ICDA 4

4th International Conference on Dosimetry and its Applications

Book of abstracts

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Message from the Conference Chairs:

Dear Colleague,

Welcome to Valencia! We are very pleased to host the 4th International Conference on Dosimetry and its Applications (ICDA-4) at the Polytechnic University of Valencia (UPV), a leading Spanish University of Engineering, Science and Technology.

The previous ICDA Conferences were held in Prague (ICDA-1, 2013), Surrey (ICDA-2, 2016) and Lisbon (ICDA-3, 2019). Building on the success of the previous Conferences, ICDA-4 is a major gathering of experts from several tens of countries, worldwide. It addresses a broad range of dosimetry topics. The involvement of experts from Spanish and foreign or international institutions has been of paramount importance for the success of this organization.

Special thanks are due to the members of the Organizing and Scientific Committee and all those who helped shaping the Conference Programme and Refresher Courses, as well as to the sponsoring institutions, organizations and corporations.

In these challenging times for Radiation Protection and Dosimetry, we anticipate that ICDA-4 will be a memorable event, rich of achievements, from the scientific as well as from the social point of views and formulate our best wishes that you profit from the Spanish hospitality and the charming atmosphere of Valencia.

Enjoy your stay in Valencia!

Gumersindo Verdú & Belén Juste

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Contributions topics

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Implementation of the First Phase of the Spanish National Patient Dose Registry

María Gracia-Ochoa, Juan V. Catret Mascarell, Alba Alegre Gómez, Álvaro Bruno Aparicio Siano

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Introduction

The BNDP project main objective is to improve patient safety and service quality in Radiological Protection within Health Services, through the use of cutting-edge technologies.

The project aims to establish dynamic and updatable Diagnostic Reference Levels (DRLs) in Spain, and to register and monitor ionizing radiation doses in the SNS through the application of advanced IT tools.

Methods

It is proposed to create an information platform managed by the CND-INGESA, which will have two repositories: SIDAP and PIDAP. The SIDAP repository will allow the recording and monitoring of the history of ionizing radiation doses received by SNS patients, while the PIDAP repository will provide the scientific community with access to anonymized information for its evaluation and dissemination. During the current phase of the project, progress has been made in the design and implementation of the SIDAP, and the PIDAP has been successfully launched.

Results

An anonymized data repository has been created to facilitate the creation of dynamic and periodically updatable DRLs. The stored data will be analyzed using statistical techniques and advanced Artificial Intelligence methods, with dynamic access to the data and analysis results through business intelligence tools. The design of SIDAP is progressing well, with the ability to collect data from the non-anonymized repository and generate preliminary reports to validate the communication services.

Conclusions

The BNDP project will bring significant improvements to patient safety and the quality of the Radiological Protection in the Health Services, by establishing dynamic and updateable DRLs in Spain, and the registration and monitoring of ionizing radiation doses in the SNS via advanced IT tools. The platform developed will enable the storage and analysis of data using statistical and Artificial Intelligence techniques, with the generation of preliminary reports to validate the communication services.

New Developments on Internal Dosimetry

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Introduction

Internal exposures can occur as a result of intakes of radionuclides by inhalation, ingestion, injection, through intact skin or a wound. The incorporation of radioactive material into the body can happen in the workplace (occupational exposures), in the population as a consequence of an emergency situation (public exposures) or in patients in nuclear medicine units.

Methods and Results

The International Commission on Radiological Protection (ICRP) has published 5 OIR Reports on "Occupational Intakes of Radionuclides", consistent with recommendations on radiological protection from ICRP Publication 103. The first EIR Report on Intakes of Radionuclides by Members of the Public (age dependent dose coefficients) was available for consultation in 2023 from ICRP web site and will be published soon; other EIR publications will follow.

ISO supports the development of standards on internal dosimetry such as ISO 23588:2023 on general requirements for proficiency tests for in vivo radiobioassay and ISO 20553:2018 on monitoring of workers occupationally exposed to a risk of internal contamination with radioactive material, which is currently under revision after the publication of OIR reports. A standard on radiation monitoring of the population and responders in nuclear/radiological emergencies is in process.

The European Radiation Dosimetry Group (EURADOS) and the WHO's Radiation Emergency Medical Preparedness and Assistance Network (REMPAN), have been involved in measurements, dose assessments and medical management of workers with radionuclide intakes via contaminated wounds.

EURADOS has important ongoing work on internal dosimetry: the intercomparison on age-dependent thyroid phantoms, the report on the implementation of ICRP OIR models, an intercalibration and intercomparison exercise on wound monitoring (in collaboration with IRSN) and the review on emergency in vitro radiobioassay methods.

Conclusions

Main outcomes of these developments are presented here.

Monte Carlo simulations for brachytherapy dosimetry

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Introduction

The introduction of model-based dose calculation algorithms (MBDCAs) in brachytherapy provides an opportunity for a more accurate dose calculation and opens the possibility for novel, innovative treatment modalities. The joint AAPM, ESTRO and ABG Task Group 186 (TG-186) report provided guidance to early adopters. However, the commissioning aspect of these algorithms was described only in general terms with no quantitative goals. The recently published AAPM WGDCAB Report 372: A Joint AAPM, ESTRO, ABG and ABS Report on Commissioning of Model-Based Dose Calculation Algorithms in Brachytherapy, from the Working Group on Model-Based Dose Calculation Algorithms in Brachytherapy, introduced a field-tested approach to MBDCA commissioning.

Methods

Its approach is based on creating a set of well-characterized test cases for which reference Monte Carlo (MC) and vendor-specific MBDCA dose distributions are available in a Digital Imaging and Communications in Medicine - Radiotherapy (DICOM-RT) format to the clinical users. These will be described in this talk.

Results

The key elements of the TG-186 commissioning workflow are described in detail and quantitative goals are provided for all published test cases, in particular the new ones that have been recently released for use by the community.

Conclusions

The AAPM, ESTRO, ABG and ABS recommend that clinical medical physicists implement the workflow presented here to validate both the basic and the advanced dose calculation features of their commercial MBDCAs. The use of the test cases for research and educational purposes is further encouraged.

Spectral CT, Deep Learning and Parametric Radiotherapy

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Introduction

CT HU units are used to measure the attenuation of structures and organs. This standardized unit is influence by various factors, including the different acquisition protocols and parameters. Spectral CT has the ability to quantitatively analyze tissue composition as a function of the different energy of the X-ray beam. CT images represent the reconstruction of the attenuation coefficient of tissues to the passage of X-rays. This Lambert-Beer exponential function shows that the transmitted intensity is related to a monoenergetic beam of incident intensity when passing through a material of attenuation coefficient and known thickness. The attenuation coefficient depends on the atomic number and density of the interposed material. The Lambert-Beer law holds true for a monoenergetic X-ray beam. Conventional CT scanners cannot properly discern beam energy. Spectral CT is the technology capable of extracting tissue characteristics. There are different models of acquiring spectral CT, depending on whether there are two independent sources, each firing an energy spectrum, if the source has a split filter that allows generating two different energy spectra simultaneously, if a single source fires two different energy spectra alternately, or if there is a single source but the detector is able to detect a high or low energy spectrum.

Methods and Results

In conventional CT the characterization of tissue components is standardized to an acquisition of 120 kVp. Two materials of different composition can have similar UH, despite having a different density and atomic number. Energy resolution is the ability to differentiate different attenuations at different energies. Spectral CT allows the reconstruction of monoenergetic images, electron density maps, and atomic number maps. Energy-attenuation curves allow characterizing lipid and bone content, removing iodine, and obtaining iodine and uric acid maps. The HU dynamic behavior at different energies is specific to certain materials depending on their elemental composition. The effective atomic number can be estimated using plots and nomograms obtained from the standard reference database, being relevant in protontherapy. It is also used to estimate electron density, which is used to calculate and optimize the effective dose in different tissues in external radiation therapy.

Conclusions

We will present the influence of scanner design in the precision and reproducibility of electron density and atomic number maps, and the use of these maps to trustworthiness delineate target lesions and habitats.

Bethe formula for the stopping power of charged particles

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Introduction

The Bethe formula for the stopping power of matter for charged particles is of paramount importance in radiation physics. Strictly speaking, it is an asymptotic formula, i.e., it is valid only for projectiles with sufficiently large energies. Its validity range is extended to intermediate energies by introducing various corrections, which account for effects that are neglected in the derivation of the basic formula.

Methods

The formula can be derived from either the plane-wave Born approximation or from the classical dielectric theory. We have performed calculations of the stopping cross section of charged particles with isolated atoms, whose wave functions are described by means of the Dirac-Hartree-Fock-Slater self-consistent atomic model. The difference between the calculated cross section and the asymptotic formula provides the shell correction. Other considered corrections are the Lindhard-Sørensen correction (which accounts for limitations of the perturbative approach), the Barkas correction (which accounts for differences between particles and anti-particles), and the density effect correction (which accounts for the dielectric polarizability of the stopping medium). These corrections can be computed from a model of the optical oscillator strength of the material, which is determined from a single parameter, the mean excitation energy or I-value.

Results

The program SBETHE, with the associated database [F. Salvat and P. Andreo, Comp. Phys. Commun. 287(2023)108697], calculates the stopping power of arbitrary materials for light charged particles (electrons, muons, protons, and alpha particles) from the corrected Bethe formula.

Conclusions

Comparison with available experimental information shows that the corrected formula yields results in good agreement with experiment for electrons, protons, and alphas with kinetic energies larger than about 1 keV, 0.75 MeV and 5 MeV, respectively, when empirical I-values are adopted.

Patient radiation dose monitoring in medical imaging: strategy and implementation

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Introduction

The new IAEA Safety Report Series 112 defines patient radiation exposure monitoring as “components, mechanisms and operational processes related to recording, collecting and analyzing patient radiation exposure data associated with clinical imaging operation”. Goals of exposure monitoring include ensuring optimized radiation protection and consistent practice of medical imaging; ensuring safe and precise imaging of individual patients; supporting the process of justification and appropriateness; providing information on collective dose to population and trends.

Methods

Monitoring involves recording, collecting and analyzing patient exposure radiation data. Depending on the imaging equipment type and generation, exposure data might be recorded and collected in a standard DICOM or non-DICOM format, or collected manually by medical staff. Exposure data cohort depends on the intended purpose of data collection and may be organized at the facility or multi-facility level.

Results

Collected data can be combined and processed to perform relevant dose analyses, such as statistics, trends and tracking of both individual (e.g. organ dose, risk estimates) and collective stored data (e.g. typical doses to compare to DRLs, collective dose to a population). Patient exposure monitoring within a healthcare facility requires a suitable organizational structure, including a multidisciplinary committee. In the selection and implementation of an automatic exposure monitoring system, key specifications pertaining to informatics, features and access should be considered. All steps of the process should be subject to quality control.

Conclusions

The easier access to a large volume of digital data allows for a transition from periodic reviews of patient doses using isolated samples, to regular or continuous monitoring and more comprehensive analysis of all of the available data to provide more benefit to patients. For maximum benefit, multifacility and national patient exposure monitoring systems should be integrated with the other healthcare electronic systems.

Individualized treatment verification based on photon emission

Gabriela Llosá on behalf of the IRIS group and collaborators

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Introduction

The interest in Compton cameras for medical imaging has been growing since their proposal in 1974. While successfully applied in other fields, in medical imaging they currently can not compete with the well established and cost-effective gamma cameras. However, they can offer advantages in some applications for which gamma cameras are not optimal. This is the case of treatment monitoring in hadron therapy, to determine the Bragg peak position, or for assessment and dosimetry of treatment with radiopharmaceuticals, in particular with alpha particles. The IRIS group of IFIC has developed a Compton camera prototype and is evaluating its performance and applicability in these two fields.

Methods

The prototype consists of three planes of LaBr3 crystals coupled to silicon photomultiplier arrays, read out by the AliVATA data acquisition electronics. The system has been tested in two clinical sites. Tests have been carried out at CCB protontherapy centre, in Krakow, where a solid water phantom has been irradiated with a 90 MeV proton beam. The prototype was employed to image the photons emitted by the irradiated material, which are correlated to the Bragg peak position. The proton energy was varied to produce 2 mm shifts in the Brag peak position. The nuclear medicine tests have been performed at La Fe hospital, in Valencia. The system has been employed to image phantoms filled with ^{18}F-FDG and ^{131}I- NaI, and also thyroid cancer patients undergoing treatments with ^{131}I- NaI after the gland resection.

Results

In the tests carried out in the protontherapy centre, the results show that the system is able to distinguish variations of 2 mm in the position of the photon distribution. In the hospital tests, the Compton camera shows better resolution than the gamma camera employed in the nuclear medicine service, and is able to detect patient lesions correlated with the gamma camera images.

Conclusions

Compton cameras show promising results in specific medical applications that can lead to their implementation in medical imaging.

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SGRT: From motion management to Cherenkov detection

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Introduction

Abundant literature illustrates the benefits of Surface-Guided RadioTherapy (SGRT) for inter and intra-fraction motion management in radiotherapy. Today, the paradigm shift is continued with the introduction of new technology able to monitor the live Cherenkov emission on the patient during beam delivery. The present work discusses the added value of Cherenkov imaging to further increase patient safety in radiotherapy.

Methods

Based on a comprehensive literature review, the work focused on assessing the performance of DoseRT, the new Cherenkov imaging solution from Vision RT (UK) in typical radiotherapy environments. Additionally, delivery incidents detected by DoseRT on two patient cohorts (64 and 622), various pathologies and anatomical sites were investigated.

Results

DoseRT was found to efficiently visualize Cherenkov emission with complex treatment plans, mixed energies (6-18 MV photons and electrons), and modulated treatment fields (IMRT/VMAT). It proved compatible with 100 – 2400 MU/min dose rates offering ~2.5 mm spatial resolution. Published data also suggests that approximately 10% of patients received sub-optimal treatment that can be detected by Cherenkov imaging. The most common mis-deliveries include undesired exposure of the contra-lateral breast, axilla, and chin for breast cancer patients. Similarly, undesired exposure to the patients' hands can be common for pelvis and prostate treatments. Lastly, while online in vivo dosimetry is not yet enabled by DoseRT, retrospective computation of entrance dose and comparison against TPS or point detector values proved Cherenkov measurements to represent a reliable and promising solution especially for field junction verification.

Conclusions

Combining SGRT and Cherenkov imaging capabilites will greatly allow increased delivery safety in tomorrow's standard of care in radiotherapy from hypofractionnation to flash extending also its benefits to protons and hadrons therapy.

Ultra-high dose rate dosimetry: Challenges and opportunities for FLASH radiation therapy

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Introduction

FLASH radiotherapy (RT) is attracting a significant interest since the first investigations carried out in 2014, demonstrated by the increasing number of related publications. Several preclinical studies worldwide have demonstrated that ultra-high dose rate (UHDR) beams produce an improvement of normal tissue sparing while maintaining high tumor control probability compared to conventional dose-rate RT (FLASH effect). However, to fully understand the mechanisms and the biological processes, reliable beam monitoring and dosimetry technologies must be developed, and new protocols are needed. This is crucial to support the first clinical trials and for the clinical translation of FLASH RT. Currently used detectors saturate at these extreme regimes, therefore the optimization of already established technologies as well as the investigation of novel radiation detection and dosimetry methods are required. The main challenges coming from the peculiar beam parameters characterizing UHDR beams for FLASH RT has stimulated the developments of novel solutions able to address the mentioned issues.

Methods

Attaining the desired solutions and approaches requires further optimization of already established technologies as well as the investigation of novel radiation detection and dosimetry methods. It is also crucial to fill the gap in terms of validated protocols, assessing new dosimetric procedures and standardized methods. The challenges characterizing dosimetry and beam monitoring for FLASH radiotherapy vary considerably depending on the accelerator type and technique used to produce the relevant UHDR radiation environment. Different time structure can be used for the acceleration of the radiation beams and, consequently, the dose and dose-rate per pulse and all these parameters can affect the detector response. An ideal dosimeter for reference dosimetry should be dose, dose rate, energy, and angular independent, with high radiation hardness, linearity, accuracy, and precision. Ionization chambers are recommended by the international protocols for reference dosimetry in RT. However, at very high dose rates their response is heavily affected by the ion recombination and requires major modifications of current commercially available ion chambers and the assessment of novel alternative dosimetry techniques. Some passive detectors may offer high accuracy and reproducibility, but active detectors provide less time-consuming measurements, although the accuracy and dose-rate independence require further improvements.

Results

Novel approaches have been proposed to try to solve or reduce the issues related to ion recombination on ionization chambers. These imply the design and realization of new concepts of chambers based on ultra-thin geometries or using different gas mixtures. On the other side, alternative solutions are being also proposed, based on the use of portable calorimeters for reference dosimetry and there is an increasing interest towards the assessment of scintillators and semiconductors, such as diamond, silicon and silicon carbide detectors. The mentioned new technologies have been tested with at FLASH regimes and their response was demonstrated to be dose rate independent up to several Gy/pulse.

Recently, also two-dimensional geometries are being investigated, with the purpose of realizing detectors able to measure the spatial dose distributions with one single irradiation, to minimize possible radioprotection issues coming from the conventional scanning approach. Peculiar geometrical configurations are also relevant for beam monitoring technologies that, beyond being reliable even at UHDRs, must be characterized also by high spatial and temporal resolution.

Conclusions

The development of several novel approaches require an accurate assessment of the related uncertainties and a dedicated effort to identify the most reliable technologies and to standardize the procedures, paving the way for the delivery of new protocols and codes of practice for dosimetry of UHDR beams.

Scintillation Dosimetry: Past, Present and Future Applications in Radiation Therapy

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The development of plastic scintillation detector systems for dosimetry has been evolving for more than 2 decades. Scintillation materials (organic scintillators, scintillating fibers and liquid scintillators) have many properties that make them ideal for dosimetry including water equivalence and energy independence for MV photons, linearity with dose, dose rate independence, high spatial resolution and ultra-fast response time. Therefore, these detectors do not require the usual conversion and/or correction factors used for other commonly used detectors to convert the detector reading to absorbed dose. The evolution of these detectors started with point detectors (1D), 2D array detectors to 3D volumetric detectors to respond to the ever-increasing complexity of radiotherapy treatment in external beam radiotherapy (EBRT), brachytherapy, proton therapy including quality assurance and in vivo dosimetry applications; and more recently FLASH dosimetry.

A brief overview of the dosimetric characteristics and properties of plastic scintillation detectors when exposed to high-energy photon, electron as well as proton beams will be presented. Few applications using plastic scintillation detectors in clinical radiotherapy for quality assurance, stereotactic radiosurgery, and in vivo dosimetry applications will be highlighted. We will also describe how liquid scintillators can be used for routine verification of proton treatments, and how they can be used to verify complex Intensity Modulated Proton Therapy (IMPT) and Pencil Beam Scanning (PBS) treatments quickly and accurately and to accurately measure parameters such as the range, the position and the intensity of individual proton beam spots.

Finally, a novel proton-integrating radiography system design using a monolithic scintillator detector will be presented and discussed. The potential use of this system for image guidance for proton therapy patients will be briefly presented.

A Critical View to Non-Biology Driven External RadioTherapy and Brachitherapy: Long Term Threats and Mitigating Improvements

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Theragnostics based on Radioisotopes has emerged as a powerful form of Radiotherapy (RT). Its glowing market is expected to grow even further in the coming years. It is a form of internal RT, but instead of placing the radioisotopes in seeds at the tumor site, like in Brachytherapy (BT), they are driven towards the cancer cells by targeting molecules. Therefore, they are hybrid compounds with a targeting part and beta or alpha emitting isotopes. By now, it is only applied to very few cancers, mainly prostate and neuroendocrine cancers. However, it is expected to be extended to other tumors where the biology is well understood and specific targets have been identified. Secondary effects of theragnostics are very unlikely and consists mainly in blood cancers. But as these therapies are extended to other tumors and applied to younger populations, those very harmful effects might not be accepted.

However, Boron Neutron Capture Therapy (BNCT), though currently very expensive, avoids those secondary effects of theragnostics by producing the radioactive isotope at the tumor. In this case, the hybrid compound does not carry radiation emitters but it consists of a targeting molecule and a part heavily loaded with boron. Once the drug reaches the tumor, an external epithermal beam of neutrons is directed towards it. The high neutron affinity of boron ^{10}B absorbs the neutron into ^{11}B, which subsequently emits an alpha particle, and sometimes also a high-energy gamma ray, and decays into a ^{7}Li atom.

Biology has entered the RT game and standard RT needs to become more specific, oriented by biological information, if it wants to continue playing a role in the future. Current RT systems would much improve their performances if they were guided by images provided by biology (Molecular Imaging) and not by structural information (X-ray CT, MRI). Such strategy produces more effective damage to the tumors by increasing the doses where the cancer is more active and also decreases secondary effects by reducing the dose in non-active areas. FLASH RT, could also help to preserve external RT.

Dosimetry in X-ray breast imaging

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Introduction

According to the World Health Organization (WHO), at the end of 2020, 7.8 million women alive were diagnosed with breast cancer in the past 5 years, making it the world's most prevalent cancer. It is largely recognized that early detection represents the first strategy to follow in the fight against cancer. The effectiveness of mammography screening for early breast cancer detection has been proven in several surveys and studies over the last three decades. The estimation of the Mean Glandular Dose (MGD) is important to understand the radiation-associated risk in X-ray breast imaging. It continues to be the subject of numerous studies and debates, since its accuracy is directly related to risk estimation and for optimizing breast cancer screening programs.

Methods

In this review, the main dosimetry formalisms used to estimate the MGD in screening and diagnostic programs will be showed and discussed. The dosimetry protocols were formulated initially for mammography. Digital breast tomosynthesis (DBT) either in conjunction with synthesized digital mammogram (SDM) or with digital mammography (DM), is routinely used in many breast cancer screening programs and consequently the dosimetry protocols were extended for these techniques. In addition to these techniques, breast dosimetry from emerging X-ray based imaging techniques such as phase contrast imaging (PCI), use of monochromatic X-ray sources, breast CT and Contrast Enhanced Mammography (CEM) are reviewed.

Results

The main results in terms of MGD comparison among the different X-ray imaging techniques will be reported. In addition to the breast absorbed doses, also some studies about extra-target doses involved in breast imaging will be discussed.

Conclusions

The continuous effort to reduce MGD over the last forty years and at the same time to maintain the same image quality in X-ray mammography is directly reflected in the development of new techniques that appear to be very promising for the future of more personalized X-ray breast imaging.

Development of Real-time Radioluminescence Sensors for Medical, Industrial and Security Applications

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We are developing radioluminescence (RL) systems, initial studies concerning doped silica optical fibers and time-resolved radiation dosimetry, merits including high spatial resolution and wide dynamic range. For Ge-doped optical fiber samples irradiated at rates between 100- and 600 MU/min from use of a 6 MV clinical X-ray beam, and with a counting circuit gating time of 100 μs, linear response has been obtained, unconstrained by afterglow. Subsequent study has been of the effect of high dose (kGy) electron beams on two undoped silica core fibers differing in hydroxyl (OH) content, interest being in remote real-time dosimetry for radiation processing applications. Exposed to electrons from a medium powered linear accelerator, delivering doses of the order of tens of kGy (from 10 kGy through to 70 kGy in individual exposures), the RL spectrum demonstrated a central wavelength of 650 nm and 550 nm for the high and low OH scintillators respectively, RL intensity with dose being found linear, the sample of greater OH content showing the greater sensitivity. Finally, moving to the low dose regime of naturally occurring radioactive materials (NORM), present devices have a number of operational limitations, including an inability for localization in hard to access places, also an inability to operate in aqueous environments. Characterization has been made of an optical fiber system based on a LYSO:Ce scintillator, compared against Geiger Muller (GM) device, tested thus far using monazite and xenotime at in-contact dose rates down to 20 μGy/h. With measurements comparable to that of the GM counter, and with intrinsically safe RL remote capabilities, the study points to RL potential in a variety of industrial scenarios.

Radon Exposure and European Union Regulations

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Introduction

The very first studies of detrimental effects later attributed to radon exposure are dated in the 16th century when numerous deaths of miners were noted in Central Europe. Expressions „Schneberg krankheit« and "Jáchymov miners' disease" associated with the names of mines were used. In 2020 UNSCEAR published a report on lung cancer from exposure to radon. Nowadays it is estimated that about 20 000 of deaths in the European Union Member States (EU MSs) can be attributed to radon exposure in dwellings which represent about 9% of all deaths related to lung cancer.

EU Legislation

Already in 1990 the EC published recommendation on the protection of the public against indoor exposure to radon. Recommendation on radon in drinking water followed. Nowadays 2013/59/EURATOM Directive specifically tackles radon in dwelling and in workplaces. The National Radon Action Plan (NRAP), prepared by each EU MSs is a basic document addressing all activities related to radon exposure in a specific EU MS including reference level for indoor radon exposure, survey to identify risks, remediation and preventive actions.

Dose coefficient to be applied for the estimation of the effective doses were challenges for decades. ICRP published ICRP 126 on radiological protection against radon exposure. ICRP 137 specifically addresses occupational intakes of radionuclides. In June 2023 the Group of Experts referred to in Article 31 of the Euratom Treaty issues the Opinion to use ICRP 137 coefficients noting that the values "may pose challenges in their implementation into practice meriting further discussions and exchanges of experience on these challenges".

Conclusions

Management of risks associated with radon exposure in EU MSs is one of the biggest challenges in radiation protection. EU MSs are implementing legal obligations. It seems that there is still a room for improvement concerning optimization of this specific radiation protection area and for EU research programs.

Energy imparted and ionization yield at the nanometer scale: a broken relationship?

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Introduction

In dosimetry and microdosimetry, measurements of energy imparted are generally carried out through a measurement of ionizations, relating the two quantities by means of W, the mean energy expended to create an ion pair. However, the applicability of this procedure becomes questionable when the measurement is pushed towards the nanometer level, because the number of radiation-induced collisions becomes small and the stochastics of energy transfer per single collision could play an important role. Since absolute measurements of energy imparted are not feasible at the nanometer scale, this problem can be studied by Monte Carlo simulations only.

Methods

Monte Carlo simulations were performed with the Geant4-DNA track structure code in water spheres of nanometric size. The study was focused on light ions (up to Z = 6) from very low energy up to 100 MeV/u, considering two beam geometries: a pencil beam crossing centrally the sensitive sphere or a large beam twice its diameter. Energy imparted and ionization yield were scored for each primary particle to build the probability distribution for the two quantities. Their mean values and variances were calculated.

Results

Once the size of the sensitive sphere is fixed, a constant ratio is found between the mean energy imparted and the mean ionization yield, regardless of primary particle energy. Deviations for different ion types and beam geometries are within 8%. The ratio of the variance of energy imparted and ionization yield is also approximately constant. A comparison of the probability distributions must deal with the discrete nature of the ionization process, as opposed to energy imparted which is continuous.

Conclusions

Energy imparted and ionization yield are independent quantities, and their different stochastic behavior becomes dominant at the nanometer scale. However, a relation can be drawn between them using a conversion factor which depends, as a first approximation, only on sensitive volume size.

Radiation Shielding and Dosimetry at Accelerators

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Introduction

A growing number of intermediate-energy (from a few tens MeV up to several hundreds MeV per nucleon) accelerators is being installed worldwide for proton and ion therapy. The shielding design of the accelerator facility is obviously of primary importance for its licensing. From this point of view, the beam losses, the workload, the occupancy and use factors of the facility should be assigned carefully.

It should be mentioned that, apart from incidental situations, shielding barriers have to be designed against the secondary radiation generated via primary beam interactions with the structural materials of the accelerator system and the patient. For charged-hadron accelerators the secondary radiation field is complex and constituted mainly by neutrons. Anyway, other field components (such as photons from nuclear de-excitation) should be accounted for.

Methods

Secondary neutron attenuation curves in concrete are available in the literature, mainly based on the line-of sight model. This analytical procedure should be considered as a first step for calculating the shielding barrier thickness. As a second step, detailed Monte Carlo simulations should be carried out preferably considering distributed beam losses (where necessary). The final step is to assess the risk indicator (the H*(10) in most of cases) beyond the shield experimentally. For this purpose, rem-meters and spectrometers with responses extended to high energies should be employed.

Results

After reviewing the models leading to the attenuation curves in concrete, the results of the shielding design of a hadrontherapy facility will be discussed in this work. In particular, the neutron H*(10) calculated with the line-of-sight model, with a very detailed Monte Carlo simulation and assessed with measurements performed with an extended-range neutron specttrometer will be presented and discussed.

Conclusions

The data from the detailed Monte Carlo simulation of the hadrontherapy facility and from the measurements are in a very satisfactory agreement (within 15%), thus proving the reliability of the Monte Carlo codes. Some discrepancies might be expected with the data from the line-of-sight model since it considers point sources for all the beam losses.

Biodosimetry and clinical dosimetry to support medical management as part of radiation emergency preparedness

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Large-scale radiological and nuclear scenarios are back on the list of threats to European countries. Even the potential use of nuclear weapons in recent conflicts, improvised nuclear devices in the hand of terrorists, or deployment of dirty bombs are discussed by the public.

Novel treatment options for acute radiation syndrome (ARS), including cytokines, biosimilars, and specialized stem cell treatment options, have been available for some years. Still, optimal allocation of these countermeasures requires early and high-throughput diagnosis.

Clinical dosimetry aiming at TRIAGE might help to classify patients into three distinct groups:

1) unexposed or very low exposed individuals who might be concerned (worried well) and who require no hospitalization or immediate care,

2) irradiated individuals who later develop a low degree H-ARS (after, e.g., low total body irradiation [TBI] or partial radiation exposure) and who require no immediate care and

3) irradiated individuals who will later develop a higher degree H-ARS (after high TBI) and who require immediate hospitalization and early onset of treatment.

The initial clinical radiobiological-based TRIAGE can be accomplished by different means of biological dosimetry to fit the scenario and exposure.

For example, variants of the Bundeswehr differential blood-based scientific triage tool: H-module, and gene expression options, including point-of-care diagnosis and high-throughput use of a four-gene set, will be presented to discuss their potential use in large-scale scenarios.

Keywords: ARS; biomarker; gene expression; radiation preparedness.

What can really do EPR retrospective dosimetry? Feedback experience on 25 years of radiological accident management

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The aim here is to look back over more than 25 years of EPR dosimetry in support of the medical management of victims of radiological accidents and to draw out the main lessons learned. Different types of materials can be considered for EPR: biological materials (bone tissue, tooth enamel, fingernails) or materials worn by the victim (fabrics, polymers, glass, sugars, etc.). Counter-intuitively, the most commonly used materials are not those with the best dosimetric properties or those that are easiest to collect, but simply those that are most available. Bone tissue, for example, is by far the most widely used and relevant material, despite the fact that sampling is highly invasive, has a high detection limit (a few Gy), is highly variable and protocols are not standardized. The distribution of doses is always heterogeneous and, in many cases, it involves localized irradiation at very high doses, ranging from a few tens of Gy to a maximum of 1900 Gy. In these cases, it is not the whole-body dose that is the most relevant data, but the distribution of the dose and the maximum dose. In the absence of any other means of dosimetry, when an estimate by simulation is impossible, bone tissue samplings may be perfectly justified, either to estimate the dose in bone or to surrounding tissues. Another important lesson is that samples are only available, at best, several weeks after the accident. It is therefore inappropriate to devote resources to developing dosimetry techniques that can be only used in limited time windows (e.g. <24-48 hours). We also had the opportunity to use materials that had never been studied before, which meant that we had to develop dose estimation protocols during the expertise time. Similarly, pre-established and fixed protocols are rarely useful, as materials very often have very different characteristics, which means that procedures have to be adapted in real time. The success of the expert assessments we have carried out has more to do with the adaptability and responsiveness of the teams we have built up over time than with an advanced standardization framework.

Hospital la Fe experience in biodosimetry of nuclear medicine patients and in children of Chernobyl

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The biodosimetry laboratory of the La Fe University and Polytechnic Hospital has been operating since 2008, when it was authorized by the Valencian Department of Health in Spain. This laboratory is associated with the irradiated and contaminated center (CAIC), within the medical service of the radiological protection service of our hospital and was similarly authorized by the competent authorities. This laboratory is part of the RENEB Network, a European network of excellence in response to radiological and/or nuclear accidents with multiple victims since 2010, and the WHO BiodoseNet Network, and both the laboratory and the CAIC are also part of REMPAN, Network linked to the WHO for medical response in nuclear and radiological emergencies. This activity is related to the possible response to nuclear and radiological accidents, but the laboratory has participated in other studies, such as performing biodosimetry using two different techniques to estimate acute and chronic doses in workers from our hospital exposed to ionizing radiation. In this work we present another two applications of biodosimetry performed in our laboratory. Firstly, in collaboration with the NGO Juntos por la Vida, which carries out foster care programs for children from Chernobyl, a study of health, nutrition and biodosimetry was carried out in children living near Chernobyl. The objective of the study was to probe the possible presence of chromosomal damage and internal contamination in a group of Ukrainian children and adolescents, 20 years after the Chernobyl accident at the Nuclear Power Plant. This work was published and the results of the total of 53,477 scored metaphases were completed. Secondly, with the support of the nuclear medicine department, a biodosimetry study with high-risk neuroblastoma pediatric patients was performed. The aim of this project was to estimate the absorbed dose throughout the body with the dicentric chromosome assay (DCA) for 131I-metaiodobenzylguanidine. (131I-mIBG) treatments and to obtain an initial correlation with physical absorbed dose calculated with the Medical Internal Radiation Dosimetry (MIRD) formalism. A case report has been published.

Gene expression based biodosimetry in blood and skin tissues

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Introduction

In the event of a large-scale event leading to acute ionizing radiation (IR) exposure, high-throughput methods are required to rapidly assess individual biological dose estimates for triage purposes. Blood-based gene expression is a broad source of biomarkers of IR exposure which present great potential for providing large population rapid dose estimates. It has demonstrated its utility and robustness in several multi-centre' exercises. Time is a crucial component in radiological emergencies and the shipment of blood samples to relevant laboratories presents a concern. We recently performed nanopore sequencing analysis to demonstrate that the technology can be used to detect radiation-inducible genes in human peripheral blood mononuclear cells. The technology can lead to the development of a portable device which can overcome issues involving sample shipment

However, as a downside, it is difficult to identify partial body exposures. Skin biopsies are easily accessible and can provide information on the localisation of the exposure; moreover, it offers a new source of gene expression biomarkers and its transcriptional response might be more persistent overtime than in blood.

Methods

Multiplex quantitative PCR and nanopore technology for RNA long read sequencing are being used in validated protocols to analyse quantitatively RNA content from human blood and skin samples.

Results

We identified an IR signature in human blood consisting of 46 differentially expressed genes. Amongst them, Ferredoxin reductase (FDXR) has a remarkable IR-induced transcriptional responsiveness; we identified FDXR transcript variants with dose-dependent up-regulation. This was confirmed in vivo in radiotherapy patients.

In skin punch biopsies, a gene signature was also identified.

Conclusions

Overall, these studies confirm the robustness of gene expression for dose estimation and its potential as a biological dosimetry method for triage purposes in large-scale radiological incidents.

RENEB – the biodosimetry network in Europe

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Introduction

The current international situation makes it clear to us that preparation for radiological emergencies is once again on the priority list. The possible use of nuclear weapons, as well as the attack on nuclear facilities are a serious threat. We may be facing scenarios where hundreds or even thousands of people could be exposed to radiation. Biodosimetry and retrospective physical dosimetry offer tools that allow screening and subsequent dose estimation. The European Network of Biodosimetry RENEB (Running the European Network of Biological Dosimetry and Retrospective Physical Dosimetry) offer these techniques.

Material and methods

Networking and collaborating with specialized laboratories have been recognized as an essential strategy for emergency preparedness and response in case of a major RN event with numerous potentially exposed victims. Between 2012 and 2015, the RENEB project was used to initiate a European Biodosimetry Network from which the legal association RENEB e.V. emerged in 2017. Up to now, 16 organizations as decision-making organizations from 12 European countries have joined the RENEB entity, and a total of 42 partners from Europe and around the world collaborate in RENEB activities.

Results

RENEB has promoted periodic quality-controlled interlaboratory comparisons (ILC) of a broad battery of dose biomarkers, from dicentric or gene expression to electron paramagnetic resonance. The results of these ILC have been periodically published in the scientific literature, and more importantly have moved towards the harmonization of laboratories.

