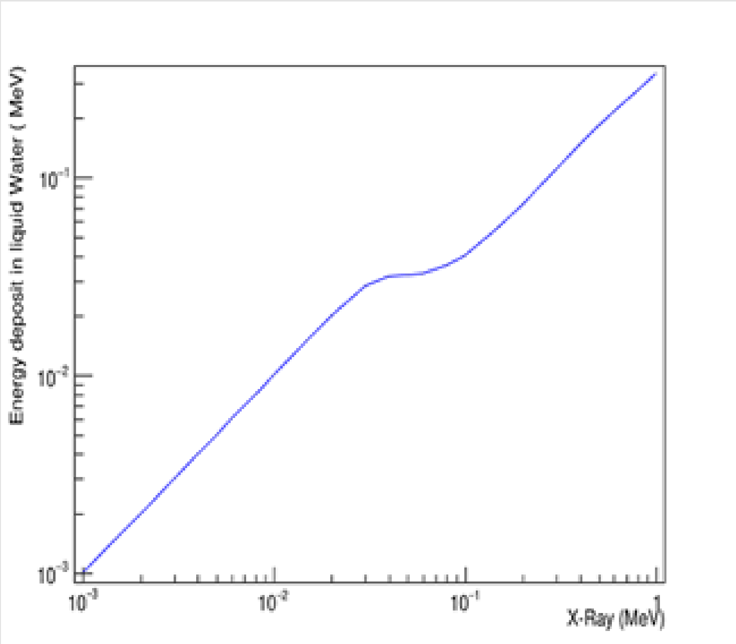

Figure 2: Variation of dose deposited in a volume of water as a function of the incident energy of X-rays.

Results and Discussions

Figure 1 illustrates the variation in the mass energy absorption coefficient describing the attenuation of the number of photons in a volume of liquid water. The curve in blue color represents our results of GEANT4 modeling and the curve in red color is the result of an analytical calculation of the coefficient of absorption of mass energy [5,6]. The curve decreases sharply at very low energy ranging from 1. keV to 100. keV approximately. This energy range corresponds to the zone of the predominance of the photoelectric effect where the absorption of the photon by liquid water is almost total. So, there is a high probability of ionization of the water molecule at this energy range. A very good agreement is observed by comparing these two results. This good correlation confirms the degree of accuracy of the GEANT4 simulation software used in this study. Figure 2 gives the dose distribution deposited in a 10cm thick liquid water cube for a photonic energy range from 1. keV to 1000. keV. It is observed that the curve giving the dose variation as a function of incident energy increases linearly for an energy range between 1 keV and 2 keV.

Then it continues to grow non-linearly. Examining these results, it is found that for the energy of the photon between 1 keV and 2 keV approximately, the loss of energy in liquid water is total because all the energy of the incident photon has been deposited in the considered medium of interaction. And for photonic energy greater than about 2 keV, the photon loses part of its energy in a water cube 10cm long and the other part of its energy passes through the interaction medium without interacting at all. This study found that the dose deposited in the water varies with the energy of the incident radiation. Indeed, when an X-ray beam passes through matter, it deposits an amount of energy according to the intensity of the incident energy. This energy deposition causes ionizations and therefore molecular changes that can lead to enormous damage such as mutation and death of the cell. For a human target, this could have adverse health consequences such as skin cancer for example.

Conclusion and Recommendations

In this study, a Monte Carlo GEANT4 simulation calculation on the modeling of the effects induced by the passage of X-rays through liquid water was performed. Thus, this simulation made it possible on the one hand to calculate the coefficient of absorption of mass-energy, and on the other hand, to calculate the dose distribution deposited by the X-rays in a volume of liquid water considered to interact. This study found that the dose deposited in the water varies with the energy of the incident radiation. In radiology and scanner, medical imaging saves lives in many cases, but it should be noted that the benefit of the latter is not always greater than the risk of exposure of the patient to X-rays. therefore, we recommend limiting this type of examination, or at least, if necessary, rigorously monitoring medical imaging equipment to ensure that each X-ray or CT scan uses the smallest possible dose and does not exceed the permissible dose limit. Otherwise, the patient is exposed to the risk of catching other diseases.

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