Conclusions

The experience gained over all these years allows us to say that in the event of a large-scale radiological incident we have the capacity to effectively evaluate a large number of potentially exposed people. RENEB continues to work to develop faster analysis methods, improve the precision of estimated doses, and incorporate new methodologies that improve preparedness for radiological emergencies.

Uncertainty assessment for various exposure scenarios in biological dosimetry

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Introduction

Radiation specific biomarkers provide an important tool to obtain a retrospective assessment of the blood dose in cases of unclear overexposures to ionizing radiation. In addition to the estimation of parameters, it is required to assess the corresponding uncertainties. Several statistical methods have been developed to enable the estimation of the dose and other parameters and the corresponding uncertainties for several exposure scenarios. Nevertheless, the development of statistical methods for uncertainty estimation is still in progress, especially for complex exposure scenarios.

Methods

Statistical methods for dose and uncertainty estimation will be discussed with special emphasis on the development of software tools for the harmonization of statistical analyses in biological dosimetry. Monte-Carlo simulations were performed to compare different methods in terms of the reliability of the estimated uncertainty intervals. Moreover, novel statistical approaches will be introduced and possible fields for research in the near future will be discussed.

Results

Statistical methods are required for several parts in the workflow of biological dosimetry (e.g. lower limits of a method, exposed or not, homogeneous or heterogeneous exposure, dose estimation, etc.). This presentation provides a summary of existing statistical methods for biological dosimetry and their strengths and weaknesses and the potential for developments in the future. A new open-source software tool, the Biodose Tool, will be introduced which enables the assessment of doses and uncertainties in a user-friendly way.

Conclusions

The assessment of uncertainties must be a central part of the workflow of biological dosimetry and it is important to compare existing methods for their reliability, to develop novel methods for more complex exposure scenarios and to provide software tools to the end-user which enable a harmonized assessment of doses and uncertainties.

Dosimetry challenges in Radiological and Nuclear Emergency Preparedness and Response

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Introduction

Nuclear and radiological accidents involving significant releases of radioactivity are very complex situations in which a good radiological characterization of the situation is fundamental for taking decisions on the implementation of protective actions for the population and emergency responders. Therefore, dosimetry issues are very important in all phases of an accident.

ICRP recommendations establish reference dose levels as the main tools to guide optimization in order to restrict inequity in individual dose distributions and to focus attention on the higher levels of exposure. However, the implementation of this approach is not simple, and there are many dosimetry challenges to address to achieve acceptable intervention strategies. All the exposure pathways in each phase of the accident, and all relevant protection options, have to be considered when deciding on the optimum course of action to be taken. The full protection strategy must be justified "resulting in more good than harm" and optimized with the objective of mitigating radiological consequences for people and the environment whilst, at the same time, ensuring sustainable living conditions for the affected people, suitable working conditions for the responders, and maintaining the quality of the environment.

Methods

Challenges for the early phase with respect to emergency responders include the need to provide individual dosimetry, whole body counting and in vitro measurements of biological samples and other methods as necessary. Concerning population, it is important to improve prognosis by reducing uncertainties, including a better integration of monitoring data —from on-site fixed radiation monitoring systems, off-site surveillance networks and mobile units, both terrestrial and airborne— with calculations. In complex scenarios, with significant releases and people potentially irradiated, decisions on their treatment would require an initial screening (triage), decontamination if needed, followed by a more detailed dose evaluation using biological dosimetry and whole body counting, also for babies and children, together with in vitro measurements of biological samples and other methods. Attention is necessary to thyroid dose monitoring, especially for children and pregnant women.

In the intermediate phase, a detailed radiological characterization of the environment -including air, food and water, with particular attention to hot spots-, is essential for decisions concerning the termination of the urgent protective actions adopted during the early phase and for the adoption of new countermeasures, mainly food bans, decontamination of areas and particularly the relocation of people from the hottest zones. Measurements of concentrations of radionuclides in foodstuffs and in the environment locally are key elements. Also, besides the official experts, other actors like affected citizens or local institutions may collect radiological data, and a challenge is to develop protocols to assist in such data collection by stakeholders and how to integrate them. Realistic dose projection models should be employed together with those monitoring data to produce a good assessment in which to base such transcendental decisions.

Likewise, to allow people knowing their radiation exposure, including where, when and how they are exposed, suitable individual dosimetry systems should be made available to the public, with qualified personnel ready to help them.

Conclusions

The great challenge for improving emergency preparedness and response is the participation, motivation and commitment of the interested organizations and the population. A good preparedness must address all the challenges identified, develop representative accident scenarios for training and testing of protocols, and favoring interaction and cooperation between experts and stakeholders through open networks.

Decision making in a nuclear or radiological emergency and how monitoring supports this

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Introduction

Decision-making in case of nuclear or radiological emergencies have to deal with large uncertainties, in particular in the early phase. Decisions are often taken based on prognostic simulations that consider the possible source term, the start of the release and the weather conditions.

Methods

The decision-making team applies often so called decision support systems (DSS) that can digest all the necessary information to perform the prognostic calculations. The DSS contains also information about necessary countermeasures such as evacuation, sheltering, distribution of iodine tablets and food restrictions. However, as soon as measurements become available, in particular from dose rate monitors, decisions can be adapted.

Results

This presentation informs about the information needs for decision making in a nuclear or radiological emergency highlighting the uncertainties in the early phase and demonstrating means to reduce uncertainties by using monitoring information as well as combinations of simulations and monitoring information. The consequences of a nuclear detonation – a threat that has received new attention recently – will be also briefly discussed.

Conclusions

Mathematical models together with monitoring information have the potential to significantly reduce uncertainties in the case of decision-making during a nuclear or radiological emergency. The important point is the question how to best combine them.

Monte Carlo Analysis of dosimetric issues in space exploration

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Introduction

The radiation protection is of paramount importance in the planning of human exploration activities in space.

The related risks must be considered with respect two aspects: devising a proper shielding and answer to the requirement of an effective dosimetry evaluation during astronaut activities.

Both aspects have been considered using as reference tool the Monte Carlo code MCNP 6.2.

As case study a possible application to the NASA Artemis program has been chosen.

The project aims to establish a sustainable human presence on the Moon, envisioning the realization of an outpost that will serve as a steppingstone for space exploration endeavors.

Methods

A Class III shelter, ISRU derived habitat with local resources available on the Moon, has been designed through computational methods and topology optimization techniques, and analyzed in terms of radiation shielding performances and structural behavior.

Results

The outpost must be able to withstand temperature variations, micrometeorite impacts, and the absence of a substantial atmosphere.

Any solution studied to respect the constraints must devise robust and innovative materials and techniques to create habitats that have as goal the shielding from the Galactic Cosmic Rays and from the solar flares to provide a safe and habitable environment at the time scales scheduled for the mission.

Resource utilization is crucial for sustaining long-duration missions on the Moon as envisaged in the ARTEMIS program.

This implies the outpost design must incorporate strategies for extracting and utilizing local resources.

Conclusions

The design of a lunar outpost for the NASA Artemis program is a complex undertaking that involves addressing challenges related to lunar environment, resource utilization, power generation, logistics, and crew well-being.

Overcoming such challenges will pave the way for the establishment of a sustainable human presence on the Moon and serve as a crucial leap for future space exploration missions.

Space Radiation Protection in the Modern Era: New Approaches to Familiar Challenges

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Introduction

Astronauts are exposed to many stressors during spaceflight, including reduced gravity, isolation, and elevated radiation levels. In contrast with the radiation environment experienced on Earth, the space radiation environment is dominated by highly charged, energetic heavy ions that deposit energy through interactions with atomic electrons and nuclei, producing secondary fields that challenge traditional shielding techniques. The unique radiation environment, demands on astronaut performance during space missions, and the lasting duty to protect astronauts from harm caused by space travel encourage a space-specific radiation protection paradigm founded in the principles of justification, limitation, and optimization.

Methods

Recent developments in space radiation protection include NASA's transition from a risk-based space permissible exposure limit (SPEL) to an effective dose SPEL; emergence of longitudinal radiation worker studies with chronic, low dose rate exposures similar to those experienced by astronauts; active pixel readout-based detectors that provides unique insight into the composition of the intravehicular space radiation environment; and active shielding concepts with the potential to drastically improve space radiation shielding approaches using far less mass than required by passive shielding alone. These advances are helping to close important knowledge gaps in preparation for extended human presence in space.

Conclusions

Despite the recent progress in space radiation protection, several important challenges must be addressed before long duration missions to the Moon and Mars can occur. These include characterizing the space neutron environment at ultrafast energies; understanding whether radiation and other spaceflight stressors act synergistically or antagonistically; and technology development required to implement active shielding on a mission scale.

Transforming Internal Dose Assessment: Unleashing the Power of Mathematical, Multiphysics, and AI Integration

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Introduction

Advancements in artificial intelligence (AI) have revolutionized modeling complex systems and large datasets, including the physiological behavior of internalized radiation. This focuses on AI-driven internal dosimetry research at Georgia Tech, aiming to improve modeling of multiscale systems in the human body.

Methods

To model anatomical variability in the inhalation pathway, 3D CT scans were used to reconstruct high-fidelity models of the oral cavity and airways using computer vision and convolutional neural networks. Computational fluid and particle dynamics models were employed to obtain particle deposition profiles from inhaled radioactive aerosols. Simulating a normal breathing cycle, particle deposition in the lungs for various particle sizes will be described using a Lagrangian tracking and a turbulence model. These results will be integrated with biokinetic models to study particle interaction, organ dose distribution, and temporal activity during the clearance process. Additionally, a novel data-driven approach using machine learning is being developed to reconstruct intake for biokinetic modeling. Leveraging historical data from large-scale experiments, a Bayesian framework approach was employed to determine the relative importance of features and better understand the landscape of data in exposed populations.

Results

An artificial neural network reconstructed inhalation activity with varying normalization and architecture complexity. Normalizing uptake achieved a minimized RMSE of 688.211 μCi, with predicted values having 0 variance and actual values 278539.027 (squared μCi) variance. Batch normalization on intake resulted in a minimized RMSE of 0.2517, with predicted values having a variance of 0.00215 and actual values 0.05602. Historical data quality posed challenges for rapid and accurate machine learning-based intake reconstruction.

Conclusions

The combination of AI and multiphysics models enables enhanced multi-scale physiological modeling, potentially integrating down to a radiobiological system scale. However, challenges related to the quality of historical data must be addressed to further improve the accuracy and effectiveness of machine learning models in intake reconstruction representative of the breadth of exposed populations.

Radiation **P**rotection and **D**osimetry in **N**ORM industries

An approach for the indirect determination of U-238 and Th-232 content in ceramic products based on gross alpha and gross beta measurement

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Introduction

In the ceramic industry some raw materials and products are NORM (Naturally Occurring Radioactive Material) with activities of the natural chains of ^{238}U and ^{232}Th higher than the exemption limits of 500 Bq/kg (RP 122, part II exemption/clearance levels). The activities of these samples are usually assessed by gamma spectrometry, however, in the case of small sample quantities or low activities, it is necessary to use alternative techniques with lower detection limits. They are based on radiochemical methods, which permit the direct estimations of ^{238}U and ^{232}Th activities, but they are more complex, time consuming and expensive. The aim of this work is studying the indirect characterization of ^{238}U and ^{232}Th in ceramic products using the quantification of gross alpha and gross beta activities in a low background proportional counter. This work is part of different research projects founded by the Valencian government (CIAICO/2021/290; IDIFEDER/2021/047).

Methods

Multiple Linear regression analysis has been used to predict the activities of ^{238}U and ^{232}Th considering as independent variables the gross α and gross β activities obtained in a LB-770-2. The uncertainty associated to the estimation of the ^{238}U and ^{232}Th activities is evaluated using prediction intervals. The models have been obtained for two groups of ceramic products, zirconium flours and micronized zircon, and spray-dried ceramic powders, and validated using a test sample.

Results

Four regression models have been obtained corresponding to ^{238}U and ^{232}Th activities for each of the two types of ceramic products analyzed. The models obtained to predict of ^{238}U activity explain more than 95% of the variability in the data. Regarding ^{232}Th prediction models, their predictive capacity varies depending on the product considered. Thus, for zirconium micronized flours the model explains 95% of the variability while for atomized zirconium it drops to a value of 65%.

Conclusions

The new approach for the indirect characterization and measurement of the ^{238}U and ^{232}Th radioactive content in ceramic materials has been demonstrated to provide quite good results in the case of secular equilibrium of the natural chains of ^{238}U and ^{232}Th, which has the advantage of being simpler, requiring a smaller amount of sample, less measurement time, and is also less expensive than radiochemical analysis or measurement by gamma spectrometry.

Determination of internal doses to workers exposed to suspended radioactive dust in the ceramic industry by radiochemical methods

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Introduction

Some of the raw materials used in the ceramic industry are NORM ("Normally Occurrence Radioactivity Material") with activities of the natural chains of ^{238}U and ^{232}Th higher than the exemption limits of 500 Bq/kg (RP 122, part II exemption/clearance levels). These materials can be found in suspended powder form, so they can generate internal doses to exposed workers by inhalation. In order to assess such internal doses, small sample quantities or low activities must be characterized to estimate ^{238}U and ^{232}Th chains by radiochemical methods. This work presents the results of the evaluation of internal doses in zircon sand milling plants, which is part of different research projects founded by the Valencian government (CIAICO/2021/290; IDIFEDER/2021/047).

Methods

The internal dose depends on the concentration and activity content of such powder in the workplace and the time of exposure of the workers. Dust sampling was carried out with personal air sampling (PAS) pumps in different companies for the most exposed homogeneous exposure groups (HEGs) following regulatory guides. To achieve the characterization of the radioactive content in the samples, a radiochemical procedure developed at the LRA-UPV was used for the determination of uranium and thorium isotopes by alpha spectrometry. The method consists of dissolving the sample by fusion with borate salts and separating the isotopes of interest with anion exchange resins.

Results

The average of the specific activities of ^{238}U and ^{232}Th obtained with the personal pumps for the filters analyzed by radiochemical separation were 2038 Bq/kg (RSD 32%) and 431 Bq/kg (RSD 34%) respectively. The results show that the filters have lower activity, approximately half activity than the raw materials handled by the workers. Based on these results, the internal dose for the HEGs corresponding to the personal filters analyzed range between 0.04 - 0.45 mSv/year, being lower than those calculated from raw materials, whose values vary between 0.07 - 0.7 mSv/year.

Conclusions

The study demonstrates that the annual internal doses received by these workers in the ceramic industry are all below the limit of 1 mSv. In addition, the developed radiochemical method obtained more realistic characterization of the radioactivity content in the suspended dust with half activity of the raw material. Therefore, the estimated internal doses indicates a lower exposure of the worker.

Determination of long half-life radioisotopes by mass spectrometry techniques in norm materials

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Introduction

Concrete is one of the most widely construction materials ever used. Its generalized use and the inherent content of some radioactive materials like U, Th, K make this material as a first order of importance to be permanently investigated. Despite the existence of several concrete reference materials, it is almost unavailable U, Th certified concrete. Recently the Joint Research Centre – European Commission organized a proficiency test on radioactivity in building materials. The most common analytical techniques for these purposes comprise alpha and gamma spectrometry.

We aim to present the preliminary results of a fast sensitive approach to determine U, Th and K in concrete by taking the capability of analysis of the atomic spectrometry and the power of the sector field configuration.

Methods

The three materials provided during the JRC PT were used in this work. Sample preparation was based on the well stablished method EPA 3052 total dissolution by acid microwave assisted digestion. Potassium measurement was performed by ICP-OES and ICP-QMS and uranium, thorium concentration was explored by ICP-QMS and SF-ICPMS.

Results

A comparison between the results obtained by using each technique is presented in this work.

The uranium reported as ^{238}U was significantly lower when ICP-QMS (83% recovery) was applied than by using SF-ICPMS (95% recovery). This behaviour is more substantial for the ^{232}Th analysis (67% vs. 92% respectively). On the other hand, ICP-QMS leads to poor potassium recovery due to the high spectral Ar interferences meanwhile the K recovery by ICP-OES was 90%

Conclusions

The use of microwave assisted digestion and the following measurement by atomic spectrometry allow the monitoring bodies to dramatically increase the capability of process samples. The application of SF-ICPMS in combination with ICP-OES offers a substantial advantage to the ICP-QMS in terms of precision and exactitude of the results but in terms of amount of sample required as well.

Radiation **P**rotection and **D**osimetry in **M**edicine

Computed Tomography Imaging analysis of a fused filament fabrication (FFF) 3D printed neck-thyroid phantom for multidisciplinary purposes

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Introduction

The application of the 3D printing technique for the development of low-cost phantoms is being investigated recently and requires a complex study of the interaction of printed materials with different types and qualities of radiation, as well as the characterization of printing filaments to correctly simulate human tissue. This study aims to present the Computed Tomography (CT) Imaging analysis of a fused filament fabrication (FFF) 3D printed anthropomorphic neck-thyroid phantom.

Methods

In this study, the commercial phantom ATOM MAX 711, from CIRS, was used as an anatomical reference for the 3D modeling base of the neck-thyroid phantom. Commercially available PLA and ABS XCT-A validated at IPEN were used in the 3D printing process in order to simulate soft and bone tissues respectively. It was used the RAISE3D PRO 2 FFF printer from IPEN. The imaging study of the phantom was performed through the analysis of images from a CT acquisition, comparing the Hounsfield Units (HU) numbers of the tissues between both phantoms.

Results

The modeling methodology of the 3D phantom of this study opens possibilities for using tomographic images of any objects, or even patients, to perform 3D prototyping of increasingly specific and customized simulators. The CT image analysis show great results on the analysis of the construction of the soft tissue with PLA filaments; construction of the bone tissues with ABS XCT-A; analysis of the construction of the thyroid accessory with epoxy resin; analysis of the spacing of the fit of the printed pieces; and analysis of image artifacts caused by the FFF technique.

Conclusions

The developed phantom is a feasible alternative to a tissue-equivalent phantom and presents the desirable characteristics for applications in radiation protection, measurements of radioisotopes incorporated in the thyroid (both contamination counters and nuclear medicine detectors) and training of techniques of acquisition of images with X rays.

Step-by-step of 3D printing a head-and-neck phantom: proposal of a methodology using fused filament fabrication (FFF) technology

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Introduction

3D printing has developed and become popular very quickly in the last 10 years. Its use in the health and biomedical applications. Phantoms that mimic the interaction of radiation with the human body have been manufactured for many years with various technologies with great demand in use, however, its availability is restricted, and its cost is high for considering importation taxes and exchange rates in Brazil. Thus, this paper aims to share the step-by-step of 3D printing a head-and-neck phantom using of a fused filament fabrication (FFF) technology.

Methods

For this study, a CIRS 711 Atom Max phantom CT image was used as a basis for the segmentation of the phantom. Radiopaque FFF filaments XCT-0, XCT-A and XCT-C were used to build soft tissue, bone, and dental enamel respectively. The phantom's design and segmentation were performed using the "3D Slicer Software", as 58 different 3D models of the slabs of phantom and it was used a GTMaX Pro Core H4 3D printer accoupled with a Mosaic Pallet multimaterial and Simplify3D software to print the phantom. An imaging analysis was then performed in order to compare the original CIRS 711 Atom phantom and the 3D printed.

Results

The proposed methodology of this study shows possibility of use of tomographic images of any objects, or even patients, to perform 3D prototyping of increasingly specific and customized phantoms. The phantom imaging comparison show great results on using FFF filaments to mimic the main human tissues of the head-and-neck region.

Conclusions

This methodology represents a feasible alternative to develop CT tissue-equivalent phantoms with the desirable characteristics for radiation technology and biomedical applications. In addition, the developed phantom is cost-effective and can be obtained with around 10% of the budget of a commercially available phantom.

Integral Dose Comparison of VMAT and IMRT for Rectal Cancer Treatment: A Dosimetric Analysis

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Introduction

Colorectal cancer has became the first leading cause of cancer for Taiwan in the year 2020, accounting for a total of 16,829 new cases and the third leading cause of cancer deaths (6,489 deaths). The latest guideline have suggested preoperative radiotherapy combined with chemotherapy (CCRT) followed later by rectal tumor resection as a treatment option for advaanced stage III rectal cancer, this method have down-staged the rectal cancer, resulting in improved local control and survival. Intensity-modulated radiation therapy(IMRT) is currently used as the standard technique for CCRT of rectal cancer.

IMRT, however, uses a larger number of monitor units (MU) to achieve a highly conformal radiation distribution to the tumor target volume while sparing the surrounding organ at risk (OARs) structures, leading to an increase in the amount of low dose radiation to the surrounding normal soft tissues of the body, this increase in low dose radiation has led to concerns of increased risk of secondary radiation-induced malignancies for patients with long life expectancies.

Volumetric-modulated arc therapy (VMAT) is a technique wherein treatment is delivered using a cone beam that rotates around the patient. The cone beam is modulated by dynamic multileaf collimation, variable dose rate and variable gantry speed to generate IMRT-quality dose distributions in a single optimized arc around the patient. VMAT treatments can significantly reduce the time and monitor units required to deliver for the treatment, and resulting in a lower the radiation dose to the surrounding normal tissue.

The integral dose (ID) is the product of mass of tissue irradiated and absorbed dose, it describes the energy deposition within the whole body, it is generally accepted that normal tissue complication risk and secondary malignancies risk increase as the ID increases. The aim of this study was to analyze the the nontumor integral dose (NTID) to various organs-at-risk(OARs) and normal tissues imparted by IMRT and VMAT and to investigate whether VMAT have the potential to further reduce radiation exposure. NTID is defined as the ID of normal tissues minus the ID of clinical target volume(CTV).

Methods

In this study, IMRT and VMAT radiotherapy treatment plan were generated for 33 stage III rectal cancer patients treated with CCRT from 2015 to 2020. Radiotherapy for every patient was planned for total median dose of 50 Gy in 25 fractions. Image Guided Intensity Modulated Radiotherapy (IG-IMRT) was delivered using a 6 MV photon beam with either a Varian 21EX or TrueBeam STx linear accelerator. The Author CYY was primarily responsible for all contour delineation and verifying of the gross target volume(GTV), clinical target volume (CTV) and normal organ-at-risk, the CTV included the primary tumor, entire mesorectal tissue, and internal iliac and presacral regional lymph nodes up to the L5/S1 junction and 5 cm distal to the primary tumor, A 1 cm margin in all directions was added to the CTV to obtain the Planned Target Volume (PTV), our treatment goal was to deliver at least 95% of the prescription dose to 95% of the PTV, while keeping the normalization to the mean dose of irradiated volume of OARs within the allowed dose constraint. The mean NTID to various OARs for both VMAT and IMRT technique were then compared, the student T test was used to test for any statistical significance.

Results

The NTID for body normal tissue (214.2 vs 216.8), body volume encompassed by 20 Gy (152.6 vs 165.4), 30 Gy (103.4 vs 108.6), 40 Gy dose (72.3 vs 74.8), bone tissue of outside of the radiation field (24.7 vs 25.2) were significantly lower for the VMAT when compared IMRT ($p < 0.05$). The volume encompassed by the 5 Gy, 10 Gy dose, urinary bladder, large intestine and small intestine did not show any difference ($p>0.05$). The homogeneity index (HI) and conformity index (CI) for both VMAT and IMRT did not show any significant difference. ICRU 83 defines HI as the measure of uniformity of the absorbed dose distribution with the PTV, while CI was defined as the degree to which the prescribed dose conforms to the PTV. PLA filaments; construction of the bone tissues with ABS XCT-A; analysis of the construction of the thyroid accessory with epoxy resin; analysis of the spacing of the fit of the printed pieces; and analysis of image artifacts caused by the FFF technique.

Conclusions

VMAT offers an advantage over IMRT for preoperative radiotherapy of rectal cancer in terms of a shorter treatment time, a highly conformal radiation dose distribution around the PTV, thereby minimizing radiation exposure to the surrounding normal tissues in terms of normal tissue integral dose.

Dosimetric Analysis of High-Resolution Chest Protocols for Pediatric Patients on an Aquilion ONE ViSION Edition®

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Introduction

As CT is associated with relatively high radiation doses, it is therefore important to estimate as accurately as possible the radiation output from CT scanners. Otherwise, this can lead to an underestimated dose report - most worrying scenario - and as a consequence unnecessary exposure to radiation; mainly for pediatric patients. The aim of this study was to comparatively evaluate two high-resolution chest protocols applied in the pediatric CT routine of a private health institution, also providing an opportunity to carry out an important analysis in relation to the dosimetric phantom that IEC 60601-2-44 has been establishing as a standard for all trunk protocols.

Methods

Following the guideline provided by CT scanner manufacturer, the 160-mm phantom was used for small and medium bowtie filter sizes; and the 320-mm phantom for large size.

Results

The evaluation of discrepancy between the CTDIW values reported by CT scanner's display and those resulting from dosimetries, according to the 1-mm collimation and the 4-mm collimation respectively, allowed the following finding: reported value 54% lower than calculated value (small), reported value 53% lower than calculated value (medium) and reported value 9% higher than calculated value (large); and reported value 55% lower than calculated value (small), reported value 54% lower than calculated value (medium) and reported value 10% higher than calculated value (large).

Conclusions

The occurrence of deviations in significant non-compliance with the 20% tolerance level (limit recommended by IAEA), specifically for small and medium filter sizes, emphasizes the importance about IEC reviewing its establishment regarding the use of 320-mm phantom as standard for all trunk-related examinations protocols; since in the case of pediatric trunk protocols it has been demonstrated that the most appropriate should be the establishment of 160-mm phantom as a standard for younger age groups.

Development and Characterization of the CsI:Tl scintillator grown by the Bridgman technique for use as a radiation detector

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Scintillation materials are characterized by the emission of photons of visible or ultraviolet light when exposed to ionizing radiation, partially or totally absorbing the radiation. The present work aimed to grow crystals of pure cesium iodide (CsI) and activated with thallium (CsI:Tl) by the Bridgman technique. The thallium iodide dopant concentration was 10^{-3}M. The zonal refining technique was used in order to reduce the impurities found in the CsI salt. To quantify the impurities, the plasma optical emission spectrometry (ICP-OES) technique was used. The CsI:Tl crystals were submitted to physical-chemical characterization such as: X-ray diffraction to confirm the crystal lattice, transmittance of pure and thallium-doped crystals, luminescence emission with maximum emission peak at 520 nm due to the presence of thallium, Tl concentration distribution along the crystal and optical microscopy to compare the unpolished and polished crystal surface. To evaluate the response of the scintillator crystals regarding their detector characteristics, experiments were carried out using sealed radioactive sources, namely: ^{133}Ba (80 keV, 355 keV), ^{60}Co (1173 keV, 1333 keV), ^{22}Na (511 keV, 1275 keV), ^{137}Cs (662 keV) at room temperature. The study of light responses of CsI:Tl crystal after interaction with gamma radiation was performed by acquisition of single scintillation signals using a photomultiplier (ET Enterprise, Model 9924SB, England) and PIN-type photodiode. Data were processed with an integration time of 600 s. The growth of CsI:Tl crystals by the Bridgman technique proved to be efficient and can be immediately applied for detection of gamma radiation.

Characterization of a Commercial PIN Diode for Radiotherapy Photon Beam Dosimetry

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Introduction

In this work, the dosimetric features of commercial diodes (BPW34) are investigated for radiotherapy photon beam dosimetry by evaluating their dose response, dose rate dependence, field output factor, and percentage depth dose profile (PDD). The experimental results are compared with those available in the literature and, whenever possible, benchmarked against Varian Eclipse treatment planning system (TPS) predictions, essential for radiotherapy quality assurance programs.

Methods

The low-cost commercial PIN photodiode, BPW34, supplied by Osram, was manufactured in planar technology with an active area of 7.45 mm^2. The diode was covered with a black resin and connected in the photovoltaic mode to an integrating electrometer (PTW, Unidos E model) to be used as a dosemeter. The diode was positioned at the center of a PMMA plate with 30 x 30 cm^2 and 1 cm thickness, with its front face leveled with this plate surface. The dosimetric characterization was performed using a Varian True Beam 1762 accelerator, located at Real Hospital Português de Beneficência (PE), with filter flattening (FF) photon beams of 6 and 15 MV and filter flattening free (FFF) of 6 MV.

Results

The dose-response curves are linear (R^2 = 1) with less than 0.1% nonlinearity and 0.3% of repeatability parameters, regardless of the photon beam energy. The average dose rate effect (0.7%) is almost negligible within the range of 20-600 MU/min (6 MV, 15 MV) and 400-1400 MU/min (6 MVFFF). Despite these good results, the diode response depends slightly on the energy, within 5% for 6 MV-15 MV. Moreover, the general output field factor measurements and the percentage depth dose profiles are in excellent agreement with the Eclipse TPS calculations,

Conclusions

All assessed results adhere to the standard radiotherapy dosimetry protocols demonstrating that the diode BPW34 is a low-budget alternative radiotherapy photon beam dosemeter.

Optimization protocols for head CT scans using an adult and a newborn PMMA phantom

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Introduction

Computed Tomography (CT) scans promote a higher dose deposition than conventional radiology exams. These tests significantly contribute to the increase the patient and collective dose, being a public health concern worldwide. Today, there is a need to improve protocols to seek lower doses while maintaining the image diagnostic quality. The development of phantoms allows testing different acquisition protocols. For that, the phantoms must present an absorption characteristic of the X-ray beam similar to the represented patient.

Methods

In this work, two CT head phantoms were used, the standard head phantom and another with newborn head size. The objects are cylinders with 16 cm (standard adult) and 11 cm (newborn) in diameter and 15 cm in length, made of polymethyl-methacrylate (PMMA). Tests of acquisition protocols were performed on a Toshiba CT scanner, Aquilion Prime model with 80 channels. The central slice of the phantoms was irradiated successively, and using a pencil ionization chamber, measurements of CT air kerma index in PMMA (Ck,PMMA,100) were performed. From these results, the CT Dose Index values weighted and volumetric (CTDIw, CTDIvol) were obtained for 10 cm scans of the central region of the head phantoms, in helical mode. The scans were performed using different voltage values (80, 100 and 120 kV) and charge (mA.s).

Results

The absorbed doses of the new protocols tested in the adult standard head phantom varied from 19.72 to 27.39 mGy, with the lowest dose occurring with the use of a voltage of 100 kV and 200 mA.s and a pitch of 0.813. The optimized 100kV protocol promoted a dose reduction in the patient of 31.65%. In the newborn phantom with 11 cm, the absorbed doses of the new protocols varied from 23.00 to 43.92 mGy, with the lowest dose occurring with the use of a voltage of 80 kV, 250 mA.s and a pitch of 0.813. This protocol promoted a dose reduction in the newborn phantom of 47.63%. In optimized protocols, the optimized charge value (mA.s) was adjusted to the point where the noise in the central slice was less than 1%.

Conclusions

Proposed optimized protocols reduced the absorbed dose by up to 43.05% in the smallest phantom (newborn), with 11 cm in diameter. The results allowed to evaluate that, for the generation of images with the same diagnostic objective, the volumetric dose index showed a higher dose value in the newborn phantom, corresponding to a head with smaller volume, compared to the value measured in the standard head phantom.

Dosimetric parameters and radiation tolerance of epitaxial diodes for diagnostic radiology and computed tomography X-rays

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Introduction

Ordinary Si diodes are prone to radiation damage effects, which deteriorate their overall dosimetry performance with accumulated doses. This issue has been addressed by applying epitaxy technology to fabricate radiation-hard diodes with shallow, highly-doped monocrystalline layers. The dosimetry response and the radiation tolerance of these diodes for diagnostic radiology and computed tomography X-rays are reported in this work. Sensitivity calculations assuming the diode as a thin abrupt junction give theoretical support to the data.

Methods

The p^+-n pad diode (5x5 mm^2) consists of a 0.6 µm front highly doped p^+ layer on a 50 µm n-type epitaxial layer grown on a 300 µm Cz Si substrate. The diode is housed in a light-tight probe with the front electrode (p^+) connected to the Keithley 6517B electrometer in a short circuit mode. Irradiations are performed with a Pantak/Seifert X-ray generator standardized by Radcal RC3-CT and RC6-RD ionization chambers. The current sensitivity, repeatability, reproducibility, dose-response linearity, and directional response are evaluated with the diode positioned at the center of an irradiation field of 12 cm diameter at 100 cm from the X-ray tube.

Results

The current signals produced by photon beams of different qualities (50 -150 kV) are stable and characterized by repeatabilities better than 0.3%. The current response linearly depends on the dose rate (22-120 mGy/min). The dose-responses curves are also linear but slightly dependent on the photon energy. The angular dependence of the response for 70 kV and 120 kV reference photons is below 0.1% within an angle range of ± 5º. Investigations of the effects of radiation damage on the current response and the lifespan of the diode, assessed through measurements of its sensitivity as a function of increasing doses, are underway.

Conclusions

All results so far obtained meet the requirements of the IEC 61674 norm, pointing out that the epitaxial diode might be a reliable online dosimeter for medical imaging dosimetry.

Study of bolus material for impart dosimetric use in radiotherapy

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Introduction

The bolus material is a tissue equivalent material used in radiotherapy to increase skin dose for photon beams. For this work, a bolus was designed for additional use as a yes/no indicator of the irradiation process. Initially composed of glycerin, gelatin, water and formaldehyde, was adding clinical gel/copper sulfate pentahydrate. Copper sulfate was considered as a chemical indicator of radiation exposure by changing the color of the material when irradiated.

Methods

Two types of samples were prepared and studied: sample-01 prepared only with glycerin, gelatin, water and formaldehyde; sample-02 prepared with addition of clinical gel/$CuSO_4.5H_2O$ (0.1 %). The samples were irradiated in a Category II Multipurpose Panoramic Irradiator (MDS Nordion), equipped with a dry-stored cobalt-60. The samples were irradiated with 50, 80 and 100 kGy. To evaluate the color variation in the irradiated and non-irradiated samples, they were photographed and analyzed using the ImageJ® program, right after irradiation and six months later.

Results

Samples containing clinical gel/copper sulfate showed significant color variation after irradiation. The non-irradiated sample had a blue color which, after being irradiated, turned brown to red. Six months later the samples still had a different color than the initial one, but in shades of yellow.

Conclusions

The results demonstrate the potential of bolus material added with clinical gel/copper sulfate for additional use as yes/no indicator of the irradiation process. It encourages future work on this composite for dosimetric purposes, considering a late evaluation carried out within six months after irradiation.

Optimizing radiation dose of CT abdomen via modification of acquisitions protocols with figure of merit assessment

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Introduction

Advances in CT have aided in the improvement of medical imaging, leading to improved diagnosis and patient prognosis. The substantial rise in ionizing radiation to patients from CT scans is a matter of concern, therefore, it is necessary to optimize the dose to the patient without sacrificing the image quality. Hence, this study aims to provide a quantitative analysis comparison between the existing CT abdomen standard protocol and other established methods, with the goal of reducing dose while preserving the quality of the images.

Methods

This research was conducted using a 64-slice CT scanner (Canon, Japan) and a polymethylmethacrylate (PMMA) textural water phantom. The primary CT scan parameters such as tube potential, tube current, and pitch factor modified and altered for 6 different protocols (P1-P6). The phantom was composed of five cylinders, each one representing a distinct part of the human body. The volume weighted CT Dose Index (CTDIvol) was measured, along with the HU number, noise values, Signal-to-Noise ratio (SNR), and Contrast-to-Noise ratio (CNR). This study established the Figure of Merit (FOM) by measuring the ratio between the image quality parameters (SNR and CNR) and the CTDIvol.

Results

A substantial reduction in dose was observed in P6 in comparison to the standard protocol, P1, amounting to 34.85%. This was due to the high pitch factor, yet the noise values rose by 29.59%, thus significantly deteriorating the image quality. Increasing the tube current significantly increases both the SNR and CNR values. According to the results, P1 protocol has the highest FOM for soft tissue, and P2 protocol has the highest FOM for fat. P1 is good for abdominal examination as the attenuation factor is higher in soft tissues. Meanwhile, in P2, the higher tube current setting, allows higher beam intensity to improve the CT number for fat tissues due to its high-density composition. The FOM based on SNR is highly correlated with the CNR.

Conclusions

In conclusion, altering the primary factors of CT parameters will greatly affect the image quality. Hence, FOM is useful as an optimization tool that measure the overall performance of image quality for post-optimization assessment.

Lu PSMA on ambulatory basis, a radiation safety approach

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Introduction

Prostate cancer is a significant health concern globally, accounting for a substantial number of cancer-related deaths among men. In recent times, a promising radiopharmaceutical named Lutetium PSMA (Prostate-specific membrane antigen) has emerged as a cutting-edge therapeutic option for patients with metastatic castration-resistant prostate cancer (mCRPC).

Lu-PSMA therapy utilizes the targeted delivery of beta-emitting lutetium-177 to PSMA-expressing prostate cancer cells. By binding to PSMA, Lu-PSMA therapy enables precise radiation therapy to prostate cancer lesions, including distant metastases, while sparing surrounding healthy tissues.

While extensive research has focused on its efficacy and safety in patients, limited attention has been given to the potential radiation exposure faced by caregivers during ambulatory treatment settings.

This aims to calculate the effective half-life during the first 24 hours of this new radiopharmaceutical, compare it with Lutetium dotatate and predict the absorbed dose by caregivers who accompany patients undergoing Lu PSMA therapy on ambulatory basis.

Methods

The study utilized live dosimetry measurements to hospitalized patients during 24 hours. The detector was placed above the bed and the data was collected every minute.

Results

Lu PSMA effective half-life was shorter and showed less dispersion than Lu dotatate. Predicted dose for caregivers was estimated to be less than 0.1 mSv/cycle.

Conclusions

From a radiological safety point of view, is safe to treat Lu PSMA on ambulatory basis. However, in future studies, the amount of Lutetium discharged into wastewater should be considered.

Study on knowledge and practices in radiological protection in health care institutions (IPS) in the city of Medellin

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Introduction

In Colombia, the subject of radiological protection is still a topic that goes unnoticed by most people, including health professionals. Ionizing radiation is not seen and little is perceived, which is why occupationally exposed workers downplay its importance.

The clinical practices related to the taking of an X-ray study are also subject to bad practices, i.e., the personnel performing the radiology study, tomography, dental X-rays, among others, omit, for example, to use the personal protection and patient protection elements.

In 2018, the Ministry of Health and Social Protection issued Resolution 482 "whereby the use of ionizing radiation generating equipment, its quality control, the provision of radiological protection services and other provisions are regulated". Based on this resolution, health service providers must ensure that occupationally exposed personnel receive periodic training in radiological protection, that periodic examinations are performed and that good practices are guaranteed based on two principles: 1. radiological protection of occupationally exposed personnel and 2. patient safety.

Methods

A survey was applied to occupationally exposed personnel of one IPS in the city of Medellin to measure their knowledge and practices in radiological protection.

Results

The survey was answered by 20 people, of whom 80% have knowledge about radiation protection, 57% have received institutional training on radiation protection, 70% have bad practices in taking X-ray examinations, 40% do not use radiation protection elements, 35% do not use the personal dosimeter, 30% do not provide protection elements to the patient, 45% repeat the study by irradiating the patient more than once.

Conclusions

Substantial differences were detected in the respondents' knowledge and practices on radiological protection, therefore it is necessary to reinforce from the institutional quality models training focused on good practices for X-ray examinations.

Establish a simulation system and develop a mini-ridge filter for proton FLASH beamline

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Introduction

The objective of this study was to establish a simulation system for the proton FLASH beamline and develop a mini-ridge filter specifically designed for this purpose. Proton FLASH therapy is an advanced treatment technique that delivers a high dose of radiation in a short period, exceeding 40 Gy/s. The implementation of a static spread-out Bragg peak (SOBP) technique is of utmost importance to enable proton FLASH therapy at such a high dose rate.

Methods

To achieve this, a Monte Carlo simulation platform, implemented using the Tool for Particle Simulation (TOPAS), was constructed to simulate the beam characteristics of the proton FLASH beamline at the Radiological Research Core Laboratory of Chang Gung Memorial Hospital, Linkou branch. Additionally, the simulation platform was used to design a unique hexagonal mini-ridge filter capable of creating an SOBP for FLASH experiments. An in-house MATLAB code was employed to calculate the optimal aspect ratio for each layer of the hexagonal structure and facilitate the design process. The resulting mini-ridge filter was fabricated using 3D printing, and its 3D model, constructed with Autodesk Inventor software, was imported into TOPAS for SOBP property simulation.

Results

The simulation results demonstrated good agreement between TOPAS simulations and measurements. The mean proton energy for FLASH experiments was determined to be 231.7 MeV, and the depth at which 90% of the proton dose fell off (R_{90d}) in water was measured as 282.9 mm. Additionally, the measurement confirmed that the hexagonal mini-ridge filter effectively generated an SOBP with a width of 3.18 cm and a flatness of 4.91%.

Conclusions

The performance of the TOPAS simulation code was found to be suitable for simulating the FLASH beamline. Furthermore, the hexagonal mini-ridge filter system proved effective in producing a uniform radiation field for applications requiring SOBP FLASH therapy.

Quality control of the stereotactic radiosurgery procedure with the Alanine-EPR Dosimetry

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Introduction

Stereotactic radiosurgery (SRS) is a procedure that uses ionizing radiation usually in a single dose or in a maximum number of five fractions for the treatment of intracranial lesions. In this treatment is required that the prescription dose be restricted to the lesion only and have a pronounced dose decay in the adjacent healthy tissue. An extensive quality control program must be employed to ensure the quality of the entire treatment procedure. The purpose of this study was to investigate the use of an alanine-EPR dosimeter as a dosimetric tool for quality control of the stereotactic radiosurgery procedure using the Volume Modulated Arc technique (VMAT).

Methods

An anthropomorphic head phantom was used to simulate a patient and SRS planning was carried out using the VMAT with the HyperArc tool (VARIAN). Planning was carried out simulating a cranial radiosurgery treatment of 4 lesions (case of multiple metastases) with a prescription dose of 18 Gy. The Somaton Definition AS SIEMENS CT scanner was used for the location of the lesions, with a slice thickness of 0.6mm. The target volume of each lesion ranged between 1.03 cm^3 to 1.43 cm^3. The teletherapy planning system was performed in a single isocenter technique with non-coplanar arcs using the Eclipse v16.1 and the Acuros XB v16.1 dose calculation algorithm. Radiation of 6FFF was used with a maximum dose rate of 1400 MU/minute. Alanine pellets from Aérial, France were used for this study, and introduced in pairs in the phantom. The EPR measurements were conducted with a Bruker Magnettech ESR 5000, EPR spectrometer operating in the X band. The microwave power and modulation amplitude applied were 10 mW and 0,7 mT, respectively. The modulation frequency was 100 kHz. Initially, the alanine responses in terms of their energy dependence, dose rate, and dose calibration were evaluated.

Results

The results showed that the alanine-EPR response is linear with the radiation dose in the range of 2 to 100Gy, with a low energy and dose rate dependence. The results of the doses measured with alanine in relation to the planned value for the four lesions (PVT) were concordant, with differences smaller than 1.2%.

Conclusions

The use of alanine as a dosimeter for radiosurgery proved to be adequate and accurate. This experiment allowed a check of the entire stereotactic procedure with the VMAT with the HyperArc tool (VARIAN) including target stereotactic localization with CT, treatment planning, and irradiation. Consequently, both mechanical and dosimetric parameters can be evaluated at the same time and the total inaccuracy of the procedure can be assessed.

Performance evaluation of activity meters using the in-situ calibration methodology with ^{99m}Tc

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Introduction

Activimeters are measurement instruments used in nuclear medicine services procedures (NMS). Their efficiency in measuring readings must ensure with safety and reliability that the dose administered to the patient is in accordance with the medical prescription. To achieve this condition, it is necessary that the activimeters are well calibrated. Another important factor that can compromise the accuracy of their results is the type of container in which the radiopharmaceutical is packaged, with the difference in the geometry of the vial being the biggest source of error. The Instrument Calibration Laboratory (LCI) at IPEN provides radiation measuring instrument calibration services for hospitals, industries, and clinics located throughout Brazil. It is also responsible for calibrating all activimeters used in the IPEN Radiopharmacy Production Center (CERAF). Activimeters are difficult to remove due to their ionization chamber being too heavy and they are usually installed in controlled areas with difficult access. Due to these factors, in-situ calibration methodologies have been developed where there is no need for removal. The objective of this work was to implement and evaluate one of the in-situ calibration methodologies proposed and developed at LCI.

Methods

Eleven activimeters belonging to CERAF that are in this condition, where there is no authorization to remove them from where they are installed, were tested. To compare the performance of these activimeters, the reference activity meter called the Standard Working System, belonging to LCI, was used. The radioactive sample, ^{99m}Tc, was deposited in two vials: the calibration standard 10R Schott used by the National Physical Laboratory and the IPEN vial usually used by CERAF for the production and commercialization of radiopharmaceuticals. Ten measurements were recorded at intervals of 30 seconds in each activity meter, considering the mean of the obtained reading.

Results

With these registered data, uncertainties were calculated with results always below 0.5% and calibration coefficients different from one were found.

Conclusions

All the activimeters tested in relation to the reference activimeter belonging to LCI have shown the need for proper calibration and that the continuity of the tests should be maintained.

Dosimetric approach of Au-198 nanoparticles with radiochromic film

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Introduction

Gold nanoparticles (AuNPs) stand out for the possibility of having unique physical-chemical properties, for being stable, easy to prepare and for having better penetration capacity due to their small size. AuNPs can be widely used for diagnostic purposes and for application in brachytherapy. Thus, with the dosimetric characterization of 198-AuNPs it will be possible to obtain relative dosimetric data of 198-AuNPs. Film dosimeters are of special interest for dosimetry, as they allow it to be performed in a two-dimensional and continuous conformation. The objective of this work is to perform the calibration of radiochromic films irradiated by a known source and subsequently the dosimetry of Au-198 nanoparticles.

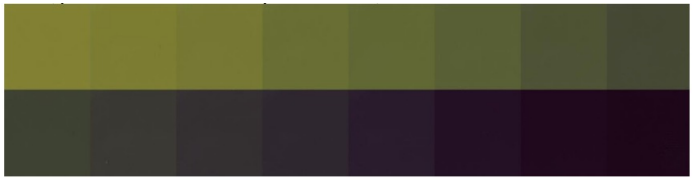
Methods

The model that was used in this work is Gafchromic External Beam Therapy 3 (EBT3). For the dosimetric system calibration process, the films were cut into 3 cm x 3 cm. Irradiations were performed at selected doses of 0, 10, 25, 50, 75, 100, 150, 200, 250, 300, 400, 500, 70, 1000, 1500, 2000 cGy by a panoramic Cobalt-60 source. For the reading, as well as for the calibration, the EPSON Expression 11000XL scanner was used.

Results

Figure 1 shows the images obtained in the region of interest for the films in each of the irradiated doses. The dose response in this dosimetric system follows the shape of the positive course of a sigmoid curve.

Figure 1: Images of the film's regions of interest used for calibration at different doses, from 0 to 20 Gy. The dose increases according to the darkening colors, from left to right, passing the line from top to bottom.



From the calibration curve, it is possible to establish the absorbed dose by a given film just by subtracting the image of the same film before irradiation.

Conclusions

After obtaining the calibration curve, a quantitative relation between the intensity of the signal detected in a single channel and the dose that is being analyzed experimentally using a source of AuNPs-198 is established.

Assessment of new dose metrics in pediatric computed tomography

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Introduction

New dose metrics have been recently proposed in computed tomography (CT) as a way to improve the estimation of doses received by patients. These metrics are based on size-specific dose estimates – SSDE, using correction factors to the traditional dose metric reported (computed tomography dose index – CTDI) that take into account patient´s body size and attenuation. Particularly for pediatric patients, which body´s proportions varies with age, clinical adoption and calculation of these new dose metrics have been a challenge. In this study, SSDE values were calculated based on effective diameter (D_{eff}) and water equivalent diameter (D_w), analyzing its clinical implementation with different approaches in pediatric computed tomography.

Methods

Two commercial anthropomorphic pediatric phantoms (6 years old) were irradiated under different clinical imaging protocols, simulating chest and abdomen CT. $CTDI_{vol}$ measurements were also performed on these phantoms. For each imaging protocol, $CTDI_{vol}$ values measured and reported by the scanner were collected and size-dependent correction factors based on body dimensions (anteroposterior and lateral thicknesses) and body attenuation were calculated to determine SSDE. Geometric and attenuation-based methodologies to obtain SSDE were analyzed for both chest and abdomen CT.

Results

A correlation was observed between $CTDI_{vol}$ and SSDE values. Differences from SSDE calculated using D_{eff} and D_w under different clinical imaging protocols were noted. A combination of AP and LAT dimensions showed to be more appropriate to calculate SSDE. There were considerable differences from SSDE calculated using D_{eff} and D_w for the chest CT examinations. The attenuation-based approach required more effort and time to calculate SSDE.

Conclusions

The implementation in the clinical routine of the SSDE based on D_w is recommended, particularly for chest CT examinations. New dose metrics based on the patient´s body attenuation and size have significantly improved the accuracy of dose estimation compared to $CTDI_{vol}$ in pediatric computed tomography.

Typical values of CTDI, DLP and SSDE for pediatric computed tomography in Brazil

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Introduction

Computed tomography dose index (CTDI) and dose-length product (DLP) are traditionally used as quantities to establish diagnostic reference levels (DRLs) in computed tomography (CT). With the advent of new descriptors based on patient size, metrics such as size-specific dose estimates (SSDE) have gained importance, particularly in pediatric computed tomography. A survey of typical values of these quantities is the first step to assist the optimization process. In this way, this study aimed to carry out a survey of the dose metrics (CTDI, DLP, and SSDE) from pediatric CT examinations performed in Brazilian hospitals.

Methods

Radiation dose reports from pediatric CT examinations were collected from four general hospitals and one pediatric hospital. Besides that, patient's data (gender, age, weight, height), anteroposterior and lateral dimensions from CT images and clinical justification or diagnostic hypothesis were also evaluated. All data were categorized and analyzed according to patient´s age and weight, and examined regions (head, chest and abdomen): 0-1, 1-5, 5-10, 10-15 and 15-18 years; 0-5, 5-15, 15-30, 30-50, 50-80 and >80 kg. SSDE was calculated from size-dependent correction factors applied to $CTDI_{vol}$. Typical values were determined from distribution of dose metrics for each group of pediatric patients and CT examinations.

Results

Pediatric CT examinations accounted for between 4% and 10% of all CT examinations performed in general hospitals. The calculated SSDE were systematically higher than $CTDI_{vol}$ values for each stratified group of patients. $CTDI_{vol}$, DLP and SSDE showed a positive correlation with the patient's effective diameter.

Conclusions

SSDE has proven to be a more labor-intensive quantity, but one that improved dose estimation for pediatric patients of different sizes and that could be adopted as DRL. Typical values determined in this study are a starting point for the optimization process and the implementation of national DRLs in pediatric CT at Brazil.

Study of Radiation Dose in Conventional Pediatric Radiological Examinations

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Introduction

The aim of this study was to evaluate the radiation dose received by pediatric patients in conventional radiology examinations in a large pediatric hospital in Brazil. Kerma-Area product (KAP) and incident air kerma (Ka,i) values were measured from examinations of the chest (Antero-Posterior and Lateral), skull (Antero-Posterior, Lateral and Towne), abdomen (Antero-Posterior and Standing Antero-Posterior), pelvis (Antero-Posterior and Frog) and sinuses (Antero-Posterior, Lateral and Waters).

Methods

Two methods were used to estimate the dose for each exam: the incident air kerma calculation, based on the X-ray tube output values and technical parameters; and also, a dose-area product meter (μGy*m²) manufacturer-coupled to the equipment. Anthropometric data of the patients (weight, age, height and thickness), radiographic technique data (voltage, electric current, exposure time and dose-area product) and examination classification data (clinical indication) were collected. The research involved 632 pediatric patients between 0 and 17 years old and 1400 projections. The patients were classified into 4 age groups, weight and body mass index, as children can present great variations in development and only one classification does not reflect the reality of the population.

Results

The results obtained were compared with other studies and with international dose reference levels. Data analysis showed a heterogeneous population within the same age group, resulting in the use of different radiographic techniques in the exams. The projections showed values of incident air kerma and kerma-area product higher than expected for weight and age. In the routine of the service, the anti-scatter grid was used in all examinations.

Conclusions

Considering that each study uses different technologies, it is important to perform an optimization analysis in order to assess whether the values reflect the radiation levels of the imaging center.

Attenuation images of Optical CT using Fricke xylenol solution for dose mapping in radiotherapy

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Introduction

Fricke gel solution is interesting for dosimetry due to its density close to water. Ionizing radiation produces chemical reactions in the Fricke solution that generates ferric ions proportionally to the absorbed dose. Combined with a binder and edible gel, Fricke Xylenol Gel (FXG) allows 3D dosimetry. Optical computed tomography is used to reconstruct three-dimensional images of the solution, correlating attenuation variations with the deposited dose.

Methods

A flask with FXG solution 7 cm height and 5 cm in diameter was positioned inside a water phantom with dimensions 30 cm x 30 cm x 20 cm. Irradiation with a dose of 5 Gy was delivered using a cobalt-60 gamma source from the Theratron 780c system with a 10 cm x 10 cm field size and source-surface distance of 100 cm. Lead filters 3 mm and 5 mm thick and 14 mm diameter were fixed in the flask, positioned in front of the beam and irradiated with 5 Gy also.

Results

The FXG solution was evaluated using the Vista 16 equipment (ModusQA) before and after irradiation. The results of these evaluations are reconstructed images from the obtained projections. From these images it is possible to extract the attenuation values of each region of the irradiated FXG solution. Figure 1 shows (a) the irradiated region without a lead filter, (b) the region with a 3 mm lead filter, and (c) the region with a 5 mm lead filter.

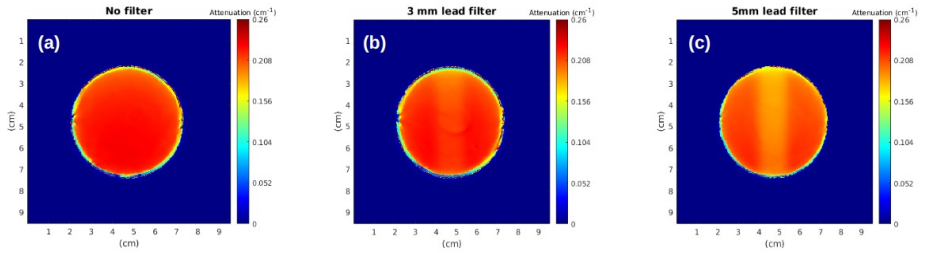

Figure 1: Reconstructed images of the FXG solution regions and a color bar correlated to the attenuation value. (a) Irradiated region of the FXG solution without a filter, (b) irradiated region with a 3 mm lead filter, (c) irradiated region with a 5 mm lead filter.

Conclusions

The optical computed tomography technique used in this study presents the potential to be employed in future works to evaluate the doses delivered in radiotherapy procedures. The relationship between dose and attenuation can be used to predict the dose distribution in irradiated tissues allowing a more precise assessment of treatment efficacy and minimizing the risk of collateral damage to the patient.

Monte Carlo multiscale modelling of photon and proton distribution in heterogenous tissue

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Introduction

Improvements in radiotherapy treatment outcomes can be achieved by reducing uncertainties in dose distribution. Treatment planning cannot effectively calculate dose distribution in complex heterogeneous areas, which increases uncertainty associated with dose distribution. This research aims to study microscopic dose distribution in temporal bone and cochlea.

Method

An open-access DICOM format of the data for the resected temporal bone and cochlea tissue was used with the FLUKA MC code to imitate potential high-dose scenarios associated with volume-modulated arc therapy using the FLOOD option. Twenty-three photon and proton energy levels ranging from 0.055 to 5.5 MeV for photons and 37.59 to 124.83 MeV for protons were simulated separately to calculate dose distribution.

Result

The largest proportion of the dose (48.8%) was deposited in high-density bone, with photon distribution in the low energy range 0.055-0.09 MeV, whereas above 0.125 MeV, the change in dose distribution occurred in low-density tissue where there was a greater deposition, reaching 53%. The dose distribution in the soft bone's intermediate density was 26.4% at 0.07 MeV and dropped to 19.7% at 2.5 MeV. There was a 29% percentage difference in dose distribution on the soft bone between the low and high energy. Dose distribution in low energy (37.59 MeV) did not show any significant changes in protons between the low (54.86%), intermediate (19.75%), and high-density (25.39%) areas. Similarly, the dose distribution in high energy (124.83 MeV) was 54.21% in low-, 19.79% in intermediate-, and 26% in high-density areas.

Conclusion

The simulation concluded that the proton dose distribution was not affected significantly by the region's heterogeneity in micro-CT data. The photoelectric effect in low energy beams did not add a significant dose to the soft bone, depositing the dose in high-density bone, despite having a small weighting factor in low energy compared to high energy.

Feasibility Study of Fricke Xylenol Gel as a Dosimeter for Low Dose Rate Brachytherapy Sources

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Introduction

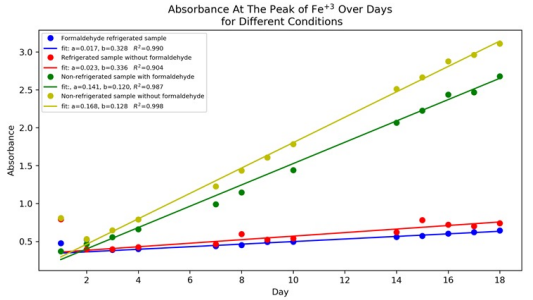
The Fricke Xilenol Gel (FXG) is a widely used chemical dosimeter in medical dosimetry. Its main limitation lies in its tendency for auto-oxidation, which restricts its use to short-duration exposures. The focus of this study is to evaluate a dopant and storage conditions that enable the utilization of FXG in radiation sources with low dose rates and longer durations.

Methods

Dosimeters were produced with and without a dopant. The groups were evenly divided, with half of the samples being refrigerated and the other half kept at room temperature. Spectrophotometric data were collected from the samples over the course of several days, and the average absorbance was calculated for each group. The data were analyzed based on the absorbance at 585 nm, which corresponds to the peak of Fe^{3+} and reflects the dosimeter oxidation.

Results

The addition of formaldehyde as a dopant proved to be highly effective in reducing the natural oxidation of the dosimeter. Temperature also played a crucial role in controlling the dosimeter's natural oxidation. The results obtained were promising towards the intended objective.



Conclusions

The non-doped samples kept at room temperature showed a growth of 2.579 in absorbance at the Fe^{3+} peak, whereas the doped samples refrigerated only exhibited an increase of 0.166. This demonstrates that this method can be effective for dosimetry of low dose rate sources that require longer irradiation times, due to their low natural oxidation.

Investigating a dopant for mitigating the natural degradation of Fricke Xylenol Gel dosimeters

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Introduction

Despite its excellent properties, such as tissue equivalence, which make the Fricke Xylenol Gel (FXG) dosimeter highly attractive for medical dosimetry, it has a limitation in terms of irradiation time compared to other dosimeters due to the oxidation of iron ions by external influences other than radiation. One possible solution to address this limitation of the FXG is the addition of a dopant that minimizes external oxidation. This study aimed to evaluate the feasibility of adding formaldehyde as a stabilizer and compare its long-term effects on the dosimeters.

Methods

Dosimeters were produced with different concentrations of a pre-prepared dopant solution and irradiated in groups with various doses. Spectrophotometric analysis was performed to calculate the average absorbance of dosimeters irradiated with the same dose and to analyze the spectra. Additionally, an analysis of absorbance over time was conducted in the Fe^{+3} region for both the irradiated dosimeters and a non-irradiated group.

Results

The results demonstrate formaldehyde as a promising dopant when used in intermediate quantities for mitigating the natural oxidation of the Fricke Xylenol Gel dosimeter.

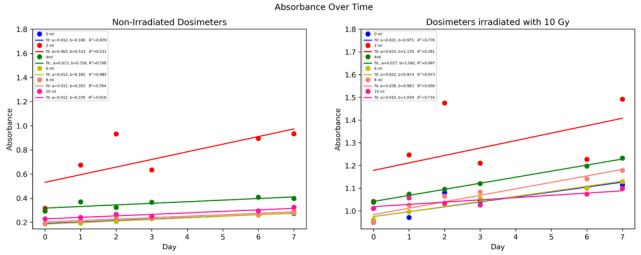

Figure 1: Average absorbance over time for different dopant quantities in irradiated and non-irradiated dosimeters.

Conclusions

It was found that irradiated dosimeters undergo accelerated degradation, which can be mitigated by adding an intermediate dose of a dopant. Adding small amounts does not yield significant differences compared to dopant-free dosimeters, while high amounts lead to a loss of sensitivity.

Personalized dosimetry in ^{177}Lu-DOTATATE/DOTATOC treatment with a single measurement to the patient after 4 days. Theoretical-practical analysis of the proposal of Hänscheid et al. with patients at La Fe hospital in Valencia, Spain

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Introduction

Activity in patients is usually measured several times after administration of the radiopharmaceutical to estimate its effective half-time (T_{eff}) in organs and lesions, thus evaluating the dose. Hänscheid et al. propose a single measurement after 96 h. This work analyses its validity with patients at La Fe hospital, Valencia, Spain.

Methods

Dose can be estimated (assuming monoexponential decay) as where t_i is the time from injection to measurement of activity A and S is a conversion factor from activity to dose rate.

It is not possible to know T_{eff} by performing a measurement, the approximation is proposed so that the dose can be estimated as , making it unnecessary to know the value of T_{eff}. If measurements are made at 96 h, this approximation is valid up to 10% difference for the range of values T_{eff} = [38, 128] h. Range of radiopharmaceutical T_{eff} in kidney and lesion measured are equivalent for the 13 patients at La Fe hospital (24 kidneys and 17 lesions) and for the 29 patients by Hänscheid et al (54 kidneys and 30 lesions). T_{eff} for each patient fits within the range of [38, 128] h.

Results

Theorical relative differences in dose calculation when using the approximation and measuring at 96 h are as follows in La Fe patients: 9 kidneys and 5 lesions have less than 5% difference. 14 kidneys and 11 lesions have between 5% and 10% difference. 1 kidney and 1 lesion have a 13% difference.

Conclusions

An alternative method for performing dosimetry supported by theory is presented, and its validity should be checked with experimental measurements.

The absorbed doses in different organs and lesions could be estimated with reasonable added uncertainty (~10%) by performing a single measurement 4 days after administration of the radiopharmaceutical.

This method drastically decreases the workload and machine time employed. It does not reduce patient visits to the hospital.

Thermoluminescence study of a novel Yb^{3+}/Tm^{3+}-coactivated CaF_2 material for radiation dosimetry applications

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Introduction

This study shows the most important features of a new TL material (CaF:Yb,Tm) for dosimetry in Medicine. Stability of the traps and their structure is addressed, as well as the response and applicability in Medicine. In addition, the study performs an analysis of the GCF and the kinetic parameters with the Tm-Tstop and VHR classical methods.

Methods

Two compact samples (CaF-Tm and CaF-YbTm) were fabricated using an own method of pressure and annealing (Rodriguez, R., et al.). SEM/EDX elemental mapping and composition were obtained at the UAM (Autonomous University of Madrid), Spain. Next, the TL response of the irradiated samples with gamma and X-rays was determined in the Ciemat External Dosimetry Service, accredited by ISO 17025 (Romero, A.M., et al.). Finally, the VHR method was used for various heating rates and the Tm-Tstop method through several pre-reading cycles.

Results

SEM/EDX analysis showed the homogeneity of the two prepared samples: CaF_2:Tm(0.5at%) and CaF_2:Yb(1.0at%),Tm (0.5at%). The stability of the irradiated samples was evaluated after 1 month of storage in the dark. The TL response of CaF-Tm and CaF-YbTm was quite different; regarding the second component, fading was significantly lower for CaF-YbTm. Another significant feature is related to the first component at low temperature, whose traps remain stable due to the added Yb. This behavior is especially useful for dosimetry of mixed fields neutron-gamma, e.g. in proton therapy, due to the different TL response between low and high temperature peaks (Muñoz I.D., et al.). In addition, fitting of the glow curves to the found kinetic parameters confirms a first-order kinetics.

Conclusions

This study determined a lower fading of the two TL components of CaF_2:Yb,Tm compared to CaF_2:Tm. The most relevant finding is that the incorporation of Yb allows maintaining the stability of the low-temperature TL component, particularly useful for dosimetry applications in Medicine.

Characterization of FXG dosimeters with gold nanoparticles for brachytherapy applications

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Introduction

Chemical dosimeters are based on detectors produced by chemicals sensitive to radiation. Fricke xilenol gel dosimeters have advantages such as well-known solution chemistry and tissue equivalence over a wide range of photon energies. In addition, it is also a viable and low-cost dosimeter, despite being non-reusable, and it can be implanted in the measurement laboratory and radiotherapy clinics. The objective of this work is to produce a Fricke xylenol gel (FXG) dosimeter with the addition of formaldehyde and gold nanoparticles for low dose rate brachytherapy dosimetry.

Methods

The FXG recipe was adapted using the previously established protocol with the addition of formaldehyde and different amounts of gold nanoparticle solution. A ^{60}Co source (Gammacell) was used for irradiation; to analyze the visible spectrum, a Shimadzu UV-1800 and for 3D attenuation analysis, a Vista16 optical computed tomography scanner with a 590 nm light source were used.

Results

The results were promising, showing that a small amount of 1%(v/v) gold nanoparticles significantly increased the sensibility of the dosimeter, showing that both Fe^{+2} and Fe^{+3} peaks increased absorbance with the addition of gold nanoparticles (Figure 1). Which is particularly important in medical applications where patient exposure to radiation must be minimized.

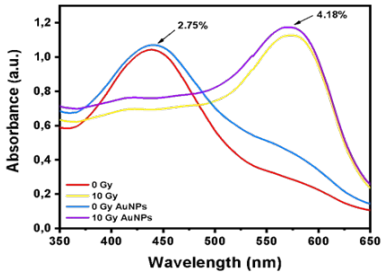

Figure 1: FXG spectra with the addition of 1%(v/v) gold nanoparticles with doses of 0 and 10 Gy.

Conclusions

Summarizing, the addition of gold nanoparticles to Fricke Xylenol Gel is a promising area of research that may result in a more sensitive and accurate dosimeter for ionizing radiation measurement. This could have important implications in medical applications, where accuracy in measuring radiation dose is essential.

Establishment of a local Diagnostic Reference level for Paediatrics Computed Tomography in Saudi Arabia

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Introduction

Due to the increased sensitivity of pediatrics to ionizing radiation and the radiation dose received during computed tomography (CT) examinations compared to other x-ray imaging techniques, it is necessary to monitor the pediatrics' CT doses to investigate and establish remedies to reduce the possibility of errors or negligence, that may lead to radiation doses unnecessary received by patients. This study aimed to estimate pediatric doses during CT procedures as a basis and part of the optimization process for pediatric computed tomography procedures.

Methods

The study was conducted using CT machines from various vendors. The study was carried out at radiology department at King Abdulaziz university hospital Jeddah, Saudi Arabia. Pediatric patients were defined as aging from 0-15 years. Each group divided into three sub-groups, group 1 (0-5 years), group 2 (6-10 years), and group 3 (11-15) years. Pediatric patient data related to radiation doses, including volume CTDI (CTDIvol (mGy)), dose length product DLP(mGy.cm).

Results

A total of 265 patients were divided into three groups according to their age. The mean and range for pediatric CTDIvol (mGy) and DLP (mGy.cm) were 374(10- 2373) ,334 (31-1739) ,508 (23-2393), and the CTDIvol (mGy) were 19.9 (0.4–153), 15.6 (0.36–83), and 19.9(1.2-101.1) for group 1,2 and 3,respectively. The estimated diagnostic reference level(DRL) in terms of CTDIvol (mGy) and DLP (mGy.cm) were 15.3 & 253, 22 & 436 and 14 & 600 for group 1,2 and 3, in that order.

Conclusions

Wide variation of patients doses were noticed up to 20 folds on average for the same clinical indication. The radiation doses are within the published diagnostic reference levels (DRL). Still, continuous efforts are required to optimize the imaging protocol based on clinical indication, patient size, and staff training for better dose reduction outcomes

Computational evaluation of the bucky components influence on the estimation of normalized glandular dose in digital mammography

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Introduction

The mean glandular dose (MGD) is the most suitable dosimetric quantity used in mammography to describe the absorbed dose by the breast, which cannot be acquired directly. Studies have provided conversion factors widely implemented in international dosimetry protocols to estimate MGD, such as normalized glandular dose (DgN). Over time, the DgN estimation was refined by considering geometric models that approach a real clinical environment, such as new anode/filter combinations, compression plate and breast models. However, there is no detailed study on how the bucky (support plate, anti-scatter grid and detector) can affect the DgN estimation.

Methods

A modified PENELOPE Monte Carlo code was used to DgN estimation. The irradiation geometric model was built as a complete digital mammography system, considering different typical bucky models present in commercial mammography units. The simulations were carried for mono and polyenergetic beams for different imaging geometries.

Results

Studies with monoenergetic beams showed that the bucky presence affected DgN mainly for higher beam energies and thinner breasts. The support plate was the bucky component that most affected the DgN, followed by the anti-scatter grid and finally, the image detector. Studies with polyenergetic conventional (low-energy) spectra showed that the bucky exerted minimal influence over the DgN values (<1.1%). For high-energy spectra, mainly employed in modalities such as contrast enhanced digital mammography, the DgN values were more affected by the bucky, increasing in 4.8% the DgN values for a 2 cm thick breast and a W/Cu 50 kV spectrum.

Conclusions

The bucky inclusion in computer simulations is highly recommended mainly for thinner breasts and high-energy spectra. To simplify the simulations, we suggested that a thick homogeneous carbon fiber block support, with thickness between 3 and 4 mm, placed under the breast, can be used as a substitute for a complete bucky model.

Optimisation of radiation protection procedures in angiography system commisioning

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Introduction

Angiography or arteriography is an invasive diagnostic method for examining the inside of blood vessels in the human body, arteries, veins and chambers of the heart. The purpose of angiography is to determine the anatomy and degree of obstruction inside the arteries. It is performed by injecting a radio-opaque, hydro-soluble (liquid-soluble) contrast agent, through numerous special catheters made for this purpose. They are injected into the blood vessel, and then an image of the blood vessels is taken with an X-ray technique - fluoroscopy (digitally or on film). Taking into consideration, the imaging procedure is performed in the presence of an angio team, max radiation protection of the personnel is highly important. Because of that, the aim of this paper is to optimize the procedures for radiation protection in angiography system commissioning. It implies, calculation of the thickness of the protective walls in accordance with the frequency of operation and utilization of the surrounding rooms; control of the working parameters of the angiograph; staff training for proper handling and compliance with the ALARA principle; control with personal dosimeters and control of lead protective clothing.

Methods

New GE Innova 2000 angiograph is installed in Acibadem Sistina clinical hospital. Number of employees is 12, number of procedures are 20/week. Utilization of fluorography / fluoroscopy up to 1500 s/procedure. Operating voltage - 120 kV max, 60 kV аверare, 88 kV most often used. TLD personal dosimeters are with monthly readings. Lead protective clothing (skirts, vests, suits and thyroid collars) 60 pieces in total, with frequency of control once a year.

Results

Measured ambient dose equivalent (0.037mSv/h at the workplace fluoroscopy in the controlled zone and 0.18 mSv at the work desk) ensure safe working in the area analyzed here. The monthly readings of the personal dose equivalent, Hp(10), show values in the range of 0.1 - 1 mSv, which is far below the permissible limit for professionally engaged persons. Even more, the worker shifts are planned on a way, everyone has more or less same professional exposure. Protective clothing control shows 1 damage every second year. The damaged piece is evaluated and removed from service.

Conclusions

Optimisation of the radiation protection procedures is necessary during angiography system commissioning, in order to improve the work conditions in ionizing area. To be able to achieve the maximum possible radiation protection during a specific angiography procedure, each part of the control chain is equally important. The training of the staff to optimize the parameters that will give a sufficiently good image with the minimum exposure is extremely important for the radiation protection of the staff and of course the patient.

A new natural detector (Curcuma Longa L.) for photodynamic therapy (PDT) measurements with blue LED irradiations: Application of Convolutional Neural Networks (CNN) and Multilayer Perceptron (MLP)

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Introduction

The objective of this work was to apply for the first time methods used in Artificial Neural Networks (ANN) such as Convolutional Neural Networks (CNN) and Multilayer Perceptron (MLP) for prediction and classification in the photodynamic therapy measurements with blue LED irradiations and a new natural detector from Curcuma (*Curcuma Longa L.*).

Methods

Artificial neural networks present great potential for modeling complex nonlinear relationships between independent and dependent variables, which may be viable in modeling scientific research results from irradiations carried out with LEDs and evaluated by the technique of UV-Vis spectroscopy.

Results

The training + validation and training + testing phases were suitable for models that use ANN in their computational experiments, which corroborates the excellent results obtained for the reconstructions and classifications carried out by CNN and MLP. In the reconstruction, the results of CNN were better than those of MLP.

Conclusions

Therefore, as a final conclusion, ND samples can be used in photodynamic therapy measurements as natural dosimeters for quality control associated with spectra reconstruction and classification via convolutional neural networks and multilayer perceptron computational experiments.

Computed radiography for total body irradiation: image quality and clinical feasibility

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Introduction

In radiotherapy, the risk of radiation pneumonitis after total body irradiation (TBI) is reduced by the use of lung shield (LS) blocks during each treatment session. Currently, MegaVolt (MV) imaging with dedicated silver halide based films is used for lung delineation (simulation) and position assessment (treatment). However, the availability of these films has recently become a problem. Therefore, Agfa NV has proposed a computed radiography (CR) solution for TBI. We investigated its clinical performance in comparison to the radiographic films and the potential improvement of image quality by filtering.

Methods

A standing position setup at 5m source-to-surface distance was employed to capture images of various objects for both simulation (6 MV) and treatment (15 MV) verification purposes using CR and classic film. The objects included an aluminum block and penetrameter (contrast and sharpness), the PTW EPID QC phantom (image quality), and an anthropomorphic chest phantom (clinical performance study with 2 independent observers). For CR, the influence on the image quality of different filter positions (before/after the active phosphor layer, inside/outside the cassette) and materials (copper, lead, Ba-based coating) was assessed. Dedicated Musica (Agfa NV) processing was applied for evaluation of the chest phantom images.

Results

The signal-to-noise ratio improved using filters in front of the cassette (lead vs. no filter: +19%), while placing filters inside the cassette also improved 10-90% rise distance (in: 1.32 mm vs. out: 4.72 mm). However, the use of processing had the largest impact on the visual grading analysis scores of the visibility of the clinically relevant anatomy for the chest phantom.

Conclusions

Overall, CR including processing and filtering is suitable for imaging for LS creation and position verification. Compared to radiographic film, the CR has the advantages of a shorter procedure time, a reusable image plate and lower dose delivery during simulation.

Connecting Monte Carlo multiscale dose distribution outcome with brain cancer VMAT and Gamma knife treatment

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Introduction

The treatment planning system (TPS) cannot effectively calculate dose distribution in complex heterogeneous areas, causing uncertainty that can affect treatment outcomes. Increasing model accuracy using micro-CT data and MC computation improves the calculation accuracy of dose distribution. This research aims to study microscopic dose distribution in temporal bone and cochlea in modern radiotherapy treatments.

Method

Cases were selected from 280 datasets of patients diagnosed with gliomas and 34 cases of schwannoma. An advanced model was created to connect Monte Carlo simulation using Micro-CT data to a clinical routine when treating brain tumours. An advanced model was created to calculate a weighted factor for the scattered dose to connect micro-CT data to the clinical routine of VMAT and Gamma Knife treatment.

Result

11 scenarios were identified from the database and divided into two groups. The first group had a lower distribution compared to the fluence distribution of the original data, and the second group had a higher distribution, and only mean dose (8.8%) and NTCP models showed clinical significance. A short distance (<1 cm) allowed more uniform dose distribution, producing a higher difference between the MC and the TPS. Extra cases were selected for further testing and divided into three categories; two had lower energy fluence than the original data and were not clinically significant in dose distribution and NTCP models. However, the third category had higher energy fluence indicating a clinically significant difference in dose distribution and NTCP models. Four cases in the Gamma Knife treatment of schwannoma cases revealed a significant difference in the scattering dose to the cochlea, with a maximum difference in mean dose reaching 8.3%.

Conclusion

The advanced model decreased the dose distribution uncertainty, which may help to increase the dose distribution to the target, thus improving treatment outcomes.

Calculation of ambient instantaneous dose rates (AIDR) depending on the mode of delivery in a single proton therapy treatment

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Introduction

Proton therapy is a firmly established therapeutic option for the treatment of many types of cancer, and a very active discipline from the point of view of technological development. Currently, there are several research areas with the aim of improving clinical results, reducing the size and cost of centers, and enabling access for more patients to this radiotherapy. Considering the physical characteristics of clinical proton beams, these improvements will definitely impact on radiation protection, sometimes in ambient instantaneous dose rates (AIDR), and consequently, the goal of this work was the calculation of these ambient dose rates, yielded in a single treatment, depending on the delivery modality, both, with actual techniques and others under development.

Method

The cornerstone of current active methods, Modulated Proton Therapy (IMPT), was compared with delivery modes under research, Proton Monoenergetic Arc Therapy (PMAT), Proton Flash Therapy (PFT), Proton Mini Beams (PMB), and finally, a blending active-passive method known as Pencil Scanning with Collimator (PSC). Calculations were developed using Monte Carlo codes (MCNP and PHITS) and experimental measurements, in IMPT and PMAT modes, whilst for PFT, PMB and PSC, only calculation with Monte Carlo were reached.

Results

Considering IMPT as baseline, results show that with PMAT, higher neutron fluences are yielded, but with lower energy, with great on activation, but lower on ambient dose equivalent. With PFT, however, current shielding should be reviewed with caution since the energies are the higher and the Ambient Instantaneous Doses Rates (AIDR) outside walls could overtake legal limits in some countries. With mixed methods, PMB and PSC, activation of collimators must be assessed.

Conclusions

Mitigating actions could be limiting orientation of beam and occupancies in some spaces, using special concretes in different areas, or change the design and location of treatment control room. Experimental measurements could help to achieve more precise assumptions, but neutron monitors must be able of measuring high-energy neutrons in pulsed fields. Active measurements should be supported with reliable data from passive monitors.

Natural detector irradiated with blue LEDs for measurements in Photodynamic Therapy (PDT) via Spectroscopy (UV-Vis), Design of Experiments (DOE) and Multiple Linear Regression (MLR)

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Introduction

Favored by chemical and biological means, the action of light incident to the focus generates relations with the photosensitizing agent, destroying cancer cells. The objective of this experiment is to investigate a satisfactory response for the use of Curcuma Longa L. (CLL) as a detector in Photodynamic Therapy (PDT) measurements.

Methods

The experiment consisted of a set of interconnected elements for the irradiations characterized in LEDs, for the irradiations in two concentrations of samples CLL-C1 and CLL-C2. Results of the spectra were evaluated in a Design of Experiment (DOE) associated with Multiple Linear Regression (MLR) for best response of the factors. The absorbance and wavelength readings were performed with 2^3 factorial in statistical analysis of the importance of the factors and their combinations.

Results

The results showed that detectors CLL-C1 and CLL-C2, propitious in their characteristics for the field of photodynamic therapy, equally the DOE and MLR evaluations; they are appropriate in the experiment for ascertaining the combinations of photosensitizer temperature and light.

Conclusions

In conclusion, the results of CLL samples indicate an acceptable linear response in function of dose, and therefore this material presents a potential use as a light radiation detector and for applications of quality control in photodynamic therapy.

Validation of a radiotherapy sector with an END-TO-END test in an anthropomorphic phantom for radiosurgery from a 3D printer

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Introduction

The present work aims to study the quality control in radiosurgery and to present the results of a phantom created in a 3D printer for END-TO-END testing (end-to-end verification test for the whole process of image acquisition, design, planning and dose delivery).

Methods

An END-TO-END test was carried out at the Hospital Regional de Juazeiro (HRJ) – Bahia, for the inauguration of the Radiotherapy Service. The test was carried out using a SIEMENS SOMATON tomograph and a VARIAN CLINAC CX linear accelerator, a dose of 10Gy and a dosimetric set consisting of: FC65-P - IBA ionization chamber and Dose 1 IBA electrometer.

The planning carried out used three radiation fields (angles of 0º, 270º and 180º), isocenter in the lesion and with the target being the sensitive volume of the FC65-P ionization chamber.

Results

Table 1 presents the collected dose (cGy) corrected by polarization factors K_{pol}, temperature, pressure and humidity K_{pt}, chamber response K_s and the difference defined (%) at the end of the test. It is part of a document delivered to the hospital that proves the validation of the END-TO-END test at the institution, so that the service can start its services.

Table 1. Result of the END-TO-END test performed at Hospital Regional de Juazeiro (HRJ)

Dosimetry	TPS[1] (cGy)	Reading (C)	Kpt	Kpol	Ks	Chamber Factor (nC/Gy)	Dose (cGy)	Difference (%)
Phantom	10.197	2.034E-7	1.010	1	1.003	20.91	9.724	4.63
		2.095E-7					10.015	
		1.952E-7					9.335	

[1]TPS - Treatment Planning System

Conclusions

The END-TO-END test is of fundamental importance to verify all possible errors during the patient flow in a radiotherapy service. The phantom presented results of extreme interest, a dose delivery below 5% difference between the planned and the collected doses, taking into account that the positioning at the time of the treatment presented a small deviation and this may have interfered in the result for a greater difference.

Repeated pediatric computed tomography examinations: Assessment of cumulative radiation dose and radiogenic risks

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Introduction

Computed tomography (CT) is the primary source of medical exposure to the general public for medical purposes representing 70% of the collective dose. Cumulative doses from CT procedures raised concerns about the biological effect of ionizing radiation due to the high dose per procedure. Pediatrics and children are more sensitive to ionizing radiation than adults due to their rapidly devising cells and long life expectancy. This study aims to calculate the cumulative dose, recurring radiation exposure, and potential radiogenic risks for pediatric patients during CT exams.

Methods

Data on pediatric cases from 2018 to 2023 were obtained from the radiology archives of King Abdulaziz university hospital Jeddah, Saudi Arabia. All investigations were conducted using two CT machines (SOMATOM Definition Flash & AS). CTDIvol and DLP of each CT study were extracted from radiology archives.Pediatric ages ranged from 0 to ≤15 years and were included in this study. The cumulative CT radiation exposure was estimated by summing typical CT effective doses per procedure. The effective and organ doses were estimated using CT-Expo software.

Results

The data showed that 2660 of the repeated exams for the age group 0-5, 1431 were females, and 1327 were males . . 485 (249 female and 332 males) of repeated exams for the age group 6-10 years. The number of repeated exams for the age group 11-15 years was 744 procedures (350 females and 394 males). The number of repeated CT procedures ranged from 2 to 12 for all groups. The mean and range of the DLP (mGy.cm) per procedure are 378(310-3986), 516 (129-4572), and 572 (160- 6474) for age groups 0-5, 6-10, and 11-15, respectively. The cumulative effective dose range from 65 mSv to 260 mSv. The average cancer risk per procedure is one cancer incidence per 1000 CT procedures.

Conclusions

The study showed that many repeated CT procedures were carried out frequently. The number of repeated exams is high and challenges clinicians and medical specialists. Pediatric doses varied up to 30 times for the same CT procedures, suggesting that the imaging protocol was not optimized. Implementing appropriateness criteria and establishing radiation protection guidelines ensures that CT scans are performed without unnecessary radiation exposure.

Evaluation of capabilities of a new measurement algorithm based on recombination chambers and methods, for radiation protection in medicine

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Introduction

Recombination chambers and methods are used in radiation protection and dosimetry, e.g. for the study of radiation fields used in medicine. A new measurement algorithm was developed and tested in experimental conditions, which allows for a significant reduction in measurement time, extending the possibilities of using recombination methods and detectors, especially in the area of dosimetry and radiological protection of the patient and medical staff in medical procedures using ionizing radiation.

Methods

The change in the measurement algorithm, and thus the entire electrometric system, mainly concerns the change in the method of data acquisition and the change in the operating mode of the electrometer. In the new algorithm, the current mode was changed to the integrating mode, in which the current is determined indirectly, as the derivative of the charge.

A measurements of a $D^{*}(10)$, Q_4 and $H^{*}(10)$ dosimetric parameters for the scattered radiation field around the Versa HDTM Elekta medical linear accelerator were carried out. Repeated measurements (for existing and new algorithm) were carried out for three accelerating energies of 6, 10 and 15 MV, for 5 gantry settings and 3 detector positions around the accelerator. Many tests were also conducted in the laboratory conditions.

Results

For only 2 out of 90 measurement points, the differences between the values for the two methods differed significantly. The new algorithm allows to increase the density of measurement points up to 200 times and shortens the measurement time about 20 times.

Conclusions

The results allow us to conclude that the new measurement algorithm not only fully replaces the existing one, but also significantly extends the measurement possibilities, e.g. studies of variable radiation fields. The improvement of the measurement time parameters is important from the point of view of radiation protection for medicine due to the dynamic changes of radiation fields in medical procedures.

Verification of electron radiotherapy treatment using micro silica glass bead TLDs

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Introduction

Verification of electron radiotherapy dosimetry is critical to accurately treat cancer patients. Silica bead TLDs have been used in photon beams, including in-vivo, due to small size, inert nature, high sensitivity, linear dose response, dose rate & angular independence[i],[ii],[iii]. This study is the first to characterise and evaluate micro silica bead TLDs for use in electron radiation treatment.

Methods

A radiotherapy linac (Varian Truebeam) was used to irradiate TLDs in various conditions: dose range 1-30 Gy, dose rates 100-1000 mu/min, and 0°,45°,90° angles, 6, 12 and 18 MeV. Characterization of response and Percentage Depth Dose (PDD) curves compared to reference data. A TLD reader (Harshaw 4500) was used. Each measurement point used 3-5 beads for repeatability/ uncertainty.

Results

A dose response linearity with an R^2 correlation coefficient of >0.999 was obtained for investigated range (fig1(a)). Dose rate response agreed within experimental uncertainty (fig1(b)). Response of beads with angles of irradiation was within ±1%. Maximum PDD shift to reference data (ion chamber) was 0.5 mm. Entrance dose measured -5.2%, -6.3% and -5.2% at 6, 12 and 18 MeV respectively. PDDs showed up to 2.0 mm differences in proximal and distal ranges of R_{90} at 6, 12 and 18 MeV. R_{50} range differed 0.0, 0.5, and 0.5 mm at 6, 12 and 18 MeV respectively (fig1(c)).

Conclusions

The results showed that silica beads TLDs' performance matched that of benchmark detectors and can be used as a novel dosimeter in electron dosimetry and for in-vivo assessment of radiation therapy.

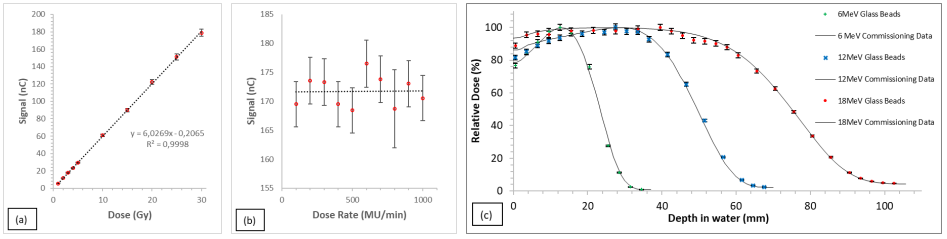

Figura 1: (a), Percentage Depth Dose (PDD) for 6, 12, 18MeV . (b), Dose rate response at 6MeV. (c), Radiation dose response at 6MeV

[i] S.M. Jafari (2014). Low-cost commercial glass beads as dosimeters in radiotherapy. Radiation Physics and Chemistry, 95-101

[ii] Antony L. Palmer (2017). Evaluation and clinical implementation of in vivo dosimetry for kV radiotherapy using radiochromic film and micro-silica bead thermoluminescent detectors. Physica Medica, 47-54

[iii] Maeve Masterson (2022). A review of micro silica beads in radiation dosimetry applications. Radiation Physics and Chemistry

Annual radiation exposure assessment of Diagnostic Nuclear Medicine Personnel

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Introduction

Nuclear Medicine (NM) personnel are exposed to ionizing radiation from external sources, mainly gamma-ray emitters. Previous studies showed that NM personnel may receive a high annual radiation dose during preparation, administration, and imaging procedure. This study aims to assess the annual radiation dose equivalent for nuclear medicine (NM) personnel (physicians, technologists, and nurses) for eight consecutive years.

Methods

Occupational exposure data from 2015 to 2022 were obtained from the NM department at King Saud Medical City, Saudi Arabia. The annual exposure data for 16 NM personnel were quantified and grouped as three physicians, 11 technologists, and two nurses. Thermoluminescent dosimeters (TLD) lithium fluoride (LiF: Mg, Ti) (TLD-100, Harshaw, USA) was used to quantify the staff doses. The TLD chips were in TLD dosimeter holders (type 8814 Harshaw). The occupational doses were quantified quarterly in terms of deep doses (Hp(10), mSv)).

Results

The average and range of the annual external radiation dose (Hp(10), mSv) during the eight years for NM physicians, NM technologists' and nurses were 1.3 (1.1-1.4), 2.1 (1.8-2.5), and 1.4 (0.8-2.0), respectively. Wide variation of annual exposure per staff member at the NM department. Hotlab personnel and nurses received the highest radiation dose compared to NM physicians.

Conclusions

The study showed that the annual radiation exposure for NM personnel is below the annual dose limit of 20 mSv/year. Annual doses showed wide variation per staff due to the workload and operator experience. Reduction of NM personnel doses is achievable by operators' training and strict adherence to protection measures.

Particle identification in proton boron fusion reaction using Timepix3 detector

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Introduction

Proton-Boron Capture Therapy (PBCT) is a novel possible approach of radiation therapy aimed at enhancing proton biological effectiveness to cancer cell killing. PBCT uses a nuclear fusion reaction between low-energy protons and ^{11}B atoms, which produces highly DNA-damaging α-particles. As a result of the interaction of low energy proton with ^{11}B nucleus, three alpha particles are generated, which eventually stop inside the tumor and release all their energy in cancer cells:

$p + {}^{11}B \rightarrow 3\,\alpha + 8.68$ MeV

This study presents experimental results about the ^{11}B (p, α) nuclear reactions, which were conducted using proton beams within the energy range of 1.25 to 2.5 MeV.

Methods

Experimental measurements have been performed at the Nuclear Physics Institute of the CAS, CANAM laboratory in Řež using 3 MV Tandetron accelerator. Low energy proton beams (2.5, 1.5 and 1.25 MeV) were incident on ^{11}B and natural boron isotope mixture targets. Generated particles were detected using pixel Timepix3 detector with 300 mm silicon layer. This device enregistered not only alpha particle emission from the nuclear reactions of protons with boron, but also backscattered protons.

Results

Python scripts and data processing engine (DPE engine) have been applied to analyze the obtained data. Detailed spectral and tracking analysis was performed by pattern recognition of the single pixelated tracks. Extended and high-resolution information on the reaction products was obtained. Spectral-morphology parameters have been analyzed in order to characterize radiation at the position of the detector.

Conclusions

The research focused on using Timepix3 detectors for particle identification in the proton boron fusion reaction. The study demonstrated that this type of detector showed high efficiency in accurately identifying and separating the particles generated during the nuclear reaction. The successful identification and separation of produced alpha particles and backscattered protons contribute to a better understanding of the reaction dynamics and provide valuable insights for proton therapy applications. The findings highlight the effectiveness of Timepix3 detectors in enhancing ability to characterize and study nuclear reactions, opening up possibilities for further advancements in the field.

Analyzing the Effect of Proton Beam Nozzle Design on Dose Distribution in Small Proton Fields

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Introduction

Accurate and safe radiation dose delivery in proton therapy relies heavily on the design of the proton beam nozzle, especially in small fields. Beam size, dose divergence, beam penumbra, and Multiple Coulomb Scattering (MCS) are crucial factors affecting dose distribution. In this study, we investigated three proton nozzle designs: Double Scattering (DS), Wobbling Scattering (WS), and Pencil Beam (PB), using the Monte Carlo (MC) toolkit.

Methods

We used the Geant4-based PTSim toolkit to virtually construct the proton delivery modalities. Detailed geometry information provided by Sumitomo Heavy Industries, Inc. was utilized, and measurements were compared for validation. Dose distributions were determined for small fields (5, 10, and 30 mm) with a beam energy of 190 MeV, incorporating patient-specific beam modifiers like Multi-Leaf Collimators (MLC) and brass apertures.

Results

Distinct variations were observed in the delivery of proton beams through different nozzles, as indicated by the PDD and beam profiles. In larger fields, DS and WS nozzles showed similar dose distributions, while the PB nozzle delivered 4.2% less dose in the plateau region due to collimator scattering. In smaller fields (<30 mm), the PB nozzle delivered 5.5% and 3.8% lower doses compared to DS and WS, respectively. Notably, in the 10 mm field, the surface region exhibited a 10% reduction compared to DS and a 25% reduction compared to WS. Primary proton angularity and MCS were identified as significant factors affecting PDD, particularly in small fields.

Conclusions

MC simulations demonstrated superior accuracy in dose calculations under challenging measurement conditions. Each proton modality exhibited distinct primary proton angular interactions, leading to a substantial 25% impact on the plateau region.

Assessment of Extremity Dose for Medical Staff Involved in Positron Emission Tomography/Computed Tomography Imaging

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Background

There has been an increase in PET/CT imaging procedures, and medical workers involved in PET/CT are at increased risk of occupational exposure. Data on extremity dose exposure are limited globally. The current study aimed to evaluate the occupational radiation dose for extremities for medical workers (nurses, radiographers/radiologic technologists, and nuclear medicine physicians) working in PET/CT scanners at five large hospitals in Turkey.

Materials and Methods

Optically stimulated luminescence (OSL) and Thermoluminescent dosimeter (TLD) ring dosimeters were used to measure equivalent dose values. Hospitals 1, 2, and 5 used OSL, and 3 and 4 used TLD.

A total of 502 readings were obtained from 55 workers. In mSv, the average annual effective dose for all workers was 14.5 ± 17.7 (0.2– 157.2). A radiography technologist received a maximum dose of 157.21. Nurses received the highest average annual effective dose (15.2 ± 19.46) (0.32-65.58), followed by radiography technologists (14.7 ± 18.03) (0.4-157.2), and nuclear medicine physicians demonstrated the least dose (8.6 ± 10.5) (1.2-24.4).

The results show that the extremity dose is well below the annual dose limit of 500 mSv. However, there is a wide variation in dose among the workers, underlining a need for careful assessment of working conditions to ensure safe practices for all workers.

Reduction Radiation Dose for Paediatric patients undergoing CT examination Using Iterative

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Introduction

Dose reduction in paediatrics CT is important priority. Dose reduction might affect image interpretation as it increases noise and artifacts. Iterative reconstruction techniques used to reduce noise and artifacts, although reconstruction algorithm, magnitude of dose reduction, and effects on image quality vary.

Objective

The objective of the study is to compare the dose reduction and image quality parameter (SNR) for paediatric CT and chose the best CT protocol with lower dose and an acceptable image quality to paediatric patients.

Materials and Methods

An experimental study using an anthropomorphic paediatric phantom to perform chest and abdomen as they are common examinations that require follow-up CT. A total of 11 different protocols were performed including; A) 5 automatic protocols (High quality, Quality, Standard, Low-Dose and Ultra-low-dose) and B) 6 manual setting protocols (30, 40, 50, 60, 70 and 80mA). A fixed kVp(100), tube rotation time(0.75s) and FOV(400mm) were used. The dose was evaluated during the procedure in terms of CTDIvol (mGy) and DLP (mGy.cm) for each protocol. Using the RadiAnt software, the SNR ratio calculated for each protocol.

Results

An average dose reduction of up to 37% with acceptable image quality was achieved using the 50mA protocol (manual-setting) and low dose (automatic) comparing to the high quality, quality and 80mA protocols which give better quality and relatively high dose (200.4 mGy.cm). Standard, 60mA and 70mA protocols provided images with good quality but with higher doses compared to the low dose and 50mA protocols as shown in graph(1). Ultra-low dose, 30mA and 40mA protocols will give lower doses compared to the low dose and 50mA protocols, however the image quality will be bad, and it may affect the diagnosis process.

Conclusion

This study is helpful in promoting the use of iterative reconstruction techniques in paediatric CT scans to lower radiation exposure.

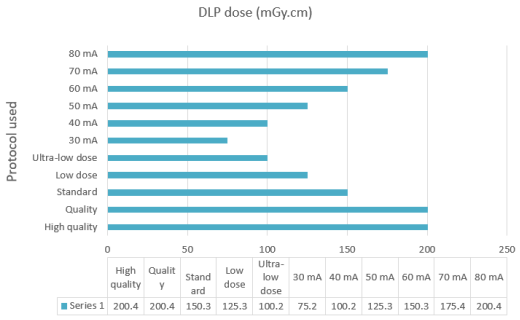

Figure 1: DLP dose (mGy.cm) obtained from various protocols.

The variation of the Thermal Index (TI) and Mechanical Index (MI) During Routine Obstetric Examination

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Introduction

Fetal US is used frequently during three trimesters of prenatal development.

Objective

The study is to analyze the values of TI and MI during routine obstetric examination.

Methods

A prospective an observational study was conducted to quantify the TI and MI during obstetric examinations and the samples were selected randomly. Quantitative design was used in this study and in quantitative studies the collected data (numbers). The participants in this study were obstetric patients, the sample size was 30 patients. Observation was used in this study to collect the parameter from the monitor of the US machine including age, gestational age, TI, MI, depth, transducer frequency and scam time.

Results

A total of 7 first-trimester, 11 second trimester and 12 third-trimester examinations were evaluated. The TI was the highest in the second trimester, while the least in the third trimester. The MI was the highest in the second trimester, while the least in the third trimester though they are still close. The exam duration was the least in the second trimester, and the highest in the third trimester. The transducer depth used in the third trimester was the longest, and the one used in the first trimester was the shortest.

Conclusion

All of TI, depth and scan time were high at third trimester and because the as the fetus developed and more bones are formed so it require more TI to penetrate it compared with the first and second trimesters, the diameter of the mother's baby will be at its highest diameter value and that will require more depth to visualize the fetues, that only will be done by increasing the depth and for the scan time it's normal to be high because of time consuming to observe fetus development like FL,TAD and CRL.

Table 1: Mean and SD of TI and MI in each trimester.

Trimester	Thermal Index		Mechanical Index	
	Mean	±SD	MI	Mean ± SD
First	0.61 ±	0.08 (0.6- 0.7)	1.10 ±	0.0 (0.0)
Second	0.63 ±	0.21 (0.3- 0.9)	1.12 ±	0.04 (1.1-1.2)
Third	0.57 ±	0.28 (0.3 – 0.9)	1.08 ±	0.04 (1 – 1.1)

Impact of low-dose protocols on Computed Tomography of lung cancer screening on the intrinsic performance metrics: A phantom study

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Introduction

This research aims to assess the task-based performance of low dose CT lung examination with different acquisition parameters, evaluate the acquisition parameters of lung cancer in low dose CT lung examination, and explore the effect of the iterative reconstruction (IR) algorithm on the image quality of low dose CT for CT lung examination.

Methods

This study employed a Catphan 600 to assess the maximum performance of multi-slice CT scanners for radiation therapy planning, utilizing increased sensitometry samples. The CTP404 test module of the Catphan 600 included sensitometry samples of Teflon, Delrin, Acrylic, Polystyrene, LDPE, PMP, Air, and a small water vial. The protocols were divided into three categories: standard, low dose and ultra-low dose. The standard protocol includes a tube voltage of 100 kVp for standard dose computed tomography (SDCT), a pitch of 0.75, detector collimation of 0.60 mm, and a gantry rotation time of 0.33 seconds. The slices were 5 mm thick and reconstructed using a standard reconstruction kernel, for example B80f and 170f, combined with FBP or various IR

Results

The low dose group used an acquisition parameter with 100 kVp and a pitch of 0.9, while the standard dose used a pitch of 0.75. The difference in pitch allows for thinner image slices, which improves partial volume averaging and optimizes the (low contrast detectability (LCD). We compared the noise power spectrum (NPS), target transfer function (TTF), and contrast-to-noise ratio (CNR) values for different IR algorithm levels in the low dose group for both acrylic and LDPE inserts. As the IR level increased, the peak value of NPS (HU2 mm2) also increased, with FBP having the highest peak value. Additionally, the NPS spatial frequency decreased with increasing IR level.

Conclusions

To sum up, research is being conducted to determine how CT image quality is affected by low dose CT acquisition parameters and IR algorithm. It is essential to adjust IR levels accurately as higher levels can reduce image texture and influence NPS spatial frequency. TTF and CNR are considered the most important performance measures for protocol optimisation as they enhance the contrast and spatial resolution for the background and region of interest.

Occupational ionizing radiation exposure monitoring in several medical departments

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Introduction

Occupational ionizing radiation doses for medical radiation workers (MRWs) from different medical departments in a major specialized hospital in Saudi Arabia were measured and analyzed to establish a baseline for the annual mean effective dose (AMED) for MRWs.

Methods

In this investigation, a retrospective study was conducted on effective doses for 355 MRWs in a major specialized hospital in 2019. TLDs with bar codes were used to measure the personal dose equivalent at the 10-mm depth, Hp (10). Thus, the effective dose in this study was estimated by setting it as equal to the measured personal dose equivalent, Hp (10). TLDs readings were descriptively analyzed to obtain the annual mean effective doses (AMED), standard deviation and ranges. A one-way ANOVA test was performed to examine differences in the effective doses between the medical departments, which the significance level was set equal to 0.05 ($P \leq 0.05$).

Results

The overall AMED for all MRWs reported in this study was 1.60 mSv. The AMEDs in each medical department were 1.17 mSv in diagnostic radiology, 1.61 mSv in interventional radiology, 2.72 mSv in nuclear medicine, 1.59 mSv in radiation therapy, 1.32 mSv in operation room, 1.06 mSv in dentistry, and 1.54 mSv in others. A one-way ANOVA test indicated statistically significant differences between the departments' workers ($P = 0.001$). The study reveals that the workers in the nuclear medicine department received the highest AMED among the other workers. The results reveal that no single occupational dose has exceeded the annual dose limit of 20 mSv. However, to avoid unwanted radiation exposures, it is still required to control the workplace and manage MRWs, particularly for workers in NM, who were found to get more dose than MRWs in other medical departments.

Conclusions

The purpose of this study is to estimate a baseline for the occupational dose, AMEDs, for MRWs in different medical departments. The AMED was 1.60 mSv, which is well below the recommended occupational dose limit for radiation workers (20 mSv). However, to avoid unwanted radiation exposures and to slow down the increase of the AMED with respect to results reported from previous studies, it is still required to control the workplace and manage MRWs, particularly for workers in NM, who were found to get more dose than MRWs in other medical departments

Assessment of Secondary Radiation Dose in Radiology Units

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Introduction

In hospitals and clinics, medical imaging using ionizing radiation is one of the most important and powerful diagnostic techniques that exposes patients, workers, and the general population to radiation through primary and secondary radiation. Thus, routine leakage testing of X-ray tubes and scattered radiation testing are important in ensuring the absence of leakage and scattered radiation.

Methods

In this investigation, background, and secondary radiation exposure assessments of 17 X-ray machines were conducted in radiology units of three randomly selected major public hospitals. The dose per week in both controlled and uncontrolled areas were measured using a Ludlum Model 9DP-1 ionization chamber dosimeter and were expressed in μSv/h.

Results

The highest dose was recorded in the controlled area of the CT scan room in Hospital A, where the mean dose rate was 12.16 μSv/h (in the control door) and 8.38 μSv/h (in the main door). The dose rates in these areas were approximately ten times higher than those measured in corridors. Generally, the measurement results showed that the scattered radiation doses in the controlled and uncontrolled areas of the radiology units were within the permissible limits set in the NCRP 147. This finding may be attributed to the distance between these locations and the X-ray sources and to the lead lining of the area.

Conclusions

The secondary radiation levels in the assessed diagnostic rooms were within the reference exposure level for the public and for workers, indicating that appropriate barriers (doors and walls) had been installed in the investigated hospitals.

Radiation shielding properties of synthesized Boro-tellurite glasses influenced by heavy metal

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Introduction

Recently, different kinds of glasses are considered important materials for protection from ionizing radiation. The glasses have interesting chemical, physical and optical properties, so they can be used in different technological applications. The addition of heavy metal oxides (HMO) is one of the most common ways to improve the radiation shielding performance of the glasses. The present study involved the synthesis of a series of Boro-tellurite glasses with HMO.

Methods

The glasses were prepared using the conventional process of melt-quenching-annealing.The structural characteristics of the samples was examined through X-ray diffraction analysis within the 10° to 80° range, in order to establish the amorphous state of the glasses. In order to investigate the optical characteristics of transparency as well as indirect, direct, and Urbach energy band gaps, optical absorption measurements were conducted within the 200-800 nm range. The radiation shielding properties for the prepared glasses will be simulated using Monte Carlo simulation. We will compare the simulated results with theoretical results obtianed by Phy-X software.

Results

The results showed that the addition of HMO causes an increase in the density of the glasses. The XRD results proved the amorphous nature of these glasses. The results demonstrated that the addition of HMO causes an increase in the linear attenuation coefficient, ande decreases the half value layer. The radiation protection effecincy of these glasses are better than other traditional shielding glasses.

Conclusions

The inclusion of the HMO with suitable concentration is one way to increase the density of the glasses, and thus to improve the radiation shielding performance of the glasses. The input file for Monte Carlo simulation used in this work can be used to further investigate the radiation shielding properties of other kinds of glass systems.

Measurement Campaigns to Identify Healthcare and Research Workplaces Prone to Receiving Annual Lens Doses Exceeding 6 mSv

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Introduction

The reduction of the annual equivalent dose limit for the lens of the eye to 20 mSv for workers is a challenge in the design of dosimetric surveillance programs and the implementation of new radiological protection strategies. In the framework of the EDOCI *"Estimates of occupational doses to the lens in healthcare and research facilities"* project, various measurement campaigns have been carried out to identify groups in the healthcare and research sectors that may be affected by the new dose limit.

Methods

The measurement campaigns have been carried out in various Spanish healthcare centers and one Research center. In total, 71 interventional workers and 21 nuclear medicine workers have participated. Lens and badge TLDs and OSLs, along with direct reading dosimeters RaySafe i3 and Thermo Scientific model EPD Mk2, were used.

Results

It is estimated that 14% of interventional doctors receive an annual lens dose between 6 mSv and 20 mSv, and 16% receive more than 20 mSv. The rest of the groups do not exceed 6 mSv per year. It has been confirmed that the badge dosimeter located above the apron allows for a good estimation of the dose at eye level in interventional settings. It is also shown that the use of direct reading dosimeters is very useful to increase awareness of the exposure and to optimize procedures.

Conclusions

The results of the campaigns, together with international recommendations on this topic, have been used to develop a practical guide that describes a methodology for identifying groups affected by the new lens dose limit and for carrying out individual dosimetric control, highlighting the advantages and limitations of the different techniques available.

Metrology of high dose rate high energy photon beams: standardization of dosimetry for UHDR beams in medical and research applications

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Introduction

The dosimetry for high energy radiotherapy has been since long subjected to very strict metrological requirements and all measurements must be performed according to well established standards, be it IAEA TRS 398, DIN 6800-2 (2008) or AAPM codes of practice for radiotherapy accelerators issued by AAPM-TG51. All these codes and standards rely on the use of ion chambers, still considered as the golden standard in ionizing radiation metrology.

Lately, the development of high dose rate techniques of treatment, like the FFF, and the advancement towards FLASH techniques, raised the question of how valid are the already existing metrology methods for the systems that are used to measure doses in such high dose rate beams.

Methods

For such ultrahigh dose rate beams (like those used in FLASH therapy or generated at the gamma beams at ELI-NP) several corrections must be applied in order to calculate a correct dose from the measured charge. Given the fact that the usual quality of the calibration beam is still Co-60 for consistency reasons, the number of correction factors is rather large. Our presentation will insist on the recombination and polarity correction factors, which are the most laborious to determine in most circumstances. Both have standardized methods of measurement, but are time consuming and our team developed a method which reduces the time for their measurement by making a single measurement for dose, recombination factor and polarity factor by simultaneously using 4 different measuring volumes – using the QADDRIL detector.

Results

The prototype QADDRIL consists of an array of four ion chambers, each one with different bias. Using a standard medical LINAC we demonstrated that the usage of four chambers leads to correction factors very close to the ones obtained by the classical method.

Conclusions

The arrays of ion chambers can be used with multichannel electrometers for simultaneous measurements of dose, recombination and polarity correction factors.

Assessment of patients doses and radiation risks during vascular CT abdomen examinatons in Saudi Arabia

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Introduction

The range of 2 to 20 mSv is commonly thought to be the effective dose from diagnostic computed tomography (CT) examinations, which is comparable to the lowest dosages of 5 to 20 mSv that some Japanese atomic bomb survivors got. These survivors have shown a slight but elevated radiation-related extra relative risk for cancer incidence. Therefore assessment and optimization of patients' doses from CT examinations are crucial. The present study aims to estimate the patient's radiation dose during multiphasic vascular CT abdominal CT examinations.

Methods

The study included 630 children who underwent multiphase abdomen computed tomography (CT) at four radiology departments. The study consisted of three groups: standard protocol, high-quality dose protocol, and 3D sure exposure low dose protocol were used. Four CT machine 128 slices were installed at the four institutions.

Results

The volume CT dose index CTDIvol (mGy) and dose length product (DLP) mGy.cm values for the mean range of patient dose for the entire procedure were 13 (3.2-28.0) and 2556 (260-9260) for the standard-dose protocol, 8 (4.0-16) and 1330 (700-3290) for the high-quality dose protocol, and 5 (3-10) and 800 (483-1150) for the sure 3D sure exposure low dose protocol, respectively. The average effective dosage (mSv) and its range (3.8.0-120), 20 mSv (8-40), and 10.0 mSv (5-176) were in that order.

Conclusions

The extensive range of dosages suggests that some individuals, mainly when using the standard dose regimen, received an increased dose. For the above protocols, the predicted cancer risk per treatment was 2, 1, and 0.6 cancer cases per 1,000 procedures, respectively. The 3D Sure Exposure Low Dose Protocol offers a 30–75% reduction in effective dosage without sacrificing picture quality.

Development of a physical simulator for dosimetric experiments in ophthalmic brachytherapy

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Introduction

Cancer is a significant global public health issue, leading to a considerable number of deaths worldwide. In Brazil, there is an increasing incidence of eye neoplasms, with retinoblastomas and choroidal melanomas being the most common intraocular tumors. Brachytherapy, a form of radiotherapy that involves the use of ionizing radiation in close proximity or direct contact with the targeted region, plays a crucial role in treating eye neoplasms and can significantly improve the life expectancy of affected individuals. Conducting dosimetric studies to measure the absorbed dose in a material medium exposed to a radiation source is essential for ensuring the quality of treatment provided. Physical simulators, known as phantoms, that closely resemble the anatomical structure and possess similar density to human tissues, are used for radiation dosimetry. This paper aims to present the development of a physical simulator specifically designed for dosimetric studies in ophthalmic brachytherapy.

Methods

To achieve accurate simulation of human tissues, a combination of selected chemical and biological materials was used to prepare the phantom components. This mixture was then moulded to replicate the anatomical shape of the eye, brain, and skull, thereby simulating the physical properties of their adult human counterparts.

Results

The phantom that was developed exhibited stability, usability, and appropriateness. Tissue density calculations and radiological images were conducted to validate its performance.

Conclusions

The study of dosimetry holds significant importance in evaluating the outcomes of radiotherapy treatments. The skull simulator, including the brain and eyes, is anticipated to be utilized for future dosimetric investigations in ophthalmic brachytherapy and stereotactic radiotherapy of the eyeball. Further studies are required to develop a scalable production process for the phantom and explore potential commercial applications in the future.

Radiation dose Assessment and Suggestion of Diagnostic Reference Level for Chest and Skull Radiography and Computed Tomography in Sudan

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Introduction

Measuring or estimating radiation exposures to patients in diagnostic radiography is important in many aspects. For example, measurements allow for the establishment and verification of good practice standards, which contribute to the optimization of patient protection from unnecessary radiation exposure. The International Commission of Radiological Protection has suggested Diagnostic Reference Levels (DRLs) as a tool for optimization. By enabling comparison of existing practice, DRLs are meant to encourage advancements in patient protection. For each test or operation, for each clinical indication, and for each patient group, national and local DRLs should be established. The current work aimed in establishment of diagnostic reference level (DRL) for chest and skull examinations in Sudan for general radiography and computed tomography

Methods

810 patients underwent chest and skull examinations at Khartoum military hospital in the period from March to September 2022. All patients were adult, exposure parameters for conventional radiography and CT examinations were recorded in special designed data sheet, as well as patient demographic data. For CT examinations, computed tomography dose index (CTDIvol) and dose length product (DLP) was also recorded, in addition to the machines specifications. The DRL were achieved by selection of the 75th percentile statistical method to the estimated entrance surface air Kerma (ESAK) for conventional radiography and 3rd quartile of data from CTDI and DLP, Microsoft Excel was used to analyze data.

Results

The average ESAK for skull and chest conventional radiography were 1.82 and 0.28 mGy respectively. The average skull and chest CTDIvol were 52 mGy and 6.8 mGy respectively, while the respective values for DLP were 508.3 mGy-cm and 322 mGy-cm. The proposed DRLs for skull and chest conventional radiography were 2.45 and 0.35 mGy and for CT skull and chest examinations were 69 mGy, 8.2 mGy and 612 mGy-cm, 406,34mGy-cm respectively for CTDIvol and DLP.

Conclusions

There was little variation between practice in the center under study. The proposed DRLs in both examinations show agreement with some of the previous studies and was lower than some other studies available in the literature.

Assessing the Impact of Different Breast Sizes on Heart Radiation Dose in Dual-Energy Computed Tomography with Various Scan Modes Using Optically Stimulated Luminescence Dosimeter

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Introduction

The coronary artery computed tomography angiography can effectively help diagnose coronary artery stenosis caused by plaques. Due to the higher radiation dose of computed tomography angiography compared to other conventional radiographic examinations, there are limitations on the frequency of clinical examinations to reduce the risk of deterministic effects. Dual-source dual-energy computed tomography (DSCT) is a relatively new radiological imaging device. This study primarily investigates the heart radiation dose in different scan modes of dual-source dual-energy coronary computed tomography angiography for various breast sizes.

Methods

The research equipment uses the Siemens SOMATOM Definition Flash dual-source dual-energy computed tomography, anthropomorphic phantoms (KYOTO KAGAKU), B and D-CUP breast phantom, and optically stimulated luminescence dosimeters (OSLDs). The computed tomography scan modes are divided into Dual Energy Spiral Mode, Dual Source Sequence Mode, Dual Source Flash Mode, Chest Mode, and Low Dose Chest Mode, totaling 5 scan modes. The dosimeter placement positions were based on ICRP-103 recommendations.

Results

The research results show that the heart dose caused by Dual Source Sequence Mode scan mode for B-CUP breast is 3.29 cGy, and for D-CUP breast is 4.42 cGy. The heart dose caused by Dual Source Flash Mode for B-CUP breast is 3.77 cGy, and for D-CUP breast is 5.06 cGy. The heart dose caused by Dual Energy Spiral Mode for B-CUP breast is 1.00 cGy, and for D-CUP breast is 1.26 cGy. The heart dose caused by Chest Mode for B-CUP breast is 0.96 cGy, and for D-CUP breast is 1.00 cGy. The heart dose caused by Low Dose Chest Mode for B-CUP breast is 0.38 cGy, and for D-CUP breast is 0.39 cGy. Dual Energy Spiral Mode, Dual Source Sequence Mode, and Dual Source Flash Mode show that the larger D-CUP breast causes a higher heart dose, mainly due to the influence of scattered radiation, with Dual Source Flash Mode having the highest dose of 5.06 cGy. The two Chest Modes have no difference in dose results.

Conclusions

This study can review the need to increase the number of coronary computed tomography angiography examinations in Taiwan due to patient conditions, without considering radiation dose issues and the healthcare system as factors.

Phenomena observed in use of a pulse-by-pulse Radioluminescence dosimetry system in electron EBRT

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Introduction

Time-resolved radiation sensing is argued to be of considerable importance in ensuring accurate dose, in particular during the delivery of external beam radiotherapy (EBRT) by linear accelerators (LINAC). One method for time-resolved radiation dosimetry is via the technique of radioluminescence (RL) with the use of doped-silica optical fibre scintillators linked to a photon counting device through a PMMA optical fiber. This allows for measurements to be made at a distance. Among the prominent additional benefits of RL measurement technique include the ability to obtain real-time dose measurement of the pulse-by-pulse beam at high spatial resolution.

Methods

In present work, Ge-doped optical fiber scintillator samples are irradiated under a range of electron beam energies (6, 9, 12, 15 MeV) as supplied by an Elekta Synergy® LINAC. Two types of scintillators were used, one being a smaller core compared to the other. The range applied for the irradiation dose and dose rate was between 50 to 600 cGy and 50 to 600 cGy/min respectively. The dosimetric and time-resolved measurements were made using an MPPC detector, with a gating time of 1µs, providing the high temporal resolution measurements.

Results

Linear RL response to dose was observed, with minimal detectable memory, afterglow and no saturation effects. A rise time of 189.3 ns and a decay time of 260 ns have been recorded, indicating promising potential for time-resolved radiation dosimetry. The pulse sub-structure, reflecting the mechanics of the magnetron used in the LINAC was also observed for the first time. In addition, it is seen that the larger doped core scintillator displays a phosphorescent tail in the return to baseline due to higher level of dopants.

Conclusion

The findings from use of the Ge-doped optical fiber scintillators indicate the capability of the system to perform pulse-by-pulse radiation measurements, much required in high dose rate radiotherapy such as FLASH RT.

Assessment of annual personal equivalent dose, skin and eye lens doses during interventional radiology

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Introduction

A considerable amount of the radiation with heterogeneous X ray beam energy scattered from the patient was exposed to interventional radiologists, their assistants, and the nursing staff over a protracted period. Recent research revealed that interventionists are more likely to get cataracts and brain cancer were reported for some cardiologists. This study aims to assess the radiation exposure of radiology and interventional radiology employees.

Methods

Data were collected from four hospitals in Riyadh, Saudi Arabia for a total 60 employees including cardiologists, vascular surgeons, technologists and nurses. Personal dose equivalents were calculated using Hp (10) and Hp(0.07) to assess the radiation dose and related risks. Exposure equivalent values were calculated using the units Hp (10) for deep exposure and Hp (0.07) for skin dose, with ring dosimeters used to calculate extremity doses. The measurements were conducted using calibrated thermoluminescent dosimeters (TLDs) of the LiF: Mg, Ti (TLD-100) type.

Results

For Hp (10), and Hp (0.07), the corresponding mean yearly personal equivalent dose and range were 5.2 6.5 (0.3 - 21.2) and 5.3 6.7 (0.2 -22.1). The eye lens's projected dosage (mSv) is 7.5(0.1-18.2).

Conclusions

Interventional radiologists and vascular surgeons received the highest doses compared to other personnel. The study revealed that 15% of the staff received a personal equivalent dose higher than the yearly dose limit. The annual eye lens doses are below the dose limits. Implementing radiation protection measures is recommended to ensure that staff receive minimal doses within the yearly exposure limits.

Radiation risk to children during diagnostic procedures

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Introduction

Even though computed tomography (CT) scans offer many medical advantages, their increased usage since the 1980s has prompted concerns about cancer risks, particularly after young patients' exposure. CT scans generally deliver 5.0-50.0 mGy ionizing radiation to each scanned organ. Due to the enormous number of exposures, estimating patients' doses and related risks is recommended.

Methods

This study aims to assess the radiation risk to children during diagnostic procedures. A one-year radiation risk dosage was assessed for 25 pediatric patients. The patient's exposure was calculated using a Computed Tomography instrument (Siemens Somatom Sensation 128 (128-MDCT)). The volume CT dose index (CTDIvol) and DLP were among the measures.

Results

For one year, the mean and range of CTDI and DLP were 17.7 (4.36-45.77) and 391 (93.73- 1077.15), respectively.

Conclusions

Pediatric patients received high radiation doses during CT facial bones. The eye lens, a radiosensitive organ, received a significant dose. The wide variation of patient doses per CT procedure suggested that the CT dose is not optimized. The fixed scan protocol exposes pediatric patients to unnecessary radiation doses, generating avoidable radiogenic risks.

Estimate Radiation Dose and Cancer Risk in Adult Computed Tomography Angiography for Upper and Lower Extremity CT Procedure

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Introduction

The use of computed tomography (CT) for diagnostic evaluation has increased dramatically over the past two decades. Even though CT is associated with substantially higher radiation exposure than conventional radiography, limited data are available worldwide. We sought to estimate the radiation dose associated with common CT studies in clinical practice and quantify the potential cancer risk associated with these examinations.

Methods

The researchers conducted a retrospective cross-sectional study describing radiation dose associated with the two common types of diagnostic CT studies (upper and lower CT angiography). The researchers estimated lifetime attributable risks of cancer by study type from these measured doses. The patient's exposure was calculated using a Computed Tomography instrument (Siemens Somatom Sensation 128 (128-MDCT)). Then, Volume Computed Tomography Dose Index (CTDI vol) and Dose Length Product (DLP) were calculated.

Results

The CTDIv for upper and lower extremity had ranged (1.16 – 7.16) and (2.57 – 14.81), respectively. Values of DLP had a range of (100.88-662.87) and (167.96 – 1545.15) for the upper and lower extremities, respectively.

Conclusion

Radiation doses from commonly performed diagnostic CT examinations are higher and more variable than generally quoted, highlighting the need for greater standardization across institutions. Radiation doses varied significantly between the different types of CT studies.

Radiation dose and diagnostic reference level for certain computed tomography angiography procedures

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Introduction

Medical X-rays are the most significant artificial source of public exposure to ionizing radiation. While the advantages of Computed Tomography (CT) are widely acknowledged in precise diagnosis, such benefits are not risk-free. CT is a device with increased patient exposure compared to conventional radiation techniques. This study aims to evaluate radiation doses to patients from Computed Tomography (CT) examinations in Riyadh Care hospitals and define diagnostic reference level (DRL).

Methods

Patient-related data on CT protocol for five standard CT examinations, including chest and abdomen angiography, were collected. The patient's exposure was calculated using a Computed Tomography instrument (Siemens Somatom Sensation 128 (128-MDCT)). Then, Volume Computed Tomography Dose Index (CTDI vol) and Dose Length Product (DLP) were calculated.

Results

The CTDIvol (mGy) for chest and abdomen angiography ranged (10.79 – 46.63), (5.52 – 24.01), respectively. Values of DLP (mGy.cm) had a range of (280.6 – 1830.73), (299.08 – 1302.68) for chest angiography and abdomen angiography, respectively. The proposed quantity for DRL is the third quartile of CTDIvol, derived from dose distribution for each examination.

Conclusions

This study's results demonstrated large doses for the same examination among different centers. For all examinations, our values were lower than international reference doses.

Establishment of Diagnostic reference level for computed tomography examinations in elected hospitals in Saudi Arabia

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Introduction

Computed tomography represents the source of the most considerable portion of patients exposed to ionizing radiation in medicine. The international atomic energy agency (IAEA) and Saudi Food and drug authority (SFDA) are advised to implement and use diagnostic reference levels (DRL) to optimize patient doses and reduce unproductive exposure. The current study aims to create a national DRL in elected hospitals for the specific CT procedure.

Methods

A total of 500 patients were examined in this study, involving eight radiology departments equipped with different calibrated CT modalities from different vendors. The patients were examined for CT brain, chest, and abdomen examinations.

Results

For the CT brain, chest, and abdomen, the dose length product (DLP, mGy.cm) was 840 to 1690, 140 to 1100, and 1330 to 3180, respectively. The mean and range of the volume CTDIvol (mGy) respectively ranged from 30-120, 3.0-20.0, and 3.0-15 for the CT brain, chest, and abdomen examinations.

Conclusions

Wide variations in technical settings indicate the necessity for staff training in CT dose optimization approaches since patient doses during CT procedures are shown to differ between departments and within the same department. The patient dosages seen in this study are higher than those typically found in comparative trials conducted worldwide. For every CT technique under investigation, DRLs are suggested.

Image Quality and Radiation dose for patients who underwent radiological examinations at the emergency department

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Introduction

The primary task of medical diagnostic radiology is to provide high-quality diagnostic image information about any process or anatomical detail within the patient's body. Providing the best possible diagnostic information while the dose the patient receives is kept to a minimum. This study aimed to evaluate the radiographic image quality and patient radiation dose in emergency departments at Saudi Ministry of Health hospitals in Riyadh based on the american college of radiologists (ACR) guidelines and assess patient radiation doses, image quality, personnel qualifications, and patient safety measures.

Methods

The data was collected from two emergency departments (general and specialist hospitals) equipped with digital x-ray systems. The study population consisted of 550 patients. Patient radiation dose will be collected from calibrated radiographic equipment equipped with a Kerma area product (KAP) meter. The investigated procedures are skeletal radiology. Image quality was evaluated using specific clinical criteria based on three parameters criteria. Two radiologists will evaluate the image.

Results

The results showed that 30-43% of the images had high image quality and high diagnostic findings. The results showed that 5-25% of the image has the poor image quality and low diagnostic values. The range of effective dose is from 0.4 to 4.5 mSv per procedure.

Conclusions

The effective dose per procedure is higher compared to previously published studies. The image quality results were above the acceptable range. Poor radiation safety and protection were reported by staff.

Utilizing Monte Carlo Methods for Optimizing the Dimensions of a Novel Collimator System in Small Animal Radiotherapy

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Preclinical radiotherapy applications require dedicated irradiation systems which are expensive and not widely available. Our research team has devised and constructed an add-on collimator to allow for targeted irradiation of mice using a standard clinical ^{137}Cs cell irradiator [1]. In previous studies, we showed that our irradiation system is an effective method for irradiating mice with xenograft tumours [2,3,4]. The aim of this study was to evaluate the mouse doses irradiated with our irradiation system as a function of the collimator design, including the thickness and dimensions of the collimator.

We generated a MC mouse phantom from a tumour-bearing mouse micro-CT image set. The MC modelling of the mouse phantom irradiation was performed and the dose delivered to the mouse phantom was calculated, and dose volume histograms (DVHs) were generated for the tumour and organs at risk (OARs). To investigate the effect of the collimators dimensions variations on the MC mouse phantom, the thickness, height, and the main chamber diameter of the collimator was modified in MC modelling of the collimator and the DVHs were reanalysed.

DVHs analysis results indicate that the dose was effectively delivered to the tumour while dose to other critical organs was minimized. Variation of the collimator dimensions did not exhibit any significant effect on tumour's DVHs. However, as the thickness of the collimator increased the out of field dose decreased and DVHs of the OARs improved.

This method provides a quantitative method for characterizing the irradiation systems for small animal RT.

[1] Fontanarosa, D., Benitez, J., Talkhani, S., Fielding, A., Entezam, A., Trapp, J., ... & Mazzieri, R. (2020). Medical Physics, 47(6), 2461-2471

[2] Entezam, A., Fielding, A., Bradley, D., & Fontanarosa, D. (2023). PLOS ONE, 18(2), e0280765.

[3] Entezam A, Fielding A, Fontanarosa D. InMEDICAL PHYSICS 2022 Jun 1 (Vol. 49, No. 6, pp. E976-E976). 111 RIVER ST, HOBOKEN 07030-5774, NJ USA: WILEY.

[4] Entezam, A., Fielding, A., Moi, D., Bradley, D., Ratnayake, G., Sim, L., ... & Fontanarosa, D. (2021). Radiation Physics and Chemistry, 189, 109691.

Estimating Effective Dose Measurements During Common Computed Tomographic Procedures

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Introduction

Effective dose estimation in routine computed tomography (CT) scans reveals the likelihood and risk of developing cancer, especially in youngsters who are particularly radiosensitive. The purpose of this study is to estimate the effective dose for pediatric and adult patients during computed tomography examinations to establish local Diagnostic Reference Levels (DRLs).

Methods

Data for 425 patients (224 (52.72%) pediatric and 201 (47.29%) adult patients with whole-body CT scans) were collected from four different hospitals and centers in Khartoum state, Sudan. These are Alya Hospital (A), Alzaytouna Hospital (B), Ibn AL Haitham Specialist Hospital (C), and Modern Medical Center (D). using the following machines: two Toshiba Aquilion 64 slices, one Siemens Sensation 16 slices, and one General Electric 16 slices. The effective dose was calculated during whole-body scans using the dose-length product (DLP), which is provided automatically by the scanner, multiplied by a conversion factor (ICRP 2007 publication 102). Measurements were acquired for the head, chest, and abdomen of both pediatric and adult patients.

Results

The mean effective dose (mSv) results were: 2.94 for pediatrics and 6.79 for adult patients; 3.57 mSv for pediatrics and 2.13 mSv for adult patients; 3.16 mSv for pediatrics and 4.59 mSv for adult patients for head, chest, and abdomen, respectively.

Conclusions

The study found significant variations that can be attributed to a variety of factors, including manual errors from the technologist due to the lack of professional training, which may lead to using the same protocols for adults and pediatrics, or technical errors by the medical engineer who may have not activated the automatic exposure control (AEC) option for medical devices specially used with X-ray and CT machines.

Dose Distribution of ELEKTA VERSA HD: Experimental Measurement

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Introduction

The increasing number of cancer cases in recent years has made the diagnosis and treatment of cancer a top priority for society. This research aims to experimentally measure the dose distribution of photon beams emitted from the VERSA HD accelerator at Cho Ray Hospital onto a water phantom. It investigates various aspects such as field size, shielding capacity, depth dose, and dose distribution absorbed by the phantom and patients. The obtained results will be used to validate simulation calculations and leverage artificial intelligence (AI) for future studies. These findings will aid nuclear medical engineers in developing rapid, accurate, and effective treatment protocols for tumor eradication using accelerators, ultimately helping patients regain their normal daily lives.

Methods

The experiments in this study were conducted on a linear accelerator installed at Cho Ray Hospital, specifically the VERSA HD linear accelerator manufactured by ELEKTA [2]. This machine is capable of delivering two photon beams with energy levels of 6 MV and 15 MV. In addition, dose measurement devices such as a water phantom (IBA Dosimetry), an ionization chamber (Scanditronix Wellhofer IBA), an electrometer (UNIDOS E), and OmniPro Accepts 7 software were used for experimental measurements.

Results

Lateral dose distributions were studied for 6 MV and 15 MV photon beams at various depths. Figure 1 shows broadening of the dose distribution curve with increasing depth for the 6 MV beam, likely due to enhanced scattering interactions beyond the primary field region. Figure 2 demonstrates that the dose distribution patterns for the 15 MV beam were similar to those observed for the 6 MV beam at the evaluated depths.

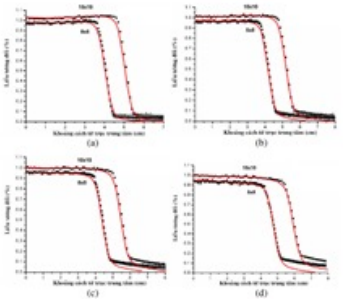

Figure 1: Lateral dose distribution of two fields at the same depth (a) 1.5 cm, (b) 5 cm, (c) 10 cm, and (d) 20 cm.

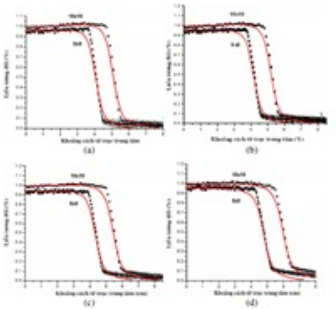

Figure 2: Lateral dose distribution of two fields at the same depth (a) 2.8 cm, (b) 5 cm, (c) 10 cm, and (d) 20 cm.

Conclusions

The study experimentally measured dose distribution on a water phantom for 6 MV and 15 MV photon beams at various depths. These measurements included depth dose distribution and lateral dose distribution at specific depths. The obtained results serve as a valuable database for evaluating simulation results and AI calculations in future studies involving ELEKTA systems.

Proposition of an in-vivo dosimetry system based on Cherenkov light measurement in radiotherapy treatments

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The interaction of a high-energy radiotherapy photon beam (6 MV) with a typical human tissue can enable the occurrence of the phenomenon known as Cherenkov light emission [1]. The capture of these emissions can be done simultaneously with irradiation of the treatment beam from CMOS imaging devices. The emitted and recorded Cherenkov signal will be proportional to the deposited dose. In this way, it is possible to extract instantaneous in-vivo dosimetric information that evaluates the correspondence between the superficially measured dose and the ideal dose expected by the planning systems [2]. At the same time, the capture of Cherenkov emissions can provide accurate information on the surface dose distribution in a given area in the beam incidence region, detailing any alterations that impair the distribution of doses in depth. This work established criteria for the most appropriate positioning of CMOS cameras to capture the Cherenkov spectrum, which must be installed in a Radiotherapy Bunker to enable a technological solution for instantaneous in-vivo measurement of the dose deposited on the surface of a patient under treatment. Several hypotheses were tested for luminosity, absorption and scattering correction. The capture device installation project took into account all the typical parameters of radiotherapy equipment that directly or indirectly influence the position of the patient undergoing treatment. In parallel, the best geometric conditions of the Setup to capture scattered photons via Mie and Rayleigh scattering were studied and explored. In order to test the proposed hypotheses, an additional experimental study was carried out to determine the exposure received by the cameras that were eventually not foreseen in the simulations. The results of this work proposed 3 eligible configurations for the installation of Cherenkov capture devices. Some positions initially listed as options empirically recorded significant exposure from leakage radiation from the linear accelerator head. Noise minimization and light signal optimization were proposed based on the use of filters and signal amplifiers. The next stage of the work will be to test the positions presented in treatments performed in water simulators.

[1] Hachadorian, R. L., Bruza, P., Jermyn, M., Gladstone, D. J., Pogue, B. W., & Jarvis, L. A. (2020). Imaging radiation dose in breast radiotherapy by X-ray CT calibration of Cherenkov light. Nature Communications, 11(1), 1–9. https://doi.org/10.1038/s41467-020-16031-z

[2] Jarvis, L. A., Zhang, R., Gladstone, D. J., Jiang, S., Hitchcock, W., Friedman, O. D., Glaser, A. K., Jermyn, M., & Pogue, B. W. (2014). Cherenkov Video Imaging Allows for the First Visualization of Radiation Therapy in Real Time. International Journal of Radiation Oncology*Biology*Physics, 89(3), 615–622. https://doi.org/10.1016/j.ijrobp.2014.01.046

Study on the radiation exposure of Portable X-ray Fluorescence

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Introduction

Portable X-ray Fluorescence (pXRF) analysis is an analytical technique that allows for the almost instant determination of the chemical composition of a wide range of samples. The technique is non-destructive, and the equipment is lightweight and easily portable, making it highly useful in various situations. Recent studies suggest that the application of pXRF for multi-elemental analysis in blood samples shows very promise for clinical practice. Despite the low levels of radiation emitted by these devices, caution must be taken in their handling. The objective of this study is to conduct a radiometric survey of an experimental setup for pXRF analysis of blood samples.

Methods

The X-ray Fluorescence analysis was performed using a compact X-ray spectrometer model X-123 SDD with Ag target. The experimental setup consisted of an compact X-ray spectrometer (Amptek) with Ag target, a semiconductor detector X-123SDD, and an acrylic stand, where Whatman N.42 paper were inserted. Measurements were performed using a calibrated Radcal® ionization chamber, model 10x5, the 1800 cm^3 volume, which has application for radiation protection.

The measurements were performed under two conditions: for the maximum current and voltage values of the equipment, and for the current and voltage values of the blood sample analysis protocol. Measurements were performed with the ionization chamber at various distances, 21, 35, 100 and 200 cm, and varying positioning in relation to the source.

Results

With the direct X-ray beam in the ionization chamber, at a distance of 200 cm from the source, a maximum kerma rate of 3.27 x 10^{-8} Gy/s was obtained. With the ionization chamber positioned 21 cm to the side of the detector, the maximum kerma rate was 5.25 x 10^{-11} Gy/s. The maximum kerma rate with the ionization chamber positioned 35 cm behind the source was 9.27 x 10^{-12} Gy/s, a value very close to the background.

Conclusions

Preliminary measurements showed that the equipment operator is safe when positioned behind, or even to the side of the pXRF. But further tests must be carried out for the reliability of the entire system.

Evaluation of patient effective doses in interventional orthopedic procedures

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Introduction

Fluoroscopic guided intraoperative orthopedic surgery procedures are expanding rapidly due to their numerous advantages. Patients are exposed to repetitive ionizing radiation during the interventional and follow-up. The objective of this study is to evaluate the patients' radiation doses at four orthopedic departments.

Methods

A total of 57 procedures (20 (35.1%) Female and 37 (64.9%) males) were evaluated at three orthopedic departments. The procedures include Kirschner wires, Dynamic hip screw (DHS), vertebral column, and lower extremities (knee, leg, and foot). Three C-arms fluoroscopic X-ray machines from different manufacturers were used equipped with kerma area product meter (KAP). Effective doses were estimated using computer software based on Monte Carlo simulation from the National Radiological Protection Board (NRPB SR262).

Results

The mean patient age was 45±19 (18.0-75.0) years. The mean and range of patient weight (kg) were 75.2± 14 (48.0-110.0). The overall exposure parameters were 59.1±13 (42.0-82.0), 2.0±0.5 (1.5-2.7) and 0.5±0.8 (0.3-2.8) for the tube voltage (kVp) and tube current-time product (mAs) and fluoroscopic time (m), respectively. The mean and range of patient dose per procedure were 640 (40- 7580) mGy.cm^2. The effective dose (mSv) 's overall mean and range ranged from 80 (0.01 to 122.0) per procedure.

Conclusions

Patients' radiation dose per procedure showed wide variation up to 100 times due to variation in the clinical indication and examined organ. Variation of patient doses among different departments attributed to the variation in the x-ray machines settings. The probability of future cancer induction has no threshold and is dose-dependent. Therefore, dose reduction is recommended for high dose procedures such as the DHS through proper equipment setting and establishment dose reference level (DRL).

Estimation of Patient Effective dose and radiogenic risks Dose during CT Examinations

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Introduction

Medical exposure is the largest source of artificial radiation to the general population. Computed tomography (CT) has tremendous benefits to human health. However, there is increasing concern regarding the risk of this radiation exposure. This study aims to quantify the patient dose in CT examination for the brain, chest, and Abdomen and estimate the patient's effective dose and radiogenic risk resulting from this imaging procedure.

Methods

The radiation dose was measured in five radiology departments equipped with different CT modalities from different vendors. Effective doses were estimated using computer software based on Monte Carlo simulation from the National Radiological Protection Board (NRPB SR262).

Results

In this study, the mean effective dose for hospital A were 4.3±1.7 mSv, 20.5±6.6 mSv, and 62.3±32.5 mSv for the brain, chest, and Abdomen. The mean effective dose for hospital B were 3.8±1.4 mSv, 28.1±36.5 mSv, and 46.2±34.2 mSv for the brain, chest, and abdomen, respectively. The mean effective doses for hospital C were 2.7±1.4 mSv, 8.5±3.4 mSv, and 18.2±13.1 mSv for the brain, chest, and abdomen, respectively. In that order, the mean effective dose for hospital C were 3.2±1.6 mSv, 12.5±9.7 mSv, and 36.9±20.6 mSv for the brain, chest, and abdomen. The mean effective dose for hospital E was 1.6±0.9 mSv, 3.2±1.8 mSv, and 8.7±5.7 mSv for the brain, chest, and Abdomen, respectively.

Conclusions

Two departments with 64 CT slices expose patients to higher doses than departments with 16 slices. The radiation dose from these procedures is higher compared to previous international studies. A local diagnostic reference level was proposed, and actions were taken to ensure optimum radiation exposure.

Evaluation of Patient organ and effective doses and radiogenic risks Dose during computed tomography procedures

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Introduction

CT in medical diagnosis delivers radiation doses to patients higher than those from other radiological procedures. Undergoing radiation treatment for cancer that is not breast cancer increases the risk of breast cancer later in life. The aims of this study are, first, to measure patient doses during CT chest and abdomen procedures; second, to estimate the radiation dose to the breast and thyroid gland; and third, to quantify the radiation risks during the procedures.

Methods

Patient doses from two common CT examinations were obtained from three hospitals. The patient doses were estimated using measurements of CT dose indexes (CTDI), exposure-related parameters, and the ImPACT spreadsheet based on NRPB conversion factors.

Results

Radiation dose to the breast ranged from 1.6 to 32.8 mSv for the chest and 2.3 to 18.8 mSv for the abdomen. A significant variation in mean organ doses among hospitals was observed for similar CT examinations. These variations primarily originated from different CT scanning protocols used in different hospitals and scanner types. The most extensive range was found for chest CT, for which the dose varied from 2.3 to 46.9 (average 24.6) mSv, and for abdomen CT, it was 3.3 to 26.9 (average 15.1) mSv.

Conclusions

The radiation risk per procedure was high and increased the risk of breast cancer for young females. These values were mainly higher than organ doses reported in the other studies. It was concluded that current clinical chest and abdomen protocols result in variable radiation doses to the breast. Implementation of accurate referral criteria is recommended to avoid unnecessary breast radiation exposure.

A novel active dosimeter for Flash Radiotherapy

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Introduction

The recent "explosive" interest of the radiotherapy community in the novel FLASH radiotherapy (FRT) encouraged industrial and research entities to develop new accelerators and perform pre-clinical tests. However the clinical implementation requires a better understanding of the biological mechanisms and to overcome technological limits, such as developing active dosimeters able to linearly respond up to several MGy/s in terms of instantaneous dose rates. This communication describes UCD (unbalanced core detector), a new detector for FRT developed and patented by INFN Italy.

Methods

UCD is based on a spherical sensitive core whose diameter can be chosen from 4 to 10 mm, thus is intrinsically isotropic. The front-end electronics was designed to provide a time description of the radiation pulses with resolution in the order of hundreds of ns. Percentage depth dose (PDD) curves and lateral profile distributions were measured with ElectronFlash machines (produced by Soiort – S.I.T. Sordina IORT Technologies S.p.A, Aprilia - Italy) using 7 and 9 MeV electron beams with 10 cm diameter in water phantom. The radiation ageing and linearity were also tested.

Results

UCD proved to linearly respond up to about 25 Gy/pulse and its radiation-induced fading is as low as < 1% / 100 kGy. Percentage depth dose (PDD) curves and lateral profile distributions well compare to reference curves obtained with Radiochromic, qualifying the UCD as a very promising dosimeter for this novel radiation modality.

Conclusions

UCD is an excellent candidate for dosimetry in Flash-radiotherapy. Negotiations with enterprises are in progress to make it available for the market.

Acknowledgements

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Radiation response of marble-glass materials in medical radiation dosimetry

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Thermoluminescent dosimeters (TLD) have proven themselves particularly effective in radiation assessments, TLDs offering several advantages over other dosimetric forms, including typically being of small size and in certain phosphor-based cases soft tissue equivalent. Glass-based TLDs offer features that promise to extend the utility of TLD, including offering a relatively large dynamic range over which sensitivity to differing levels of radiation exposure is provided, also a water impervious nature. Several studies have demonstrated the potential of doped as well as undoped silica-glass fibres as effective dosimeters in diagnostic and radiotherapy applications. In present study, in seeking a low-cost alternative to fibres we investigate commercially available marble-glass over a range of colour and size, comparing their response over a range of radiation doses. Use has been made of three diagnostic mechines including CT scanner, chest xray, Portable. Results show linearity in the transparent samples with low TL response. However, the other colours showed unstable response over the doses. While as expected, the dose sensitivity of marble glass is less than that of much more expensive doped Photonic Crystal Fibres (PCFs), Germanium Flat Fibres (Ge-FF) and co-doped Germanium Boron Flat Fibres (GeB-FF), they nevertheless continue to provide sufficient sensitivity for radiotherapy applications.

Exploring the impact of Bi_2O_3 Particle Size on the Efficacy of Dimethylpolysiloxane for Medical Gamma/X-rays Shielding Applications

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Introduction

In this work, the effect of the particle size range on dimethylpolysiloxane (DMPS) on the attenuation and mechanical properties was investigated. We aimed from this work to explore the impact of micro and nano-Bi2O3 on the radiation shielding properties of the prepared composites.

Methods

The control sample was prepared consisting of 50% DMPS+50% Bi_2O_3-MPs and referred $(DMPS\text{-}Bi_2O_3)_{50m}$. Microparticles (MPs) were gradually replaced by Nanoparticles (NPs) to fabricate five samples coded by $(DMPS\text{-}Bi_2O_3)_{40m10n}$, $(DMPS\text{-}Bi_2O_3)_{30m20n}$, $(DMPS\text{-}Bi_2O_3)_{20m30n}$, $(DMPS\text{-}Bi_2O_3)_{10m40n}$, and $(DMPS\text{-}Bi_2O_3)_{50n}$. The LAC "Linear attenuation coefficient" was determined at different energies including low and high energies for all prepared composites using an experimental gamma ray measurements and acquisition system. The HPGe detector and various point sources (^{60}Co, ^{137}Cs and ^{241}Am) was used in the experimental technique. The LAC of control sample was evaluated by XCOM-software and compared to the experimental values to verify the accuracy of the experimental results. The other attenuator parameters (Half (HVL) and Tenth (TVL) value layer and mean free path (MFP) as well as Radiation shielding efficiency (RSE)) have been calculated.

Results

We found a good agreement between the experimenatl and theoretical LAC .The highest LAC of the prepared polymer composites was $(DMPS\text{-}Bi_2O_3)_{20m30n}$ while the lowest LAC observed for control sample $(DMPS\text{-}Bi_2O_3)_{50m}$ at all discussed energies. The HVL of $(DMPS\text{-}Bi_2O_3)_{20m30n}$ > $(DMPS\text{-}Bi_2O_3)_{30m20n}$ > $(DMPS\text{-}Bi_2O_3)_{10m40n}$ > $(DMPS\text{-}Bi_2O_3)_{50n}$ > $(DMPS\text{-}Bi_2O_3)_{40m10n}$ > $(DMPS\text{-}Bi_2O_3)_{50m}$.

Conclusions

The inclusion of Bi_2O_3 nanoparticle has a better impact on the radiation shielding properties of the prepared samples. Also, the addition of Bi2O3 causes an increase in the LAC while a decrease in the half value layer.

Effect of concentration of CuO on radiation shielding characteristics of Polyethylene terephthalate (PET)

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Introduction

Shielding is one of the fundamental principles of radiation protection and plays a significant role in reducing radiation exposure. Polymers such as epoxy resin show great promise for future advancements in radiation shielding designs for application in radioactive diagnostic, radiotherapy, and the nuclear industry. We investigated composites based on epoxy resin impeded with both micro and nano size of copper oxide (CuO) for photon shielding application

Methods

Four Epoxy-CuO composites were prepared including pure Epoxy resin material, Epoxy-CuO_{10m} (90% Epoxy +10% CuO-MPs), Epoxy-CuO_{30m} (70% Epoxy +30% CuO-MPs) and Epoxy-CuO_{50m} (50% Epoxy +10% CuO-MPs). The same composites were prepared with CuO-nanoparticles (Epoxy-CuO_{10n}, Epoxy-CuO_{30n} and Epoxy-CuO_{50n}) as well as three other composites with micro and nano together (Epoxy-CuO_{5m5n}, Epoxy-CuO_{15m15n} and Epoxy-CuO_{25m25n}). We measured the linear attenuation coefficient between 0.059 and 1.33 MeV. We determined the tranmsssion factor for each composition and the radiation protection efficiency .

Results

The results showed that the composites have mixture of micro and nano CuO have higher attenuation preference than composites with only micro or CuO-NPs at all discussed energies. It was observed that the attenuation preference of the compsoite with 50% of CuO is better than the other compsoites. We found that the impact of CuO on the LAC and other radiation shielding parameters is notable at 0.059 MeV, but it has a small effect at higher energies.

Conclusions

The composites that have CuO in both sizes (micro and nano) are preferable in radiation shielding applications. Also, it is important to increase the thickness of the composites to enhance their attenuation performance against high energy radiation.

Estimation of cardiologists annual exposure in Saudi Arabia

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Introduction

Previous studies showed a significant prevalence of eye lens opacities up to 59% of the screened cardiology personnel, and recent investigations have shown that cardiac catheter staff may be subjected to greater doses that exceed the yearly dosage limit. This study aims to quantify the annual effective dose for cardiologists, technologists, and nurses in cardiology interventional units.

Methods

A total of 45 staff members in the interventional cardiology unit were assessed for deep and skin doses. Thermo-luminescent dosimeters (TLD-100, LiF: Mg, Ti) with automated TLD readers (Harshaw 6600) were calibrated to quantify occupational doses. Skin and deep doses of ionizing radiation (Hp(10) and Hp(0.07)) were used to assess exposure.

Results

The average annual cumulative dose (mSv) for the present monitoring period was 4.0 (0.3 - 15.6) for deep doses (Hp10) and 4.2 (0.5 - 17.2) for skin doses Hp(0.07), respectively.

Conclusions

Cardiologists are exposed to higher personal equivalent doses than nurses and technicians. Experienced cardiologists receive higher doses because they usually carry out complex procedures with extended fluoroscopic exposure. Thyroid and lead goggles are not frequently used during the interventional procedures. Reduction of staff doses is the recommended guarantee that the exposure limit is not exceeded.

Radiation **P**rotection and **D**osimetry in **I**ndustry

EPR characterization of thulium-yttria micro rods

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Introduction

Radiation dosimetry demands a continuos innovation in materials development. Yttria (Y2O3) exhibits intrinsic lattice features that enable doping with other rare-earth ions, resulting in improvement of its solid state characteristics. This work aims to evaluate the EPR response of thulium-yttria (YTm) rods containing 0.1at.%Tm (at.% atomic percentage of thulium) and formed by bio-prototyping.

Methods

YTm micro rods were irradiated with gamma (^{60}Co) doses from 0.001 to 150 kGy and evaluated by Electron Paramagnetic Resonance (EPR), with an X-band EPR, and at room temperature.

Results

According to results, YTm rods exhibited a linear dose-response behaviour in a range of dose from 0.001 to 1kGy. In addition, fading signal stability was achieved from 168h.

Conclusions

These findings indicate that thulium-yttria is a promising material for radiation dosimetry.

Online electron beam monitoring with a diode-based dosimetry system in routine quality control

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Introduction

The online response of a thin diode in electron beam processing dosimetry has previously been investigated. The main results are the linear dose response with sensitivity constant for doses up to 75 kGy and the stable dose rate response with repeatability ≤ 2.0 %. In line with these previous findings, this work aims to study the suitability of this dosimeter for measuring electron beam profiles and monitoring variations in the radiation field. Such information, essential for routine quality control, enables on-spot action avoiding unexpected shutdowns and increases in production costs.

Methods

The dosimetry probe consists of a diode (230 µm thick; 7.0 mm^2 area) in a light-tight case. Its p+ front pad is connected to the Keithley 6517B electrometer in the short-circuit mode. Irradiations are performed at a 1.5 MeV electron accelerator (DC 1500/25/04 – JOB 188) by sending the probe through the radiation field in the conveyor direction, varying speeds from 2 to 10 m/min. The electron beam is made to cover a width of 1m by magnetically scanning it at 100 Hz. Alanine dosimeters and cellulose triacetate (CTA) films are used for reference.

Results

Electron beam profiles are measured at different conveyor speeds and integration times of the electrometer. The best results are achieved at the highest conveyor speed (10 m/min) and the smallest integration time (0.05s). Under these conditions, the data gathered with the diodes agree with those assessed with alanine and CTA dosimeters. The dose readings during each diode pass underneath the beam coincide with the alanine measurements regardless of the integration times. The evaluation of the reproducibility parameter is underway.

Conclusions

Online beam profile and dose measurements performed with the diode agree well with those statically obtained with a reference alanine dosimeter. However, attention must be paid to setting the appropriate integration time at each conveyor speed to achieve the best profile resolution.

Assessing radiation damage to semiconductor devices from low-energy X-rays: A study using TLD-400 dosimeters

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Introduction

The impact of radiation on semiconductors is an increasingly critical concern in our daily lives, as more commercial devices contain radiation-sensitive chips. Prior research has primarily focused on the effects of cosmic and solar radiation on satellites and aircraft. However, recent attention has been given to the damage caused by secondary neutrons resulting from such space radiation, particularly in chips used for IoT or mobile devices. Additionally, it is important to note that X-rays can also cause damage to delicate electronics. X-ray machines are widely used in various industries for non-destructive testing, but they can harm chips sensitive to even low levels of radiation. This study used TLD-400 thermoluminescence dosimeters (TLDs) to assess the doses of low-energy photons emitted by keV X-ray imagers.

Methods

This study calibrated and implemented TLD-400 on three different dual-source baggage inspection X-ray machines with a field size of 100 cm * 100 cm and distance of 147 cm. The machines used different voltages and currents such as 81.49 kV/512.74 mA, 77.83 kV/485.27 mA, and 82.86 kV/512.74mA, respectively. To avoid interference from customs officers conducting baggage inspections, the TLD-400 was exposed for varying lengths of time according to the frequency of use of each X-ray machine.

Results

After 31 days of exposure, the absorbed doses of the TLD-400 in the three dual-source baggage inspection X-ray machines were measured to be 5 cGy, 17 cGy, and 62 cGy, respectively. The corresponding mAskV^2 values were also recorded and showed a good linearity with the absorbed dose. These results show that TLD-400 can accurately evaluate the reliability of semiconductor radiation when exposed to low-energy X-rays.

Conclusions

These results demonstrate that TLD-400 can accurately evaluate the reliability of semiconductor radiation when exposed to low-energy X-rays.

Mapping of the ionizing radiation field of the panoramic multipurpose irradiator category II

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Dosimetry involves the investigation and quantification of the dose absorbed by an object or organism when exposed to ionizing radiation. The study was conducted as part of the Installation Quality Assurance Program to assess the accuracy of the ionizing radiation field emitted by the Panoramic Multipurpose Irradiator Category II, model/serial number IR-214, manufactured by MDS Nordion in Canada, and of type GB-127. This irradiator is equipped with a dry stored Cobalt-60 source with a maximum activity of 2,200 TBq or 60,000 Ci. Measurements were taken at various distances and heights surrounding the irradiator to achieve this objective. A Fricke absolute dosimeter was used to quantify absorbed dose values, following ICRU 35 standards, which provide absolute measurements with only 2% uncertainty. The results demonstrate that the radiation field around the irradiator exhibits predominantly radial behavior. Moreover, significant variations in absorbed dose values were observed, reaching approximately 70% depending on the position and height. It is important to highlight that the inverse square law does not apply to this type of irradiator. These findings have significant implications for the services offered at the Gamma Irradiation Laboratory (LIG/CDTN), as mapping the radiation field will improve positioning accuracy and precision in determining the absorbed dose of irradiated products. In summary, this study presents a comprehensive and innovative analysis of the mapping of the ionizing radiation field of the GB-127 irradiator at LIG, ensuring the quality of the performed irradiations.

Investigation of radiation doses and dose constraint values of non-medical planned exposure radiation practices in Taiwan

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Introduction

In Taiwan, the Atomic Energy Council (AEC) is the competent authority in charge of the safety of ionizing radiation operations. In recent years, the AEC hopes to introduce the concepts of as low as reasonably achievable and dose constraint recommended by the International Commission on Radiological Protection (ICRP), timely grasp and control the radiation safety situation of different radiation practices, and review the protective control measures, so that the industry understand the concepts of optimization of radiation protection of planned exposure situations.

Methods

This study focuses on the radiation safety investigation of the facility operators who use the non-medical planned exposure radiation sources (such as open beam/mobile X-ray detectors, X-ray tube static eliminators, ion implanters, cabinet-type X-rays and sealed radioactive material) in Taiwan. The AEC provides equipment rosters for sampling and the investigated objects were randomly selected. On-site radiation safety surveys are carried out with radiation survey meters, which measure the doses of radiation workers and the general public that may be caused by normal operations, and evaluate the impact of possible abnormal doses on some high-risk radiation operations; and evaluate the dose constraint values of different types of radiation practices by data statistical analysis.

Results

During the years from 2020 to 2022, a total of 1122 radiation sources (including 783 equipment capable of producing ionizing radiation and 339 sealed radioactive material) were subjected to on-site radiation safety investigations by this study. Besides, the dose constraint values of different types of radiation practices were proposed.

Conclusions

This paper conducted the investigations, evaluated the radiation doses according to the type and use of radiation sources, and proposed dose constraint values of different types of radiation practices to AEC in Taiwan for reference.

Thermoluminescence and phototransferred thermoluminescence of radiation dosimeters: analysis of the effect of UV light for transfer of charges from deep traps

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Introduction

The stored energy by some solid-state materials in the form of trapped electronic charges, after exposure to ionizing radiation, can be measured when the stimulation of those charges occurs; one way is the heating of the sample, to observe its luminescent signal by the thermoluminescence (TL) technique. Another form to study the luminescence of these materials is by means of the phototransferred thermoluminescence (PTTL) technique, that allows the observation of the light-induced transfer of charges from one kind of trap to another. The main objective of this work was to study the TL and PTTL of radiation dosimeters in ^{60}Co and UV beams.

Methods

The responses of LiF:Mg,Ti, CaF_2:Dy, CaF_2:Mn and $CaSO_4$:Dy commercial dosimeters were studied in the sequence: 1) TL after irradiation; 2) TL after irradiation + thermal treatment (TTPI); and 3) PTTL after irradiation + TTPI + illumination. The irradiations were performed using a ^{60}Co source from a Gamma-Cell system, and all the measurements were taken using the Risø reader system, model TL/OSL-DA-20. The absorbed doses were: 0.7 Gy (LiF:Mg,Ti and $CaSO_4$:Dy), 20 Gy (CaF_2:Dy) and 50 Gy (CaF_2:Mn), for the first step, and 5 Gy (LiF:Mg,Ti), 100 Gy (CaF_2:Dy), 200 Gy (CaF_2:Mn) and 25 Gy ($CaSO_4$:Dy), for the second and third steps.

Results

In the initial step, TL emission maximum peaks were observed for all four materials: at about 250ºC (LiF:Mg,Ti), 300ºC (CaF_2:Dy and $CaSO_4$:Dy) and 385ºC (CaF_2:Mn). After TTPI, in the second step of the experiments, the TL peaks arised at about 365ºC for LiF:Mg,Ti, and for the other materials no peaks were observed. In the final step, after exposure to UV light, PTTL signals appeared for LiF:Mg,Ti at 260ºC and 370ºC, for CaF_2:Mn at 398ºC and for $CaSO_4$:Dy at 200ºC; no PTTL was observed for CaF_2:Dy.

Conclusions

According to the results obtained, it was possible to study the occurrence of the phototransferrence signal of the materials, present for LiF:Mg,Ti, CaF_2:Mn and $CaSO_4$:Dy.

OSL and PTOSL of dosimetric materials: observation of the luminescence after exposure to $^{90}Sr+^{90}Y$ source and LEDs in ultraviolet range

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Introduction

The study of luminescence phenomena by crystal-based radiation detectors is suitable for radiation dosimetry, once the light emitted by them enables the quantification of their deposited radiation energy. The light emission can be promoted when a material is illuminated with a certain wavelength and time interval, as in the optically stimulated luminescence (OSL) and phototransferred OSL (PTOSL) processes. The objective of this work is to evaluate the OSL and PTOSL responses of commercial dosimeters in order to study their luminescence and the possibility of use in radiation dosimetry with the PTOSL technique.

Methods

OSL and PTOSL responses of LiF:Mg,Ti, CaF_2:Dy, CaF_2:Mn and $CaSO_4$:Dy dosimeters, commercially sold as TLD-100, -200, -400 e -900, respectively, by Thermo Fischer Scientific, were studied. The samples were irradiated with the $^{90}Sr+^{90}Y$ source of the TL/OSL reader system Risø, and the measurements were taken using the same system and signal emission stimulus time of 100 s with blue LEDs. For PTOSL signal, the dosimeters were irradiated, thermally treated and illuminated with LEDs with wavelengths between 265 nm and 420 nm.

Results

The dosimeters were irradiated with 0.75 Gy (TLD-100 and -900), 20 Gy (TLD-200) and 50 Gy (TLD-900). The most intense OSL signal occurred for TLD-100 (initial decay point of 53.308 counts), while the TLD-200 presented the lowest OSL signal (value of 1.086 counts), for TLD-400 and -900, the values were 13.291 counts and 2.916 counts, respectively. In relation to the study of PTOSL response, after illumination the TLD-100 produced a signal of 56.600 counts, TLD-200 of 450 counts, TLD-400 of 650 counts and TLD-900 of 1.200 counts.

Conclusions

Comparing the OSL and PTOSL results, it is possible to observe clearly the phototransferred effect for TLD-100. For TLD-200 and -400, no effects were noted. In the case of TLD-900, it presented a PTOSL signal in a small-scale when analyzing the curve integral.

Enhancing Beta Spectrum Unfolding in mixed Beta/ Gamma Radiation Fields: Combining Iterative and Machine Learning Approaches

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Introduction

This study focuses on beta-ray dosimetry for mixed beta-gamma radiation fields. Beta unfolding algorithms have been developed to extract beta fluence rate spectra from raw pulse height spectra that were collected by a beta coincidence spectrometer consisting of a thin silicon detector and a plastic scintillator detector. The spectrometer rejects the gamma detection events by applying a coincidence method.

Methods

Stability tests were conducted to assess the reliability of the system using calibration sources. The energy-dependent response function was computed through Geant4 Monte Carlo simulations to establish its coincidence efficiency for different beta energies and beta-gamma ratios. A Gaussian Energy Loss function was determined as the system response by comparing measurements and corresponding simulations with a Sr/Y-90 calibration source and characterizing the response of the spectrometer with respect to the beta fluence rate spectrum at the detection window. Two unfolding algorithms, P.A. Jansson's iterative method and the Richardson-Lucy iterative deconvolution algorithm, were developed based on the system response. Additionally, a convolutional neural network (CNN) model was trained using artificially generated fluence rate spectra and the system response to serve as an unfolding algorithm. The performance of each method was evaluated using various beta spectra created by adding thin plastic moderators.

Results

The CNN unfolding method can produce a fluence rate spectrum, whose shape is more similar to that of the true spectrum. However, there is a potential risk of overfitting, which could be mitigated by expanding and diversifying the database used for training. The iterative unfolding algorithms' stability and interpretability offer advantages. A hybrid algorithm combines these unfolding methods is currently under development to improve the unfolding performance. These unfolding results will be investigated comprehensively further.

Conclusions

The combination of traditional iterative unfolding and machine learning-based unfolding methods shows promising results for the beta spectrum unfolding. By leveraging the strengths of both approaches, a reliable and effective unfolding result can be achieved.

Radiation safety standards for security x-ray screening of people

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Humans are routinely screened with x-rays for security purposes. Today and in the past, such screening has occurred in airports, prisons, at borders crossings, and many other circumstances. For more than a decade, the two major radiation safety standards for security screening of people have had different dose limits for equivalent systems as well as fundamentally different measurement methods. We describe work to update and harmonize these two standards with an emphasis on the methods they use to estimate the effective dose to people being scanned.

The two main radiation safety standards for screening people with x-rays are IEC 62463 and ANSI/HPS N43.17. Both standards are currently under revision, which presents an opportunity to address the major differences that exist between them. The standards use different dose quantities (ambient dose equivalent vs reference effective dose), recommend different measurement methods, have different system classes, and set different dose limits. For example, when x-ray backscatter systems were widely deployed in US airports, their safety was mostly discussed by reference to ANSI/HPS N43.17 and its 250 nSv per screening dose limit. However, IEC 62463 has a dose limit of 400 nSv per screening for those same systems.

As part of the revision process, the IEC standard adopted the lower dose limits and improved system classes used in ANSI/HPS N43.17. The measurement methods in the IEC standard were also revised to be more consistent with the other standard, so that a single set of measurements can be used to show compliance with the dose limits in both standards. The IEC standard was also updated to reflect the recent (2020) recommendations of the International Commission on Radiation Units and Measurements (ICRU), as given in ICRU Report 95: Operational Quantities for External Radiation Exposure. The ICRU report provides new definitions for key operational and radiation protection quantities that provide better estimations of dose in both medical and security applications where persons are exposed to ionizing radiation.

It is hoped that these changes will provide a clearer set of radiation safety guidelines for these systems and safer screening of people throughout the world.

Investigation of x-ray response for flexible nanocomposite membranes of metal oxides and PVA

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In this work, flexible composite membranes of nanoparticles (CuO, ZnO, or both), poly(vinyl alcohol) (PVA), and glycerol (GL) plasticizer are fabricated of for x-ray detector applications. The nanoparticles are synthesized by a modified solvothermal technique and introduced to PVA + GL solution to fabricate the membranes. The mean sizes of nanoparticles are and , for CuO and ZnO in order. The composition of nanoparticles and membranes are investigated by energy dispersive x-ray spectroscopy and x-ray spectroscopy. Increasing nanoparticle concentration within the membranes causes their glass transition temperature to shift to low temperatures and enhances their thermal resistance. Fourier-transform infrared spectroscopy demonstrates the formation of hydrogen bonds between nanoparticles and PVA that are generated by the intermolecular and intramolecular hydrogen bonds. Impedance spectroscopy characterization reveals that the membranes hold negative temperature coefficient of the resistance. The activation energy decreases with increasing nanoparticle concentration. The composite membranes exhibit a decent response to x-ray that is proportional to its energy. The best x-ray response is for the membranes with both CuO and ZnO nanoparticles, because of their different bandgaps that cause a wide range of excitation energy to be involved. The fabricated membranes have numerous advantages such as their semiconductor features, flexibility, and feasibility of fabrication on a large scale with reasonable cost.

Nuclear **D**ata and **E**valuation

Spectra measurement of ^{238}Pu-^{13}C source

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Introduction

The knowledge of the neutron spectrum forming the neutron field is an essential task regardless of the source of its origin. The purpose of its use determines the requirements for the accuracy of the spectrum definition. In the case of a standard neutron field or a benchmark reference field, there is a strong demand for precise determination of neutron spectra in the sense of low uncertainties in narrow groups, because such fields are used for the measurement of selected cross sections. For radiation safety purposes, the requirements are not as strong because the doses are obtained by integrating the spectral flux with the flux-dose conversion factor. However, the precise knowledge is also valuable.

Methods

Neutron spectra were measured by stilbene scintillation spectrometry using a 45x45 mm large crystal. Indirect calibration using capture gamma peaks was used for evaluation.

Results

The resulted spectrum is in good agreement with previously presented data.

Conclusions

The presented results of precise spectra measurement of ^{238}Pu-^{13}C neutrons are valuable for purposes of using these sources in integral experiments focused on the testing of selected cross sections or for the testing of dosimetric devices.

Comparative analysis of shielding activation in three types of Compact Proton Therapy Centers (CPTC)

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Introduction

Proton therapy centers are growing fast, both in Spain and all around the world. Prompt radiation attenuation is essential to achieve legal dose limits, but not enough to develop efficient radiation protection of these facilities. Activation of mechanical elements, ambient (air, water, ground), and of course, the shielding, is a relevant issue, linked with radiation protection conditions, as well as future dismantling and management of radioactive materials. To estimate and reduce decommissioning costs, a sensitive part of total investment, it is essential to study the cycle of life of the facility, thus, the goal of this work was to carry out comparative analyze of neutron activation in shielding of three compact proton therapy centers, depending on the concrete used.

Methods

Calculations were developed using two Monte Carlo codes (MCNP and PHITS), in three types of proton therapy centers, similar to those working now or planned for Spain, and four types of concrete (conventional, high-density with magnetite, high-hydrogen-content, and low activation). Considering the energy of neutrons, up to 230 MeV, and the generation of radioisotopes through capture and spallation reactions, both, several physics models, and nuclear data libraries were used and benchmarked, namely, ENDF/B VIII.0, JENDL-4.0, JEFF-4T2 and TENDL2017/19.

Results

From the activation point of view, best concretes are those with low impurities. The type of activation, and the isotopes present, depend on the channel of the reaction. From the attenuation point of view, the four concretes largely meet the necessary dose attenuation conditions.

Conclusions

Induced radioactivity remains in the walls of centers for several years, even decades, after their closure, therefore, a good inventory estimation, depending on the choice of the shielding material, could be advisable in the early stages of projects. Considering the flux and neutron spectrum in each area of the center, it would be more suitable to use different concrete for each area, optimizing the selection based on attenuation, activation, and cost.

Cyclotron-based p(27)+Be neutron source for activation experiments

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Introduction

The Nuclear Physics Institute (NPI) of The Czech Academy of Sciences operates the accelerator-driven fast neutron sources with white and quasi-monoenergetic spectra using charged particle beams delivered by the cyclotron U-120M. In standard operation, proton induced reactions on thick beryllium or thin lithium targets are used for neutron field production within the fusion related research applications (e.g., cross-sections measurement and validation for IFMIF-DONES research program). Recently, the p+Be source reaction was investigated for 27 MeV proton beam and a thick Be-target at the NPI in Rez near Prague, and a new intensive neutron field of white spectrum up to 25 MeV was successfully developed.

Methods

For the neutron field determination of the p(27)+Be source reaction at close source-to-sample distances, the multi-foil activation technique was utilized. Sets of ten activation materials (Al, Ti, Fe, Co, Ni, Y, Nb, In, Lu, Au) were irradiated by neutrons from the p(27)+Be source, and the activated dosimetry foils were analyzed using the nuclear γ-ray spectrometry method.

Results

Based on the measured reaction rates, the white neutron spectrum up to 25 MeV was reconstructed utilizing the modified version of SAND-II unfolding code. The study of Be(p,xn) source reaction with a 27 MeV proton beam provided new spectral data for the energy range that is characterized by a lack of empirical data (above 20 MeV). The fast neutron flux of the investigated p(27)+Be neutron field has reached a value of 10^{10} $cm^{-2}s^{-1}$ at the close source-to-sample position.

Conclusions

The obtained p(27)+Be neutron field was determined for the first time at NPI, extending the utilization of cyclotron-based fast neutron sources and providing new experimental opportunities for future intensive irradiation experiments, such as nuclear data validation, fast neutron activation analysis, radiation hardness tests of electronics and materials for nuclear energetics, and aerospace industry.

Neutron Dosimetry

Analysis of the standard calibration method for neutron monitors

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Introduction

The Neutron Standards Laboratory of CIEMAT (LPN for its acronym in Spanish) is the Spanish National Reference Laboratory for neutron metrology. It provides metrological traceability to neutron dosimeters through calibrations. The calibration factor is a unique property of the instrument and must not depend of the calibration method or facility. The ISO 8529-2 standard, currently under review, recommends four calibration methods for neutron dosimeters. It states that at least two of them should be compared to ensure the quality of the calibration results. In this study, calibration factors are obtained and compared using the four standard methods.

Methods

Two Berthold LB6411 neutron monitors are calibrated using the four standard methods. Irradiations are made at the LPN's facilities using a 241Am-Be calibration source. These methods separate the direct and scattered neutron contributions in the dosimeter reading by different approaches The shadow cone method uses two measurements to determine the scattered component, with and without a shadow cone placed between source and monitor. The other methods use measurements at different source distances fitted using weighted lest squares to the method's equation. Calibration factors are obtained for each monitor with standard uncertainties.

Results

Despite the different methodology of each calibration method, the results for each monitor show that the calibration factors are in good agreement considering their standard uncertainties, Also, the difference between calibration factors are below 4%, as required by the ISO 8529-2 standard.

Conclusions

In this study, it is verified that the calibration protocols for neutron monitors of the LPN comply with the requirements of the ISO 8529-2 standard, which allows ensuring the quality of the calibration results in the LPN. These results may also be of interest given that the calibration methods of ISO 8529-2 standard are under revision.

Validation of the SpecUnPy code for thermalized neutron fields

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Introduction

Design, construction, and use of thermal neutron irradiators are each time more common because these devices can be used for a wide range of applications. This technology has been pushed in the last years, presenting a great framework in the next years, so unfolding codes need to be validated for these facilities. Moreover, these facilities are similar to neutron source storage devices (like Howitzer containers).

In this work, scenarios that meet the requirements of installations with thermalized neutron fields were selected for the validation of the SpecUnPy code.

Methods

Validation scenarios selected for this work have been chosen in order to validate the code in the following facilities: UPM-FANT and UPM-Howitzer container (storage and irradiation positions). Spectra unfolded with SpecUnPy have been compared with the MCNPX simulated spectra, as well as spectra unfolded with NSDann and NSDUAZ. For all cases included in this work, initial flat spectra and UTA-4 response matrices have been adopted as calculation input data.

The output values considered for the comparison of neutron spectra unfolding codes, were as follows: total neutron flux, partial neutron fluxes (thermal, epithermal, and fast fluxes), neutron spectra, and H*(10).

Results

Results show that the three algorithms implemented in SpecUnPy provide integral quantities and spectra shapes close to that provided by the simulated spectra from MCNPX, as well as spectra unfolded with NSDann and NSDUAZ.

Conclusions

This work presents the validation for thermalized neutron facilities of the SpecUnPy unfolding code. This code reliably solves the neutron spectrum unfolding problem for thermal neutron irradiation facilities.

Developing and using international standardS for Neutron ambient dose equivalent rate meters

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Introduction

Measurements of neutron dose equivalent rates are challenging because there are no "perfect" instruments that cover the entire 9 orders of magnitude neutron energy range (thermal to 20 MeV). Hence quantifying the performance requirements in a standard for such instruments presents unique challenges.

Methods

The international standard IEC 61005 Ed. 3 concerning neutron ambient dose equivalent (rate) meters was developed by Sub-Committee 45B "Radiation Protection Instrumentation" of the International Electrotechnical Commission (IEC). The standard was also trans positioned as European standard EN 61005 as well. The main characteristics of the standard are presented as well as challenges during its development.

Results

Measurements of the neutron energy, fluence and dose equivalent rates are provided which illustrate the challenges of specifying the standard test requirements for neutron dose (rate) meters when they are tested against the standard. Testing according to IEC 61005 of a portable neutron survey rate meter is also discussed. The testing includes specific tests for:

- constancy of the dose rate response;
- variation of the response due to neutron energy;
- variation of the response due to angle of incidence;
- overload;
- response time;
- temperature shock;
- protection against moisture and dust;
- drop test;
- vibration and mechanical shock test;
- various electromagnetic tests.

Conclusions

Possible fusion is considered with IEC 61322 Ed. 2 "Installed dose equivalent rate meters, warning assemblies and monitors for neutrons of energy from thermal to 20 MeV".

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Development of a graphite pile to produce a neutron thermal field at the CIEMAT - Neutron Standards Laboratory

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Introduction

The CIEMAT Neutron Standards Laboratory (LPN) is the Spanish national reference laboratory in neutron metrology. It currently has the three neutron sources recommended by ISO 8529-1 as secondary standards for the calibration of neutron measurement equipment: ^{252}Cf, ^{241}Am-Be and ^{252}Cf – D_2O, moderated by heavy water, of in such a way that the first two sources refer to fast fields and the last to epithermal ones. Within the framework of the LPN expansion project, it has been planned to incorporate a thermal neutron field based on a graphite pile. The studies carried out for the design of this new neutron field are developed here.

Methods

The thermal fields from graphite piles are based on a cubic block made up of graphite bricks that houses one or several neutron sources. Various designs has been adopted around this idea: may be a compact block of graphite or incorporates a cavity to employ both, moderation in the block and scattering in the cavity, to improve the neutron fluence rate. This is the model that has been chosen and it allows to calibrate a neutron detector, not only outside the pile but also inside this cavity.

A study has been carried out with MCNP 6.2 for a graphite pile with dimensions 150 x 150 x 180 cm^3, with an 185GBq Am-Be source (B = $1.1 \cdot 10^7$ s^{-1}) and the internal cavity with a section of 40 x 40 cm^2 and a depth of 50 cm. The main parameters of the graphite pile and the position and emission rate of the Am-Be neutron source have been varied to determine the fluence rates at several points in the pile, their thermal component and homogeneity.

Results

The position of the neutron source is one of the most important parameters to be considered to obtain an appropriate thermal percentage, fluence rate and homogeneity of the neutron field. For 45 cm of graphite, a fluence rate of around 2000 cm^{-2} s^{-1} could be obtained inside the cavity and a thermal proportion of 80-84%. Higher values of this parameter implies to displace the source, in such a way that with a graphite thickness of 95 and 105 cm the percentage of thermals would be 98 and 99% respectively and the fluence rates in the centre of the cavity would be reduced to 500 and 400 cm^{-2} s^{-1} for each model. Therefore, a balance between thermal proportion and fluence rate is necessary.

Simulated Neutron Dose on Multiple Cell Culture Configurations

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Introduction

Astronauts who embark on interplanetary space missions will be exposed to harsh radiation environments, resulting in the potential for increased risk of space radiation induced carcinogenesis. Identifying relevant biomarkers related to increased risk of carcinogenesis is crucial for ensuring the health of astronauts after returning from long-duration exploration missions. Exposing cell models to relevant radiation environments and analyzing biomarker levels as a function of appropriate radiation protection quantities is one method for identifying biological activity that may indicate elevated risk for the astronaut. An accurate understanding of the absorbed dose to sensitive cells comprising the cell model is vital for identifying biomarkers that should be further investigated in more human-like systems exposed to space-like radiation.

Methods

Fusion neutrons generated through the D-T reaction were used, since astronauts are likely to be exposed to a substantial fluence of fast neutrons. MCNP was used simulate radiation transport and determine the absorbed dose to two-dimensional (2D) and three-dimensional (3D) cell cultures. Source neutrons were simulated 6 cm away from the center of the cell layers. The entire room was modeled to account for scattered neutrons that contribute dose to the cells.

Results

The absorbed dose was recorded over the cell layer using an F6 tally and converted into milligray per hour for both the 2D and 3D cell culture plates. The absorbed dose rate to the cells ranged from 4.66 to 4.84 mGy h^{-1} with a source strength of 7.65×10^{7} neutrons s^{-1} determined via foil activation.

Conclusions

This simulated dose rate will be used to determine the total dose received by the cells in experiments conducted to identify biomarkers related to increased risk of carcinogenesis from fast neutron exposure.

A new concept for neutron dosimetry in ion beam radiotherapy: Feasibility study

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Introduction

Secondary neutrons are produced in ion beam radiotherapy (IBRT), which leads to whole-body exposure and increases the radiation-induced cancer risk potentially. The IEC requires the estimation of the dose due to neutrons outside the projection of the radiation field [1].

The energies of neutrons produced in the IBRT treatment room range widely from thermal to a few hundred MeV. Extended-range rem meters are one of the potential detectors for assessing these neutrons, but there is a difference between the response function of WENDI-II and the ICRP dose conversion coefficient. Neutrons from 1 MeV to a few hundred MeV play a key component in the ambient dose equivalent [2]. Therefore, we determined to develop a dosimeter with a response function that better reproduces the ICRP conversion coefficients in the energy range from 0.1 to a few hundred MeV to accurately assess the neutron dose in the treatment room.

Methods

Our new concept includes: 1) a hydrogen-filled proportional counter surrounded by moderators, 2) the change of response functions by changing the energy deposit threshold of charged particles produced by neutrons in the counter, and 3) the estimation of neutron energy spectrum using the unfolding method with the counts for various threshold energies. Finally, the dose by folding the energy spectrum, and the dose coefficient can be obtained. In this work, we investigated the feasibility of our concept by Monte Carlo simulation with the PHITS code assuming the secondary neutrons produced during carbon-ion RT.

Results

We confirmed the response function changes in the range of 0.1 keV to 1000 MeV by changing the threshold and the neutron energy spectrum could be estimated with the unfolding method in the assumed neutron field.

Conclusions

A new concept for neutron dosimetry in the IBRT treatment room is proposed and shown to be feasible.

Neutron Personal Dosimetry: Exploring Ciemat Track-Based Methods

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Introduction

Neutron dosimetry is an essential aspect of radiation protection in nuclear power plants, medical facilities and research centers, among other facilities. One of the most widely used techniques for personal neutron dosimetry is based on the analysis of radiation induced tracks in materials such as plastic detectors. This technique provides a reliable and accurate measurement of neutron dose and fluence and has become increasingly popular due to its relative simplicity, low cost and versatility. With the aim to implement personal neutron dosimetry at Ciemat, track detectors have been chosen as personal dosimeters. This work shows the materials, methods and advances in the characterization of the neutron dosimetry system up to date.

Methods

PADC (poly-allyl-diglycol-carbonate) material was selected for the detection of secondary charged particles produced by neutron interactions with the material.

Two chemical etching methods have been tested to check the response and background of irradiated and non-irradiated dosimeters. The detectors were read using the TASTRACK system, which is equipped with a high quality microscope and an ultra-fast three axis motorized control. A software analysis based on the size and shape of the tracks is employed in dose assessment.

Results

The energy response of the PADC and the design of the holder have been analyzed with MCNP6.2 Monte Carlo code, considering different geometries and materials (polyethylene, nylon and lithium, among others). Furthermore, the variability in the response depending on the irradiation angle incidence has been also studied to analyze the reactions produced inside the material.

The PADC dosimeters were also irradiated with calibrated ^{252}Cf and Am-Be neutrons sources on the ISO water phantom at the Ciemat Neutron Standards Laboratory (LPN) at Ciemat to experimentally characterize the response and validate the simulated results.

Conclusions

The results, although preliminary are quite promising. The characterization of the personal neutron dosimetry system according ISO 21909-1 standard is in progress.

Design and development of the extended-range Bonner Sphere Spectrometer at Ciemat

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Introduction

Neutron Standrads Laboratory (LPN) is the national reference facility on calibration of neutron measurement devices. One of the LPN research lines is the measurement of neutrons produced by cosmic rays or around accelerators. Thus, it is necessary to develop neutron spectrometry.

Methods

Ciemat LPN counts with a Bonner Sphere Spectrometer (BSS) consisting of 12 polyethylene spheres of different diameters and 2 He-3 detectors SP9 model, in addition of the data acquisition system. BSS system enables to realize neutron spectrometry up to 20 MeV. Given the necessity of performing measurements of high energy neutrons, the BSS energy range has been extended, adding two new spheres that include lead shells, where neutron spallation reactions are produced, allowing to make neutron measurements up to GeV.

MCNP6.2 Monte Carlo code simulations have been performed in order to design the two previous mentioned spheres. They consist of one inner polyethylene sphere, one intermediate lead spherical shell of 1 inch thickness and one spherical polyethylene shell, with different sizes. The response matrix of the new spheres has been obtained via MCNP6.2 simulations. Thus, nuclear reactions produced inside the active volume of a He-3 detector calculations have been performed for both spheres, using plane-parallel mono-energetic beams including values from $1{\cdot}10^{-9}$ up to $1{\cdot}10^{5}$ MeV. Furthermore, digital electronics data acquisition system has been bought from CAEN, consisting of an 8 channel preamplifier, 8 channel digitizer, two high voltage power supply and one power supply. The BSS extended range system has been completed with six additional He-3 (SP-9 model) proportional detectors.

Results

The BSS extended has been used at LPN to realize measurements with ^{252}Cf and ^{241}Am-Be neutron sources, and subsequently ambient measurements have been performed to determine neutron cosmic spectrum. The neutron spectrum has been obtained using MAXED and GRAVEL unfolding codes.

Conclusions

The new system allows to perform simultaneous measurements with 8 spheres, for ambient measurements or neutron pulsed fields, and the resulting spectra data fit the expected results.

Two-dimensional neutron beam profile measurement in the MARIA research reactor before the H2 beam shutter assembly

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Introduction

In the MARIA nuclear research reactor, a facility for irradiation in a beam of thermal and, in the future, epithermal neutrons is being built. H2 horizontal channel is dedicated to radiobiological and material research, the development of mixed radiation field dosimetry, and others. As one of the stages of beam dosimetry, a two-dimensional scan of the beam profile was carried out.

Methods

A system of two linear guides for the positioning and automatic movement of a pair of gas detectors was designed and manufactured. A pair of cylindrical ionization chambers with a volume of 7.4 cm^3 and external dimensions of the active area ø 18.5 mm and 85.5 mm height were used as radiation detectors. The chambers are tissue-equivalent (T5 type), and non-hydrogen (G5 type) so in the pair they can separate gamma and neutron components in the total tissue kerma rate. The positioning system has been integrated with the dosimetric measurement system of the detectors.

Results

Scanning in and around the beam was performed in 4.5 cm vertical and 1.55 cm horizontal steps at a distance of approximately 25 cm from the channel's cover. The spatial distribution of the tissue kerma and the contribution of the neutron and gamma components were obtained. For a reactor operating at 20 MW of thermal power, the maximum tissue kerma rate was 14.5±0.7 Gy/h, and the contribution of the neutron component for this point was about 7%. From the obtained results, it can be concluded that the beam shape is circular and the diameter for the values of the kerma rate not lower than 95% and 50 % of the maximum is 19 cm and 35 cm, respectively, with an uncertainty of 3 cm.

Conclusions

The presented research results refer to the H2 neutron channel before installing the beam shutter (which is also a collimator). The developed measurement method will allow for the characteristics of the beam at the stage of commissioning the irradiation facility.

Mixed radiation (neutron) measurements in experimental facility by nuclear reactor (dose rate from mGy/h up to Gy/s)

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Introduction

Pre-study of design specific experimental irradiation position in the reactor pool was done. Measurements using special for high doses detector KWD was performed. Supporting measurements with activation foils, alanine detectors and TLD detectors was conducted in the same place. The dose rates in proposed experimental installation was changed from mGy/h up to Gy/s with varying composition of the field (mixed radiation i.e. neutron and gamma).

Methods

Ionization chamber KWD, intentionally designed, for measurements in the field of high dose rates was conducted with a novel fast acquisition procedure was used. Four types of TLD detectors was used to distinguish neutrons from gamma radiation in low and medium dose rates radiation field. Alanine detectors and high dose TLD detectors was used in high dose rates.

Results

Gathered information about the radiation field in the reactor pool combined with calculation of neutronic of the reactor core give the answer how deep the fission chamber should be installed (prolong time of exploitation of detector fulfilling requirements for signal from detector). Measurements performed with success at several positions (characteristic for 7m of water in the reactor pool) starting from surface of water (0.5 mGy/h) ends 50cm below the reactor core (1.5 Gy/s). Activation foils and alanine detectors extend a bit the knowledge of neutron composition and the doses at the level of reactor core.

Conclusions

As a main result of this particular measurements the working position of fission chamber was set for exploitation. High dose TLD detectors, KWD and other detectors were pre-prepared for further experiments conducting research to separation of the neutron and gamma doses. Measurements shows that such construction will have wide application such:

- Calibration of detectors
- Distinguishing components of mixed radiation field
- Improving of detectors
- Research and development of measuring detectors and systems

Ambient neutron dosimetry in high energy and pulsed neutron fields

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Monitoring neutron dose rates is crucial to ensure minimal risks for workers, patients, and the public in different facilities. Concerns arise regarding the reliability of portable ambient neutron dosimeters in modern facilities, especially those with high-energy neutron fields (E>20MeV) and complex time structures [1, 2]. This issue is significant in medical facilities (e.g., proton therapy) with secondary stray radiation up to 250 MeV, synchrotron or cyclotron facilities with pulsed beams or beam losses, and pulsed facilities for research and applications (e.g., spallation, fusion neutron sources, high-intensity lasers). Furthermore, the International Commission on Radiation Units and Measurements (ICRU) recently updated the recommendations for operational quantities in radiation protection [3], directly affecting the expected performance of neutron dosimeters for energies below 100 eV and above 50 MeV.

This contribution presents the status of the LINrem project, which aims to develop novel neutron dosimeters with special emphasis on energy sensitivity, time resolution, and portability. These dosimeters address the technical requirements for radioprotection in modern particle and nuclear facilities. The technical design of LINrem neutron dosimeters is discussed, along with results from experimental campaigns in a wide range of neutron fields. These campaigns include: i) time-resolved measurements of stray secondary neutron doses in proton therapy facilities, ii) mapping the ambient dose equivalent from cosmic-ray neutrons across Spanish territory, iii) characterization of pulsed ambient neutron dose equivalent in fusion D-D plasma sources and high-intensity lasers, and iv) mapping H*(10) in a research nuclear reactor. Finally, the prospects and future plans for the LINrem project are also discussed in this talk.

Experimental determination of the neutron spectrum in the HOTNES thermal source using a Bonner Sphere Spectrometer with passive detectors

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Introduction

Well characterized thermal neutron fields are essential for correct set-up and calibration of neutron thermal detectors. HOTNES (HOmogeneus Thermal Neutron Source, located at ENEA Frascati) is a thermal source based on multiple reflection of the fast neutrons emitted by a source in the polyethylene walls of a cavity. A shadow bar is placed in front of the source to avoid direct radiation. An AmB source, with a nominal intensity of 3.5×10^{6} s^{-1}, is used in a cylindrical cavity of 30 cm in diameter and 70 cm in height. A relatively uniform thermal neutron field is obtained, in adequate volumes for checking and calibrating measuring instruments, at a relatively low cost and simple construction.

Methods

The UAB passive Bonner Sphere Spectrometer (BSS) was employed to determine the energy spectrum of the neutron field inside the cavity. Seven polyethylene moderating spheres (2.5, 3, 4.2, 5, 6, 8 and 10 in. diameter) were used, with high purity ^{197}Au foils, ~ 0.3 g in weight, in their center as activation detectors. The BSS response matrix relates neutron fluence rate with saturation activity of the foils. The ^{198}Au activity of the foils after irradiation was determined with a conveniently calibrated HPGe detector, through the 411 keV emission line, which allowed to calculate their saturation activities. Unfolding was performed using the FRUIT code to obtain the neutron spectrum and dosimetric integral quantities.

Results

The neutron spectrum at the reference location inside the thermal cavity was obtained. The total neutron fluence rate was (1140 ± 80) $cm^{-2}\cdot s^{-1}$, of which 75% are thermal neutrons (< 0.4 eV) and only 5% are fast neutrons. The total ambient dose equivalent rate was (111 ± 12) μSv/h. These results agree with the design specifications of HOTNES and previous characterization of the source.

Conclusions

The HOTNES thermal neutron field was characterized with the UAB passive BSS, thus confirming its successful performance for this type of fields.

Designing and testing a soil moisture monitor system based on neutron moderating cylinders

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Introduction

Cosmic Ray Neutron Sensors (CRNS) can be utilized for monitoring landscape soil moisture in a distance scale of kilometers, thus filling the gap between the small-scale data provided by point soil moisture sensors and the large-scale information gathered by instruments in satellites. In addition, its penetration depth of tens of centimeters is of the order of the typical rooting depth. The method is not invasive and does not disturb agricultural operations, so that it represents a valuable tool for water management and sustainable agriculture, especially in regions characterized by fragile agrifood systems and water scarcity, such as the desertic areas in the Kingdom of Saudi Arabia (KSA).

Methods

The current CRNS method relies on a large thermal neutron counter surrounded by about 2.5 cm of polyethylene, covering neutron energies from ~1 eV to ~100 keV. We propose to use a set of moderating polyethylene cylinders, with boron tri-fluoride proportional counters, in order to expand the energy response to higher energies and to provide spectrometric capability. The cylindrical geometry leads to the needed directional response to detect only neutrons backscattered in the soil. Simulation of the cosmic ray neutron backscatter in soil for different degrees of water content, as well as the response and spectrometric capability of the device, was performed using MCNP and GEANT4 codes. A prototype of the spectrometer is being built and will be soon tested on-site at KSA.

Results

Simulation confirmed that different degrees of soil water content affect mainly the neutron spectra in the range 1 eV-100 keV. The maximum discrimination capability of the method was obtained for low moisture content, up to 30%.

Conclusions

An extended CRNS device, with spectrometric capabilities, was designed and is being tested. Results from simulation indicate its capabilities to determine the soil moisture content in the low-moisture soil of desertic areas in KSA

Neutron measurements at high-elevation within the SAMADHA project

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Introduction

Within the INFN-based project SAMADHA, environment neutron spectrum measurements were performed at 3480 m above sea level on the Italian western Alps.

Methods

An extended range Bonner Sphere Spectrometer (ERBSS) was used, that was especially designed to operate unattended and to discriminate genuine neutron events from spurious ones. In addition to the neutron spectrum and ambient dose equivalent, the arrival time distribution of the events was studied. The FRUIT unfolding code was used to derive the neutron spectrum from the raw data: BSS counts, response matrix and associated uncertainties.

Results

The neutron spectrum from thermal up to Hundreds MeV was measured with the ERBSS for a 15 h period. The unfolded solution is robust, i.e. not dependent on the guess spectrum used to start the convergence process. The high-energy component (cascade component) was compared to literature data measured by other groups, with the same technique, at similar geomagnetic latitudes, as a function of the elevation. These data are fitted and successfully compared to the theoretical results from EXPACS code. Being the cascade component not influenced by materials in the vicinity of the measurement site, this experimental curve can be regarded as "universal" at the studied latitudes.

Conclusions

The extended range Bonner Sphere Spectrometer under study proved to be reliable and suited to measure environment neutron spectra. After this test it will be installed at 5300 m asl on the Bolivian Andes to contribute studying the South Atlantic Geomagnetic Anomaly within the SAMADHA project.

Acknowledgements

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Directional neutron spectrometry with a new instrument based on a collimated cylindrical moderator

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Introduction

In recent years a new class of neutron spectrometers based on a multiple thermal neutron detector embedded in a moderator was developed. They are similar to Bonner Spheres spectrometers (BSS), but they require only one exposure to determine the whole neutron spectrum. As the internal thermal neutron detectors are simultaneously recorded, they can operate as real-time spectrometers. This communication deals with the directional neutron spectrometer NCT-WES (Neutron Capture Therapy Wide Energy Spectrometer), initially designed as a spectrometric beam monitor for QA in neutron capture therapy.

Methods

NCT-WES is a polyethylene cylinder 36 cm diameter and 41.5 cm height. To achieve a sharply directional response, the sensitive part is shielded with polyethylene and borated rubber, except in the direction of collimating aperture. The instrument has been designed to mimic a 6-sphere BSS with spectrometric capability from thermal up to about 15 MeV. The internal detectors are 1 cm^2 silicon p-i-n diodes covered with ^6LiF. MCNP6.2 and FRUIT codes have been used for Monte Carlo simulation and unfolding respectively

Results

NCTWES simulated response was tested in reference neutron fields of Am-Be neutron and monoenergetic neutron beams from 0.144 keV to 5.0 MeV, with an overall uncertainty of 2%. The instrument has been used to measure the near-target neutron field from the D–D Frascati neutron generator obtaining consistent results with BSS measurements.

Conclusions

NCT-WES can be conveniently used for dosimetry, nuclear industry, neutron sources, medicine and research applications. Because of the cylindrical collimator, the device exhibits sharply directional response, thus permitting to distinguish between direct and total neutron contributions.

Acknowledgements

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Micro and Nano Dosimetry

Approaches to conceptional unification of micro- and nanodosimetry

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Introduction

Microdosimetry and nanodosimetry study the track structure of charged particles, i.e., the stochastics of radiation interaction on the microscopic scale, and its impact on radiobiological effectiveness [1-3]. The (differing) concepts developed in micro- and nanodosimetry are matched to the experimental approaches in the two fields.

Methods

Recent publications exploring the link between the two methodological approaches to characterizing particle track structure [4-8] have been examined for a common denominator. In this analysis, unification approaches emerged, which were theoretically formulated and tested on proton tracks with energies between 1 MeV and 100 MeV.

Results

Unification of microdosimetry and nanodosimetry for the same target seems to require two elements: (1) the definition of a nanodosimetric analogue to a microdosimetric event and (2) the use of conditional distributions of transferred energy as a function of ionization cluster size. Unification in a somewhat more general sense could be achieved based on the BioQuaRT multiscale model [4] by correlating nanodosimetric ionization clusters formed in smaller targets with microdosimetric energy distributions in larger sites.

Conclusions

These first attempts to overcome the conceptional gaps between microdosimetry and nanodosimetry appear promising and allow to establish the link between nanodosimetric characteristics of track structure and macroscopic fluence. Further research in this direction is needed on other ion types, on the case of very densely ionizing particles, and on the connection to radiobiological effectiveness.

References

[1] Rucinski *et al* 2021 Phys Med Biol **66** 24TR01

[2] Parisi *et al* 2022 Phys Med Biol **67** 185013

[3] Conte *et al* 2023 IJMS **24** 5826

[4] Palmans *et al* 2015 Brit J Radiol **88** 20140392

[5] Ngcezu *et al* 2021 Radiat Environ Biophys **60** 559–78

[6] Lillhök *et al* 2022 Radiat Meas **157** 106831

[7] Selva *et al* 2022 Radiat Phys Chem **192** 109910

[8] Lindborg *et al* 2023 Med Phys in press doi: 10.1002/mp.16428

First measurements with the Ion Counter nanodosimeter at HIT

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Introduction

Nanodosimetry characterizes charged particle track structure and its biological effectiveness by the frequency distribution of ionizations in a given target, the ionization cluster size distribution (ICSD). The focus of experimental nanodosimetry has been on the determination of ICSDs for primary charged particles with a well-defined energy. In this work, nanodosimetric measurements were performed for the first time in the mixed radiation field of a ^{12}C beam in clinically relevant depths of tissue-equivalent material.

Methods

Measurements were performed with the PTB Ion Counter nanodosimeter at the HIT beam line for diagnostics and research. The nanodosimeter was operated behind a PMMA collimator and PMMA absorbers of different thickness. Ions were recorded in coincidence with the signals from two silicon strip detectors to enable the determination of ICSDs depending on the impact parameter of the ions to the sensitive volume.

Results

The mean ICS M_1 from measurements in the different beam times at a refence condition was found to be reproducible within about 3 %. Measurements with different absorber thickness and beam energy, combined such as to give an energy of 1 GeV at the entrance of the sensitive volume, produced M_1 values varying by almost 50 % over the investigated beam energy range for all impact parameters. Experiments with fixed beam energy and varying absorber thickness showed significantly higher M_1 values at lower energies than expected from data from the BioQuaRT project [1] and the stopping power as calculated by SRIM [2].

Conclusions

The proof of principle operation of the Ion Counter nanodosimeter with therapeutic C-ions has been demonstrated. While a good reproducibility is achieved, significant deviations between expected and measured ICSDs are observed, which are presumably due to secondary particles and require dedicated simulations [3].

[1] Hilgers G, Bug M and Rabus H 2017 Measurement of track structure parameters of low and medium energy helium and carbon ions in nanometric volumes *Phys. Med. Biol.* **62** 7569–97

[2] Ziegler J F, Ziegler M D and Biersack J P 2010 SRIM – The stopping and range of ions in matter (2010) *Nucl. Instrum. Meth. B* **268** 1818–23

[3] Schwarze M, Rabus H, Hilgers G 2023 Simulation of the mixed radiation fields from carbon ion beams used for measurements with the Ion Counter nanodosimeter at HIT *submitted to ICDA-4*

Simulation of the mixed radiation fields from carbon ion beams used for measurements with the Ion Counter nanodosimeter at HIT

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Introduction

An essential determinant of the biological effectiveness of heavy ion beams is the ions' track structure. Track structure can be characterized experimentally by nanodosimeters in the form of an ionisation cluster size distribution (ICSD) which the ion produces in a specific target. First measurements of ICSDs were performed with the Ion Counter nanodosimeter with therapeutic ^{12}C ions at HIT [1]. Significant deviations between measured and expected ICSDs were observed.

Methods

For a better understanding of the measured ICSDs, the experiment was simulated in a simplified setup in which a gas volume containing propane at 1.2 mbar represents the nanodosimeter and two thin slabs of silicon represent the strip detectors used for particle tracking. The simulation software Geant4 was used to transport the incident particles through a degrader and collimator and the nanodosimeter in a condensed history simulation. Information about the created secondary particles, their LET in the detector planes, and their contribution to the measured signal were determined. In the simulations, electrons were stopped in the gas volume when their energy fell under a given threshold of 10 keV. Their final locations and directions served as input of a detailed track structure simulation using the PTra code.

Results

With increasing ion energy, an increasing contribution of secondary particles of higher stopping power was observed in the plane of the gas-ion extraction, while the stopping power of the carbon ions decreased. The increased stopping power of the secondaries, mainly protons, alpha particles, deuterons and tritons, appears to lead to an increased number of ionizations and thus to a higher signal in the nanodosimeter.

Conclusions

A Geant4 simulation was performed to explain the increase in the mean ionization cluster size with energy, which was observed in the measurements of the Ion Counter nanodosimeter with therapeutic carbon ions [1]. The deviation can be explained by the increased interaction probability of secondary particles in the sensitive volume of the nanodosimeter.

[1] Hilgers G, Schwarze M, Rabus H 2023 First measurements with the Ion Counter nanodosimeter at HIT *submitted to ICDA-4*

Experimental nanodosimetry – variance-covariance measurements using a single ion chamber

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Introduction

Several studies indicate a relationship between radiation induced biological damage and energy depositions on the nanometre scale. Quantifying radiation quality using parameters defined on this scale is therefore important. Lineal energy or cluster size distributions are often used but experimental studies of these quantities are difficult. Decreasing object sizes implies lower number of ionisations and hence weaker signals. Further, in high fluence fields it is difficult to separate energy deposition events originating from individual primary particles. An alternative is to use the variance-covariance method where single-event dose-mean lineal energies are determined from multiple-event energy depositions.

Methods

Dose-mean lineal energies in a ^{60}Co beam were measured using a commercial ion chamber and low-noise electronics. The detector was filled with air to low pressures. Covariance corrections traditionally obtained using a second detector were here implemented using a single detector.

Results

The measured dose-mean lineal energies agreed with previously published values using a similar ion chamber. The improved electronics enabled dose-mean lineal energies to be measured at even smaller object sizes down to 2.8 nm mean chord-length. MCNP 6.2 simulations were conducted, and the simulated and measured dose-mean lineal energies agreed. Differences between simulated and experimental results were expected due to the use of a macroscopic W/e value but due to large experimental uncertainties the difference was unsignificant.

Conclusions

Consecutive charge measurements can be used for covariance corrections in dose-mean lineal energy measurements as long as the charge sampling frequency is short compared with variations in for instance chamber gas pressure. Additional work is required, e.g. to reduce experimental uncertainties and to understand the differences between measurements and simulations.

Radial dependence of X-ray induced ionization clusters around a gold nanoparticle

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Introduction

One strategy to improve the efficacy of radiotherapy for cancer is increasing the tumor's sensitivity to irradiation, e.g., by introducing gold nanoparticles (GNPs) into cancer cells [1]. Microscopic analysis of the radial dependence of energy imparted around a GNP showed agreement of the survival rate predicted from local dose enhancement with experimental observations [2].

This work explores the enhancement of ionization clusters around a GNP, which are considered to be indicative of the induction of DNA lesions [3], a potential trigger for cell-death-inducing damage [4].

Methods

Monte Carlo track structure simulations were performed to determine the fluence of photons and electrons in water around a GNP. Simulations were performed for GNPs of different radii irradiated by these fluence spectra and the produced ionizations were scored with a clustering algorithm to obtain the radial dependence of the frequency density of ionization clusters.

Results

The influence of the GNP on the electron fluence spectrum is relatively small and occurs mainly at energies below 10 keV. Accordingly, increased ionization clustering is limited to a range up to about 200 nm. Here, smaller GNPs (radii up to 10 nm) cause noticeable peaks in the density of ionization clusters at distances around 50 nm from the GNP surface.

Conclusions

The radial profile of ionization clustering suggests that an enhancement effect may not require the application of GNPs in the cell nucleus itself.

[1] Hainfeld J F et al. 2013 Gold nanoparticle imaging and radiotherapy of brain tumors in mice *Nanomedicine (Lond)* **8** 1601–9

[2] McMahon S J et al. 2011 Biological consequences of nanoscale energy deposition near irradiated heavy atom nanoparticles *Sci Rep* **1** 18

[3] Rucinski A et al. 2021 Applications of nanodosimetry in particle therapy planning and beyond *Phys Med Biol* **66** 24TR01

[4] Lomax M E et al. 2013 Biological Consequences of Radiation-induced DNA Damage: Relevance to Radiotherapy *Clin Oncol* **25** 578–85

An innovative multi-site microdosimeter for clinical beam characterization

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Introduction

Understanding the spatial distribution of energy deposition at the cellular level is crucial for correlating the physical characteristics of ionizing radiation with the resulting damage to biological tissue. Advanced radiobiological models consider damages at various site sizes, necessitating validation through measurements. Consequently, studying the stochastic nature of the energy deposit at different site sizes, ranging from nanometers to micrometers, is essential. Microdosimetry utilizes Tissue-Equivalent Proportional Counters (TEPC) as reference devices, allowing for the variation of gas density to simulate different site sizes.

Methods

A novel TEPC is being developed at the Legnaro National Laboratories of the Italian National Institute for Nuclear Physics (INFN-LNL), featuring three coaxial electrodes: central anode, grid, and external cathode. Its key innovation is the presence of two concentric sensitive volumes (SV) in a 1:10 diameters ratio. By varying the electric field between the grid and cathode, without altering the gas pressure, it is possible to selectively define the SV for charge collection. The device allows multi-site measurements and the discrimination of short-range fragments. This capability has significant applications in complex radiation fields such as proton therapy and BNCT.

Results

Preliminary measurements using a prototypal detector served as a proof of principle for the innovative functioning mechanism of this TEPC. These measurements were conducted in a reference neutron field produced by the ^{7}Li(d,n)^{7}Be reaction, employing a 7MV Van der Graaf accelerator at INFN-LNL.

Conclusions

The availability of this detector enables fast and reproducible multi-site microdosimetric measurements in clinical settings. It facilitates the validation of advanced radiobiological models and offers the added capability of discriminating short-range fragments, enhancing our understanding of radiation fields.

Exploring nanoscale ionization distribution and biological damage: novel insights from 1 nm simulations

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Introduction

The biological response to light ion irradiation is influenced by complex DNA damage, which is correlated with the particle track structure. This study investigates the correlation between nanoscale ionization distribution and the probability of inducing biological damage.

Methods

Monte Carlo track-structure simulations were performed for protons and carbon ions of different energies interacting with a gaseous cylindrical target volume with a water equivalent diameter of 1 nm. The simulations utilized the MC-Startrack model developed by Grosswendt in 2002 [1, 2], accurately simulating the experimental response of the Startrack counter. Primary particles were directed perpendicular to the cylinder's main axis, with impact parameters ranging from 0 to 50 nm. The link to radiobiology was examined.

Results

Significant correlations were observed between inactivation cross sections reported by Furusawa [3] and linear combinations of cumulative probabilities of measuring at least 2 (F_2) and 3 ionizations (F_3), measured in a 1 nm target volume at impact parameter zero. The proportionality factor, specific to each cell line, represents the saturation value of biological cross sections.

Conclusions

Nanodosimetric quantities measured for particles passing through the target volume at its center (impact parameter set to zero) do not provide a complete description of radiation interaction at the cellular and sub-cellular levels. However, particle track structure characteristics measured at impact parameter zero seem to retain the most relevant information correlated with biological effectiveness.

Microdosimetry calculations of intra-cellular TRT using Auger emitting isotopes.

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Introduction

A comparison of dose delivered by varying ligands with terbium and lutetium.

The dose from Auger electron emitting nuclides with a high linear energy transfer (LET) is more strongly dependent on the distribution within the cell. If the radiopharmaceutical can be acurately targeted inside the cell. The treatment can take advantage of the high rate of low energy Auger electrons emitted from the TB in comparison to LU for the same radiation dose.

Methods

A microdosimetry model using Monte-Carlo was used for the dosimetry. The calculation is done on an irregular cell geometry for the cancer cells based on cell culture images. We use a dose-point kernel to calculate the dose to the nucleus.

The radiation dose-point kernels over the full electron spectrum were derived using Monte-Carlo simulations for energies below 50 eV to account for the propagation of Auger electrons over length scales at and below a cellular radius. Dose calculations were done for ligands that bind to the cell cytoplasm and into the cell nucleus.

Results / Conclusions

Terbium ^{161}Tb can be more effective that ^{177}Lu, if it can be used in conjuction with ligands which can target the interior of the cancer cell. While the average dose delivered for an equivalent activity is the same for each isotope. The short range of the Auger electrons emitted from the ^{161}Tb leads to a strong dependence on the location of the drug delivery.

Angular dependence of the PTW microdiamond in edge on mode

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Introduction

The microDiamond detector has shown promise as a relative dosimeter in proton and x-ray microbeam radiotherapy studies, although recent work suggests some large perturbations due to failure of electronic equilibrium in x-ray microbeams It is proposed that a variation on the current design could address this issue, and derive a detector suitable for both relative and absolute dosimetry in microbeams. Initial work to quantify uncertainties associated with the commercial detector uncovered a sigmoid function in the response of the detector used in the edge on mode on kV energies.

Methods

The biomedical beamline ID-17 at the ESRF was used to irradiate 3 PTW microdiamond detectors inside an EasyCube phantom. Dose measurements were made at intervals from -5 to +5 degrees for three detectors revealed a strong sigmoid response. The experiment was repeated on an Elekta linac, and the effect was confirmed (kV). A Monte Carlo Model was developed to investigate this result and to quantify this effect for a range of beam energies and exposure angles. The, preliminary simulations have confirmed the non-symmetric response and further calculations are ongoing.

Results

An angular dependence of the response was seen for all detectors at kV energies with amplitude 2.3%, confirmed with Monte Carlo experiments. The sigmoid inflection point was found at 0.05, -0.725, -0.4 degrees. Here, each detector exhibited a singularity point, measuring 4.5% below the upper plateau.

Conclusions

Tests at the ESRF and an Elekta linac showed that the PTW microdiamond exhibits an angular dependence of its response in edge-on mode, most likely due to the asymmetric design of the detector. There is a singularity point near to zero degrees which has not been revealed in the simulations. This decrease in response might be due to some reflections occurring when the radiation is perpendicular to the detector, an effect not modelled in the code. Both experimental and simulation results will be presented.

Monte Carlo and hybrid methods in Dosimetry and Radiation Measurement

Effectiveness of Volumetric Repainting Strategies in Reducing Interplay Effect in Liver Cancer Patients : A Monte Carlo Simulation Study

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Introduction

In recent years, the pencil beam scanning (PBS) technique has become increasingly popular in modern particle therapy facilities. This is because it can provide a highly conformal dose distribution without the need for any dose modulation equipment. Despite its benefits, the pencil beam scanning (PBS) technique presents a major challenge in proton therapy due to the interaction between respiration-induced organ movement and PBS scanning, known as the interplay effect. This study aims to investigate the effectiveness of various volumetric repainting strategies in reducing the interplay effect in liver cancer proton therapy.

Methods

To conduct this study, we selected five liver cancer patients with different tumor volumes and distributions to calculate the 4D dose distribution under different volumetric rescanning strategies. To achieve this, we used a Geant4-based Monte Carlo simulation toolkit called “TOPAS” and a ridge and non-rigid image registration toolbox called “Elastix” for 4D dose calculations. In addition, we took into account the real machine characteristics, such as the scanning speed of each energy layer and energy switching time. Furthermore, we considered changes in the respiration cycle from day to day in the simulation process. After performing the 4D dose calculations, we examined changes in the homogeneity index (HI) value of the clinical tumor volume (CTV) and the dose coincidence between the calculated 4D-dose and static planning dose distributions using gamma index analysis.

Results

The results showed a significant decrease in the HI value of the CTV as the number of rescans increased. In all cases, the HI value reached its lowest point after five days of treatment. Figure 1 shows the Dose-Volume histogram (DVH) of CTV in Case 2 on different days of treatment.The dose coincidence test showed that the 3D gamma passing rate, with a requirement of 3mm/3%, was also a function of volumetric rescanning number. For instance, in case 3, the gamma index increased from 85.1% with one rescan to 90.1% with 30 rescans, shows in Figure 2b.

Conclusions

This study demonstrates a methodology for 4D dose distribution simulation in a proton therapy liver cancer patient for respiration motion mitigation. The results showed that the effectiveness of interplay effect mitigation in proton therapy for liver cancer can be influenced by factors such as the number of repainting scans, tumor location, diaphragm motion magnitude, and treatment fraction. While the homogeneity of dose in a single fraction may be limited by the maximum number of volumetric overpaints in clinical practice, the total accumulated dose distribution becomes more uniform at the end of the full treatment course.

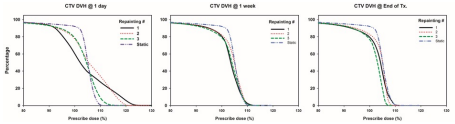

Figure 1. The Dose-Volume histogram of CTV in Case 2 on different days of treatment.

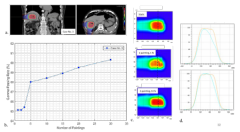

Figure 2. The dose distribution result of cases 3. (a) The dose distribution in coronal and transverse view. (b) The gamma passing rate at different numbers of repainting. (c) The dose distribution in static, 1 repainting with 1 fraction and 3 repainting treatment with 10 fractions. (d) The dose profile of the dashed line in 4c.

A new Monte Carlo particle source for the calculation of dose distributions in computer tomography

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Introduction

High-quality Monte Carlo simulations of radiation transport are of the utmost importance for new developments in personalized CT dosimetry. A method for the detailed modelling of any CT scanner is essential for this. In this work, a previously developed method for the experimental characterization of the radiation beam of any CT scanner [1] was integrated within the Monte Carlo open-source software EGSnrc [2] to perform CT-scanner-specific calculations of dose distributions based on CT scans of patients and phantoms.

Methods

Therefore, a new particle source was implemented within the EGSnrc source code, which only relies on experimentally determined data as input. For validation, Monte Carlo simulation results based on the new particle source were compared to dose measurements performed at a clinical CT scanner (Optima CT 660, GE Healthcare, USA). Free-in-air (aluminium attenuation curve, shape filter profile) and phantom measurements with a Farmer-type ionization chamber (RC0.6, Radcal, USA) in a CTDI and a thorax phantom were compared to simulation results. A detailed uncertainty analysis was carried out by varying the influencing factors including the X-ray energy spectrum, collimation, and material density.

Results

The deviations between measured and simulated values were below 6 % for all setups. All deviations were in the range of the estimated standard uncertainties of 6 % (k=1) for the simulated air kerma values.

Conclusions

The new particle source allows the calculation of dose distributions from CT scans based on a customized Monte Carlo model which can be easily adapted to any CT scanner based on a series of measurements.

[1] Rosendahl S, et. al. CT beam dosimetric characterization procedure for personalized

dosimetry Phys. Med. Biol., 64:7, 075009 (2019).

[2] Kawrakow I, Rogers DWO, Mainegra-Hing E, Tessier F, Townson RW, Walters BRB.EGSnrc toolkit for Monte Carlo simulation of ionizing radiation transport, doi:10.4224/40001303 (2000).

Simulation and Measurement of Secondary Fragmentation of Carbon Ion Beams

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Introduction

One of the major challenges in particle therapy is online monitoring of the dose during treatment to ensure that the correct dose is directed to the target within acceptable tolerances. At present, many proton therapy centres use the Monte Carlo methods for dose calculations as they provide the most accurate dose predictions. TOPAS toolkit is a recently developed MC simulation tool which allows using Geant4 toolkit radiation physics libraries easily and supports visualization. It has a more user-friendly interface and simplified input format, making it easier to use and faster to set up simulations compared to Geant4. While many studies have tested and verified TOPAS in proton therapy simulations, only few studies have attempted to validate the accuracy of TOPAS in dose calculations of carbon ion beams. The aim of this study is to evaluate the feasibility of TOPAS simulations for carbon ion therapy. Before using the HVTrack detector to measure the deposited energy in air and water and compare the simulation results with measurements.

Methods

In this work, a licensed TOPAS code is used to monitor the primary beam and secondary particles produced during the carbon ion beam interactions within a water phantom. Depth-energy profile for primary and secondary particles has been obtained. Then a silicon detection system involving two silicon pixelated detectors separated by a volume of air is developed to allow observation of particles scattering.

Results

The results show that the majority of the deposited dose after the Bragg peak is from the fragmentations of carbon ions. The scattering angles for primaries and secondary protons have been calculated and plotted as well as the dose deposited in each detector.

Conclusions

The simulation results show a good agreement with the previous studies using other MC codes. Further measurements and investigations of other channels of secondaries produced during carbon ion beam irradiations are ongoing.

Feasibility of a Linear Accelerator Commissioning in a Radiotherapy Facility using Monte Carlo: An uncertainty analysis

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Introduction

The focus of this work is to analyse the feasibility of using Monte Carlo (MC) simulations to generate all the necessary dosimetric data for commissioning or quality control of a Linear Accelerator (LINAC). One of the aspects of the method proposed here is to consider the time necessary to produce the data for the commissioning and the uncertainties associated with the measurements and simulations.

Methods

The MC simulations were performed with the software PRIMO to simulate a Varian 2100 operating at 6 MV. The phase-space file (PSF) to perform the matching of the initial beam parameters (initial electron energy; Energy FWHM, Focal Spot FWHM and Beam Divergence) were created using $3x10^7$ histories and some variance reduction techniques were used to increase the number of particles present in the PSF. An everyday computer was used containing 4 CPUs. The simulated values were compared to the measured data using the gamma function for three different fields, 3x3, 10x10 and 40x40 cm^2 at a depth of 10 cm in a water phantom with a voxel size of 0.4x0.4x0.4 cm^2.

Results

The time required to perform the simulation of the PSF was 3 days and for a file of $1x10^8$ histories the time required was 30 days. The parameters that best fit the Varian 2100 LINAC are an initial electron energy of 5.4 MeV, an Energy FWHM of 0.5 MeV, a Focal Spot FWHM 0 cm and a Beam Divergence 0º. For this situation, the result of the gamma analysis is 100% for the beam profile of the 10x10 cm^2 with 3%/3mm and 96% with 2%/2mm. The values for the PDD are 100% for 3%/3mm and 2%/2mm. The uncertainty of the dose above 50% of the maximum dose was 1.6% (k=2).

Conclusions

The use of independently generated MC data is a great tool to be used in an everyday routine of a clinically qualified physicist as part of a robust Quality Assurance Program. However, the time necessary to obtain an uncertainty below 2% (k=2) in the generated the PSFs was of 3 days for each change in the parameters of the initial beam, which may be seen as impractical to perform the commissioning. Despite this, we much be aware that a commissioning only begins after the Customer Acceptance Procedures and the MC simulations could start several months before.

Brachytherapy planning system based on Monte Carlo simulations with MCNP6

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Introduction

Brachytherapy is a therapeutic technique for the treatment of tumour lesions that consists on the placement of an encapsulated radioactive source close to, in contact with, or within a tumor. Although the complexity and precision of these treatments have increased in recent years, dosimetry in clinical practice is still calculated using the TG-43 protocol, whose dose calculations are based on a set of pre-calculated tables assuming a source placed in an infinite volume of water, or through dose calculation algorithms based on model-based dose calculation algorithms (MBDCA) that incorporate both seeds and patients characteristics. Since MBDCA offers an obvious improvement, not all of them describe dose deposition with the same accuracy as Monte Carlo (MC) methods. The objective of this work is to incorporate MC simulation into brachytherapy treatment planning.

Methods

To carry out this work, a set of programs have been developed that automate the following planning steps: reading and segmentation of patient geometries from DICOM images, exporting the geometry, assigning materials and seed positions to the input file format for the simulation code (MCNP6.2), and finally reading and visualizing the simulation results in the planning system format. These results consist of dose distributions, isodose curves, dose deposited in the organs at risk, and other dosimetric metrics. The results obtained through this methodology are subsequently compared with those obtained with other planning techniques.

Results

The results of this work show the accuracy with which the dose obtained by MC simulation is calculated compared to that obtained by other methods, while maintaining very affordable computation times, demonstrating the usefulness of this tool incorporated into a planning system.

Conclusions

This work concludes that the MC method, specifically the MCNP6 code, can be used incorporated into a planning system for brachytherapy treatment.

Dose distribution calculation in treatments with Lu-177 using Monte Carlo simulation

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Introduction

^{177}Lu-prostate-specific membrane antigen (PSMA) radioligand therapy, is a novel therapy which is increasingly applied in metastasized prostate cancer patients. Due to the benefits shown in these patients, this technique has been implemented in a growing number of centers worldwide. To assess treatment efficacy and toxicity, dosimetry in ^{177}Lu-PSMA for individual patients is essential. In this work, a dosimetric study using Monte Carlo (MC) simulation, has been carried out to obtain the personalized dose distribution in the patient.

Methods

To carry out this study, the adult male of the Mesh-type Reference Computational Phantoms (MRCP) described in the Internal Commission on Radiological Protection (ICRP) publication 145, is used. This adult male meshed geometry is composed of 8.2 million tetrahedrons in the tetrahedral mesh (TM) format, allowing an accurate dose calculation. Since the ^{177}Lu-PSMA is deposited in the metastasized region, these organs are considered as irradiation sources with different probabilities obtained from a patient PET scan. Once the distribution of activity in the patient's organs is known, the simulation is performed using the MCNP6 code capability for simulating TM geometries. Finally, this methodology is used to evaluate the dose distribution after the ^{177}Lu-PSMA administration, within the phantom.

Results

The simulation results provide an accurate estimate of the radiation dose received by each organ risk, depending on where the metastasized prostate cancer is located.

Conclusions

MC simulations have been carried out to obtain the dose distribution in a patient after ^{177}Lu-PSMA administration, in a MRCP phantom. This methodology has been demonstrated to be a valuable tool to assess tumor doses and organ toxicity, obteinin an accurate dose distribution within the phantom.

Image quality of sparse module PET scanners using normalization corrections and Monte Carlo tools

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Introduction

A PET scanner with an extended Axial Field Of View (AFOV) improves the quality of the reconstructed images, however, this can also lead to artifacts occurrence. The normalization correction is a technique used to correct these artifacts produced due to variations in the Lines of Response (LORs) detection. Different normalization methods can be found in the literature, but this study focuses on the component-based normalization. This technique allows to compute the normalization factors to eliminate the systematic variations in the data and to provide reconstructed images with high quality. Besides, extended AFOV devices allow scanning larger areas at once.

Methods

The purpose of this study is to verify the effectiveness of the component-based normalization to correct the artifacts due to the AFOV extention and the generated by sparse module configurations. Using GATE (GEANT4 Application for Tomographic Emission), two hypothetical models based on the Biograph Vision 600 PET scanner are developed, by adding axial gaps of 16 mm and 32 mm between the detector blocks. Thus scanners comprise 8 module rings and 7 gaps, with a total axial extent of 36.8 cm and 48 cm, respectively. The Data Spectrum (DS) phantom is used to evaluate the normalization effects. The results of the Biograph Vision 600 model without modifications are taken as a reference.

Results

The application of the component-based normalization model before the image reconstruction allowed to correct the counts missing in the gaps regions. The results obtained in this work indicate a good agreement between the modified PET scanners and the results obtained with the original Biograph Vision 600, despite the significant loss of counts in the regions corresponding to the gaps.

Conclusions

The limited AFOV of most conventional PET systems can be extended theoretically as a proof of concept. This study supports the feasibility of PET sparse module configurations. The artificially increasing of the AFOV lead to artifacts wich can be corrected appliying the normalization correction. This technique allows the improvement of the image quality.

PET image reconstruction and dosimetry from voxelized phantoms with GATE

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Introduction

GATE (GEANT4 Application for Tomographic Emission) is a powerful Monte Carlo (MC) toolkit that combines the algorithms integrated inside Geant4, with specific tools dedicated to Positron Emission Tomography (PET) and the patient-specific dosimetry estimation. This MC code allows the reading and examination of clinical data stored in various file formats, simulating specific geometries and radiotracer distributions. In this study, the GATE toolkit is used to import CT and PET images in DICOM format, to build a 3D voxelization, and to assign the corresponding activity of the F18 source to each voxel. This work is focused on the Nested parameterization method of GATE, which demands significantly less memory usage for geometry definition and offers faster navigation for a highly large number of voxels than other methods.

Methods

The objective of this study is twofold: firstly, to assess the information loss in images reconstructed with the GATE model when compared to experimental PET images, and secondly, to analyze and compute 3D dose maps representing the F18-FDG dose distribution within voxelized phantoms, based on clinical prostate scan data.

The GATE model is used to simulate the Biograph Vision 600 scanner, and CASTOR (Customizable and Advanced Software for Tomographic Reconstruction) is employed for image reconstruction and correction. Subsequently, the resultant images from the GATE-modeled Biograph Vision 600 and the original PET images are subjected to a comparative analysis.

Results

The reconstructed images and the original PET images are evaluated qualitatively and quantitatively applying an image quality assessment based on the NEMA NU-2 2018. This comparison reveals a degradation of the reconstructed images, although the results are reasonably successful for all the unknown details of the original study.

Conclusions

This work confirms the capability of GATE to reproduce clinical studies using antropomorphic voxelized phantoms.

Monte Carlo simulation of spatially fractionated radiation therapy collimators for radiobiology studies

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Introduction

Conventional radiotherapy used homogeneous doses in the target volume. On the other hand, spatially fractionated radiotherapy (SFRT) aims at a dose pattern with high and low doses in the target volume, using the tumor micro ambient and the bystander effect to achieve tumor control. This work studied the produced dose patterns of different collimators for SFRT, aiming to achieve a feasible collimator for radiobiology studies.

Methods

Monte Carlo package PENELOPE v.2014 was used to study the dose distributions produced by different SFRT collimators in a water phantom. The spectrum of a 100 kVp x-ray was used for the simulations. Collimators of aluminum and lead, with 3,5 cm thickness, and open/blocked field ratios of 1:0.5 (A); 1:1 (B) and 1:2 (C) were simulated. The open field for all the collimators was 3 mm in diameter. For each collimator, the dose map was obtained at planes perpendicular to the central axis of the beam. The dose profile at 1,7 cm depth in the phantom was used to obtain the valley-to-peak ratios and the full width at half maximum (FWHM) for each collimator.

Results

The valley-to-peak ratios are 0.54, 0.25 and 0.09 for aluminum collimators A, B, and C, respectively. The same ratios for the lead collimator were 0.32, 0.09 and 0.04, respectively, showing that the higher atomic number of the lead collimator produced a better dose pattern for SFRT. Moreover, the FWHM of the peaks for lead collimators are 3.3 mm and 3.0mm for collimators A and B, respectively. For collimator C the FWHM is 2.9mm, due to the larger blocked portion and less scattering to the opened portion of the field.

Conclusions

Overall, the lead collimator produced better dose patterns for SFRT. The collimators B and C also produced better valley-to-peak ratios than collimator A, being more suitable to be used in an experimental set-up for studies of the radiobiological mechanisms involved in SFRT.

The development of patient-specific quality assurance (PSQA) for a proton wobbling nozzle using PTSim Monte Carlo code

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Introduction

Patient-specific quality assurance (PSQA) plays an essential role in ensuring the safety and precision of the intended doses delivered to the patient prior to treatment. The aim of this study is to develop a Monte Carlo-based procedure for PSQA in the proton wobbling nozzle at Chang Gung Memorial Hospital.

Methods

Lateral displacement (LD) coefficient and scoring volume were adjusted to consider their impact and evaluate simulation accuracy. Different detector sizes, both with and without a guard volume (GV) combined with LD, were utilized in a water phantom to estimate depth dose profiles. The simulated central axis depth doses were then analyzed using PTSim and compared to measurements using a PTW MP3 water tank and a Markus ionization chamber type 34045. For PSQA simulation, treatment parameters for an abdomen case were extracted from the Eclipse DICOM RT Plan file. Simulated doses, including SOBP and isodose curves at different depths, were compared to measurements using Zebra and MatriXX systems, respectively. Furthermore, a geometrical trigger technique was applied to assess the track positions in certain patient-specific components.

Results

With the enabled GV, the mean dose difference between the experimental and simulated values for both LD modes was below 1% at all depth positions. During the PSQA process, all SOBP flatness values were within 2.5%. The gamma analysis performed on the 2D experimental and simulated doses, evaluated at depth positions within the modulation region, showed satisfactory results with a passing rate exceeding 90%. In the cross-field profile simulation, more than 95-98% of the dose was delivered through the range compensator, while approximately 2-5% of the dose originated from slit-scattered protons originating from the Multi-Leaf Collimator (MLC) and block's edges.

Conclusions

The PTSim simulation's performance in conducting PSQA demonstrated its capability and reliability.

Small field dosimetry employing the thermoluminescence technique using a 3D printed phantom

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Introduction

Stereotactic radiosurgery is characterized by a single dose treatment or fractional ionizing radiation to treat intracranial lesions and the characteristics of the planning involve a sharp dose gradient at the periphery of the target, seeking to preserve healthy tissue around the lesion. In radiotherapy, the new techniques have some difficulties, such as: dosimetry of the beam, geometric characterization, and the use of small radiation fields. In some cases, field sizes are reduced because the lesions are small, treatment simulations in planning play a very important role, in this way, they must be provided with data referring to these small fields. Dosimetry becomes quite complex, as precision becomes quite questionable, especially when small fields are being used in regions of low density.

Methods

The detectors (LiF:Mg;Ti, µLiF:Mg;Ti and $CaSO_4$:Dy) in this study were selected based on their sensitivity, response linearity, reproducibility, physical dimensions, and availability for use in small fields. For clinical application the 6EX linear accelerator from Varian Medical System and the Multillif collimator from BrainLab were used. The 3D printed phantom was subjected to real treatment conditions. The dynamic arc 3D radiosurgery technique was adopted, with a dose of 7 Gy. To decrease statistical variation, the treatment simulation was repeated three times for each dosimeter.

Results

The results obtained demonstrated the viability of TLDs for clinical applications from photon beams to small fields. The values showed agreement in percentage terms below ±5% as recommended by the ICRU. The greatest percentage difference found was 4.8% (µLiF:Mg;Ti) in relation to the planning system. All thermoluminescent dosimeters presented an uncertainty relatively low, with good stability and reproducibility in all measurements. The 3D printed phantom showed the possibility of achieving real treatment conditions.

Conclusions

The results obtained demonstrate that, although the manipulation and evaluation procedure of TLDs is time consuming and requires careful attention, it is possible to achieve accuracy in measurements of small field dosimetry in clinical photon beams.

We can conclude that the use of the 3D phantom with the thermoluminescent dosimeters proved to be very useful in the application of small field dosimetry, allowing a more precise investigation in the quality controls involving treatments whose doses are relatively high in techniques such as radiosurgery.

Using a Monte Carlo simulation to analyze the ideal activity for a phosphorus-32 polymeric brachytherapy source for paraspinal tumors

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Introduction

In 2020, cancer of the central nervous system (CNS) represented 1.6% of all new malignant tumor cases in the world, and about 2.5% of all new cancer deaths. A promising radioactive source for use in intracavitary brachytherapy is phosphorus-32. This source has been prominent as a minimally invasive treatment for craniopharyngiomas and in the treatment of metastatic bone diseases in general and has been developed at Instituto de Pesquisas Energéticas e Nucleares (IPEN). In this work, a Monte Carlo simulation was used to evaluate the ideal activity this source must have to deliver a 1 Gy/min dose rate.

Methods

TOPAS, a Geant4-based Monte Carlo program, was used to model the simulation, and its geometry was simulated with the source (with dimensions 5.0 cm x 5.0 cm x 0.04 cm), centered in the origin point, inserted into an isotropic volume of water of 4.5 cm^3. The source is made of silicon rubber and has the decay properties of phosphorus-32, whose beta emission spectrum was extracted from the IAEA website. The total dose was calculated using volumetric scorers. Dividing the result, dose per decays, by the dose rate of 1 Gy/min, the simulated source's total activity can be obtained.

Results

The results were promising, showing that the initial activity must be 0.013 mCi or 0.481 MBq to obtain the 1 Gy/min dose rate. Figure 1 shows the simulated geometry in TOPAS. This result facilitates the source manufacturing and is particularly important to medical applications.

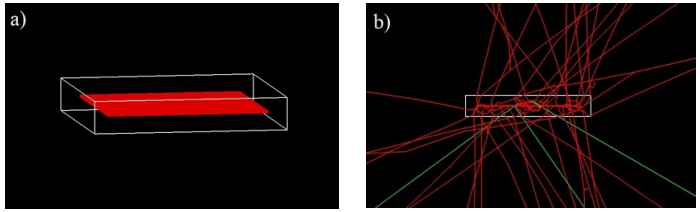

Figure 1: TOPAS outputs with **a)** representing the simulated geometry and **b)** the simulated irradiation field (beta decays in red and emitted photons in green).

Conclusions

In summary, brachytherapy with a malleable source of phosphorus-32 is a promising type of procedure to treat cancer due to its radiotherapy properties. With the initial activity measured in this work, it is possible to minimize the patient's exposure to radiation, while ensuring the quality of the treatment.

Characterization of a 3D Prototyping Semi-Automated Filter Holder System for RQR and RQA radiation qualities

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Introduction

Dosimetry in diagnostic radiology and radiation protection is a critical aspect to ensure the accuracy standards and security. Characterization of radiation measurement systems, such as the semi-automated filter holder system for RQR and RQA, is essential to ensure the accuracy of measurements. In addition, quality control of dosimetry equipment, such as the patient dose calibrator (PDC), is crucial to ensure reliable results. In this study, we propose the use of spectrometry and ionization chamber for the characterization of the 3D prototyping semi-automated filter holder system.

Methods

The semi-automated filter holder system was assembled following international standards. The characterization will be performed using an X-ray spectrometer and an ionization chamber, following the procedures recommended by international standards. Tests for the quality control program will be performed.

Results

The results showed that the system meets the requirements of the international standards TRS457 and IEC 61267, with good energy response, stability, uniformity, and linearity. The use of spectrometry and ionization chamber was effective in determining these parameters. The spectra characterization allowed the establishment of an adequate quality control, with precise and reliable measurements.

Conclusions

The semi-automated filter holder system for RQR and RQA was characterized using spectrometry and ionization chamber, and a quality control program was established. The results indicate that the system is suitable for dosimetry measurements. Additionally, Monte Carlo simulation will be used for validation of the calibration method.

Monte Carlo Simulation of GRID collimators

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Introduction

GRID therapy uses collimators to obtain non-uniform spatial radiation patterns, generating dose peaks and valleys in the target volume. Based on it, favorable conditions to preserve healthy tissues are desirable. As the radiobiological mechanisms are not fully understood, the development of experimental setups for studies is a goal. Therefore, the aim of this work was to study different materials for the construction of GRID collimators to be used in radiobiological studies.

Methods

Monte Carlo Simulation with the PENELOPE v.2014 was used to obtain the dose distributions of cylindrical collimators with 5 cm in diameter and 3.5 cm thick. The collimators have a 3 mm open field and an open/blocked field ratio of 1:1. Aluminum, brass and lead were used to simulate the collimators and water to simulate a phantom. The dose distributions were used to obtain dose profiles and the valley-to-peak ratio - the peak-dose, referring to the dose in the unblocked beam path, and a valley dose referring to the dose of the blocked areas. Matlab® was used to analyze the dose distributions and profiles. A 100 kVp beam spectrum generated with SpekCalc was used to simulate.

Results

The ratio between the theoretical value and the full width at half maximum for the blocked filed for aluminum, lead, and brass, obtained by considering only the primary photons and the collimator transmissions, are 0.11, 0.09 and 0.10, respectively. The valley-to-peak ratio obtained using the simulations for the aluminum, lead and brass collimators were 0.23, 0.08, and 0.10, respectively. The difference between the theoretical and simulated values are due to the scattering inside the collimators and in the phantom, the transmission by the collimator being larger for the lighter material.

Conclusions

The results showed that lead and brass produced the highest degree of spatial fractionation, and are more suitable for the experimental setup of a GRID irradiation system for radiobiology studies.

A methodology for automated radioactive waste characterization

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Introduction

The nuclear technology development must allow safe and secure waste management which proves from the steps of the nuclear fuel life cycle, research centers and industry, and radioisotopes applications in medicine. Proper nuclear waste characterization is complex due to the wide range of materials, processes, and applications. In this work, a methodology for final characterization was developed using deep neural networks.

Methods

The Monte Carlo Methos was applied to gamma spectra simulation in a scenario where the nuclear waste is stored in a 200 liters steel drum that can contain up to 10 different radionuclides. The simulation data was used to train and assess the performance of different deep neural network architectures. The VGG-19 architecture was chosen due to the best overall performance at the classification task, capable of identifying which radionuclides and which activity each radionuclide presented at the gamma spectra.

Results

Simulations were performed to generate a synthetic dataset containing 600 instances. This first step used several different parameters for initial multichannel energy (0.01 eV, 5 eV, 10 eV, 30 eV, 40 eV), number of simulated stories (1.0E+07, 1.0E+08, 1.0E+09), detector to drum distance (41 cm, 46 cm, 51 cm, 56 cm) and radionuclides (Am-241, Ba-133, Cd-109, Co-57, Co-60, Cs-137, Eu-152, Mn-54, Na-22, Pb-210), then a mixing procedure was applied to generate spectra with more than one radionuclide. Finally, the training dataset contains 10,575 instances, and the test dataset contains 825 instances. The final metrics for each task in the model are presented in the table below.

Metric	Training dataset	Test dataset
Accuracy	96.55%	96.01%
Mean Square Error	45.15	97.10
Accuracy with 95% threshold	69.59%	66.57%

Conclusions

The presented results show that the proposed methodology can be an important tool in the nuclear waste characterization process performed routinely by the IPEN`s Service of Radioactive Waste Management, allowing the decrease to occupational exposure to ionizing radiation.

Validation of Fricke xylene gel dosimetry through comparisons between MCNP and TOPAS simulations

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Introduction

The Monte Carlo (MC) technique has become a standard tool in medical physics, providing reliable numerical results by using large quantities of pseudo-random samplings and a physical description of phenomena. It is possible to simulate radiation transport, with special emphasis on transport involving particles and photons, for Fricke xylene gel (FXG) dosimetry. The objective of this work is to perform computational dosimetry using MCNP and TOPAS codes for the GammaCell 220 Irradiator, based on an experimental configuration that simulates an FXG dosimeter, in order to determine the absorbed dose in the environment.

Methods

The simulations of the GammaCell 220 cobalt-60 irradiator were performed using the radiation transport code MCNP Version 6.2 and TOPAS. The geometry of the irradiator was simulated as closely as possible to reproduce the experimental configuration with a FXG dosimeter with formaldehyde addition. For this work, the MCNP tally used is F6, which calculates the energy deposited in the cell, with units of energy per mass, which coincides with the definition of dose. And for the TOPAS code, volumetric scorers are used for dose or energy calculations.

Results

MC simulations were compared to FXG dosimetry experimental measurements, and both MCNP and TOPAS codes were able to predict radiation dose with similar accuracy, although they showed smaller deviations compared to the experimental values. However, FXG dosimetry has limitations that can affect measurement accuracy, despite being a well-established and widely used experimental method in radiation dosimetry. Figure 1 shows the simulated geometry in TOPAS.

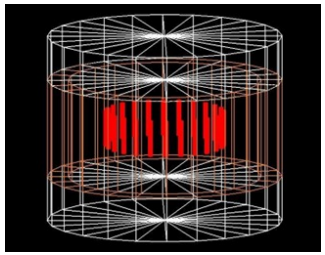

Figure 1: GammaCell 220 simulated geometry from TOPAS code.

Conclusions

Summarizing, Monte Carlo simulation with MCNP and TOPAS is a powerful tool in dosimetry but relies on accurate input parameters and models for precise modeling of energy absorption and distribution in tissue-equivalent materials.

Implementation of ICRU Report 90 to Re-evaluate the Dosimetry Standards in Taiwan

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Introduction

In 2016, the new ICRU Report 90 published the key data about the interaction of radiation with air, graphite and liquid water for ionizing radiation dosimetry. According to the recommendation of ICRU Report 90, the National Ionization Radiation Standard Laboratory of the Institute of Nuclear Energy Research(NRSL/INER) re-evaluated primary dosimetry standards: air kerma in X-ray, ^{60}Co and ^{137}Cs beams, absorbed dose to water in ^{60}Co beam, as well as reference air kerma in ^{192}Ir beam for brachytherapy.

Methods

Two techniques from the basis of primary measurement standards had been developed for measuring energy deposition with ionization chambers and calorimeters. Referring to the BIPM, the relevant physical parameters and correction factors were evaluated to determine these dosimetry standards through serial measurements and EGS calculations.

Results

The main amendments included the following three items:(1) New correction factors k_{ll} and k_{W} implemented for free-air chambers; (2) new wall correction factors, k_{wall} and stopping power ratio, $s_{\text{g,air}}$ with Monte Carlo calculations adopted for ionization chambers; and (3) dry air W_{air} vs. revising uncertainties for the $W_{\text{air}}s_{\text{g,air}}$ product. The results showed the before–and-after correction factors adopted the new uncertainty and the impact of the recommended changes in these standards.

Conclusions

This study indicates that the impact range of the new ICRU recommendation towards dosimetry standards was about 0.1% to 0.9%. The change of the primary standard will subsequently affect the measurements of the absolute dose in extensive application, including radiation therapy, radiological diagnosis, radiation protection and the industrial use of radiation. The INER/NRSL planned to formally implement the re-evaluation standards on the 1st January, 2024.

Discrete Range Modulation Method (DRM method) for Carbon Ion Radiography – A Monte Carlo Study

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Introduction

Relative stopping power derived from Hounsfield Unit (HU) is usually used for range calculation in particle therapy. However, this conversion method introduces the range uncertainties from 2% to 3.5% and results in expanded dose distributions in clinical treatment planning. To mitigate these uncertainties, the discrete range modulation (DRM) method has been developed to calculate water equivalent path length (WEPL) of various materials to reduce range uncertainties. In this study, the DRM method was applied to carbon ion beam simulation for feasibility assessment.

Methods

The simulation platform used in this study was the MCNPX (Monte Carlo N-particle eXtended). Carbon ion beams with energies raging from 90 to 430 MeV/u in 1 MeV step were simulated to establish the relationship between energy and R80. Various phantoms, such as square, step, wedge, sphere, and a heterogeneous phantom with five different materials in step shape, were designed in MCNPX and simulated. Then the WEPL was calculated using DRM method and compared to the ideal value to evaluate the feasibility of the method.

Results

The DRM method showed excellent agreement between calculation and ideal value. The maximum deviation of WEPL was less than 0.5mm in uniform phantoms. Moreover, the DRM method yielded comparable results for the heterogeneous phantom when compared to the uniform phantoms.

Conclusions

The DRM method for carbon ion radiography was proved to be feasible.

Logfile-based Patient-Specific QA for Continuous Line Scanning Proton Therapy System in CGMH Linkou branch

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Introduction

In proton therapy, patient-specific QA (PSQA) must be conducted to ensure radiation dose to be delivered correctly. However, PSQA usually requires manpower to perform measurements and occupies treatment room, and this will have influence on patient throughput. In this study, we established a Monte Carlo system combined with log files retrieved from proton therapy system to reconstruct dose distribution to improve the efficiency of PSQA procedures.

Methods

In this study, an independent Monte Carlo (MC) system was established using PTSim (Particle Therapy System simulation framework) ver. 104-002-001 and GEANT4 ver.10.04.p02. A continuous pencil beam scanning nozzle was modeled and commissioned in MC system. Log files retrieved from proton therapy system were interpreted using MATLAB program and then input to MC system for dose reconstruction. Afterward reconstructed dose distribution was compared to the dose computed by treatment planning system (TPS). Three different treatment plans, including head and neck, brain and liver, were chosen as benchmark cases to evaluate the performance of MC system.

Results

The MC reconstructed dose shows acceptable agreement with TPS, and the average gamma passing rate at various depth is 97.05%, 95.4% and 92.4% for brain, head and neck, and liver plans, respectively. In addition to high gamma passing rate, the most important value of this MC system is its ability to save valuable beam time in the treatment room and enhance the efficiency of PSQA procedures.

Conclusions

A MC system were successfully established to improve the efficiency of PSQA procedures.

Comparison between a simple analytical method and Monte-Carlo simulations on heterogeneities in low rate brachytherapy

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Introduction

In an effort to improve dosimetry calculation in brachytherapy, different MBDCAs (Model-Based Dose Calculation Algorithms) have been developed to obtain a more accurate dosimetry to the patient's anatomy. This work is an extension of Hueso-González et al. 2015, increasing the type of sources and heterogeneities.

Methods

Source Models: Two source models have been used for the calculation. A Pd-103 source of 20.2 keV and a Cs-131 source with main energy 29.7 keV.

Monte-Carlo: PENELOPE-2014 and TOPAS codes have been used. The simulations performed consist of a 25 cm water sphere. For the heterogeneities, a 0.5 cm thick spherical layer has been added. Calcium and air with different densities have been used for the heterogeneities.

Analytical method: The basis of the algorithm RayStretch, is the modification of the radial dose function. With the water-equivalent path method, we rescale the distance travelled by a photon as it passes through the heterogeneous medium.

$\Delta r_{eq} = \Delta r \cdot \lambda$

Where the factor λ is adjusted empirically compared to MC simulations.

The expression of the equivalent radial dose function is:

Results

An example of the radial dose function with the heterogeneous calcium and air layer calculated with the analytical algorithm and with the MC codes is shown in Figure 1 for the Pd-103 seed.

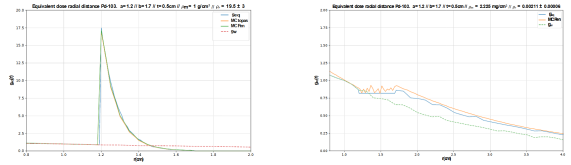

Figure1. Comparison of the g_{eq} calculated by t he RayStretch algorithm (ρ_r is visually adjusted) with the MC simulations of PEN and TOPAS and Tg-43 (gw). Calcium, ρ_m=1 g/cm^3 (left) and A ir, ρ_m=2.225 mg/cm^3 (right).

Mass Density	MC Topas		MC Pen		g_w	
	Pd-103	Cs-131	Pd-103	Cs-131	Pd-103	Cs-131
Ca 1 g/cm^3	2.81	6.13	2.92	6.21	2.67	5.99
Ca 2 g/cm^3	2.86	6.65	2.87	6.59	2.78	6.09
Aire 1.225 mg/cm^3			2.65	6.22	2.63	5.87
Aire 2.225 mg/cm^3			2.65	6.22	2.65	5.87

A quantitative evaluation has been obtained by performing the integral of the $g_{eq}(r)$ of the obtained curves and comparing it with the g(r) in water. The reference values of the g_w integral are 2.67 for Pd-103 and 5.95 for Cs-131.

Conclusions

The algorithm reproduces the simulated radial dose functions with MC better than TG-43 calculation. The analytical algorithm is simple and fast in order to be incorporated into the TPS and improve brachytherapy dosimetry.

Investigating Secondary Neutrons Production from Carbon Ion Beams for Radiotherapy

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Introduction

Particle therapy, specifically carbon ion beam therapy, is an emerging field to treat cancers because of its ability to deliver a high dose to the tumour conformably and at the same time protect the normal tissues. However, one of the main problems that could affect patients' health when they are treated by particle therapy is the secondary radiation that could raise the integral dose, which in turn, can cause secondary cancer. This work focuses on utilising the TOPAS Monte Carlo toolkit to study the characteristics of primary particles and secondary neutrons emitted during carbon ion irradiation. Before using the Dark Matter Particle Explorer experiment (DAMPE) detector to measure the deposited energy in air and water and compare the simulation results with measurements.

Methods

Through TOPAS MC simulations we investigated the interactions of carbon ion beams with a water phantom (represents human tissues) and two strips silicon detectors are placed behind the water phantom to allow measuring scattering angles and reconstruction of particles positions.

Results

Analysing the simulated data gave insights into the energy deposition profiles and scattering patterns of primaries and secondary neutrons, offering important information to assess the potential biological effects of secondary radiation and treatment planning optimization. The scattering angles for primaries and secondary neutrons have been calculated and plotted as well as the dose deposited in each detector.

Conclusions

The simulation results show a good agreement with the previous studies using other MC codes. These results contribute to enhancing treatment planning accuracy, ongoing efforts in improving particle therapy techniques, and optimizing detector design. Furthermore, our work evaluates the feasibility of the TOPAS MC toolkit for inclusive studies in carbon ion beam therapy to further developments in this exciting field.

Measurement and Modelling of x-ray absorption to High Accuracy

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Introduction

A comprehensive understanding of x-ray absorption is of great importance when it comes to understanding and working in dosimetry. Having methods of both measuring and theoretically computing attenuation coefficients to high accuracy is essential to establishing a solid baseline of knowledge upon which later dosimetry calculations can be built. In particular, the complex edge absorption fine structure has proved difficult to both measure and theoretically predict with traditional databases like FFAST and XCOM often deviating from measured values by an excess of 10%. Presented here are both measurements and theoretical modelling of the entire absorption edge region of both zinc and zinc selenide to very high accuracy.

Methods

The x-ray extended range technique (XERT) is employed to measure the attenuation coefficient of zinc and zinc selenide to better than 0.15% accuracy. This is achieved by collecting data over a wide range of parameter space enabling detailed modelling and subtraction of systematic effects. The theoretical software packages FEFF and FDMX are used to simulate the absorption spectra over both the EXAFS and XANES region and are compared to the measured data. These two software packages use the two most common methods theoretical determination of attenuation coefficients, multiple scattering and density functional theory, respectively.

Results

We report measurements of the attenuation coefficient of zinc and zinc selenide to extremely high accuracy as well as breaking down the individual contributions to the total attenuation coefficient, ie photoelectric absorption, Rayleigh scattering, thermal diffuse scattering etc. We show how in the absorption edge region existing theoretical databases like XCOM and FFAST deviate by as much as 10% from measurements. Multiple scattering and density functional theory simulations of the absorption coefficient are also presented with comparisons of the two with the high accuracy measurements demonstrating the benefits and shortcomings of each approach.

Conclusions

With highly accurate methods of both measuring and modelling the attenuation coefficients of materials a more solid and robust understanding of the fundamental underpinnings of dosimetry can be created. By carefully quantifying the effective contributions of systematic error to attenuation coefficient measurements we detail how extremely high accuracy can be achieved. We also demonstrate how new and more complex methods of simulating the edge absorption region are required to accurately capture the behavior of the absorption coefficient in the absorption edge region.

Real-time radiation monitoring at laser-driven ion accelerators using a scintillator stack detector

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Introduction

Acceleration of protons and ions with energies reaching up to tens of MeV using laser-driven techniques can now be reliably achieved in a number of state-of-the-art PW laser facilities. Laser-driven beams are delivered in extremely short (<1ps) and intense pulses, paving the way for new multidisciplinary applications from medicine to material sciences. Laser-driven beams are typically accompanied by large amounts of stray radiation, consisting of a mixture of photons and electrons, originating from the plasma at the laser-target interaction point. Such radiation pulses should be measured in real-time for radiation area monitoring and as a diagnostic tool for beam and laser conditions. The characterization of short-lived radiation fields is, however, very challenging due to their short time scale.

Methods

A scintillation stack detector was developed for this purpose and deployed during the ELIMAIA beamline commissioning at the ELI Beamlines facility in the Czech Republic, with laser intensities on target exceeding 10^{21} W/cm^2. The detector uses a novel simulation-driven unfolding procedure to estimate, after each laser shot, the ambient radiation field composition, intensity and temperature. Monte Carlo simulations are used to estimate the detector performance and generate the response matrix used for unfolding.

Results

Estimates for the amplitude and hardness of the mixed photon/electron field present during the ELIMAIA commissioning are presented. We also present results from Monte Carlo simulations of the experimental setup and calibration measurements using radiation sources.

Conclusions

The detector measurements are in good agreement with theoretical expectations and other measurements provided by diagnostic tools. They provide an estimate for the radiological conditions around the interaction point, a crucial information for the safe and efficient design of the next generation of laser-driven ion accelerators.

Dose point kernels for iodine radionuclides in liquid water obtained by simple yet reasonably accurate Monte Carlo simulations

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Introduction

Radioactive isotopes are often used in Nuclear Medicine to diagnose and cure diseases such as cancer. These isotopes are unstable atomic nuclei that emit energy due to various processes, such as β−decays or Auger electron emissions. These ejected electrons carry the excess energy of the excited nucleus and deliver it as they travel through matter, so that in the end a given spatial distribution of dose is produced around the emission point. Depending on the type of process that triggers the electron release, determined by the nature of each radioisotope, the energy emitted and its distribution around the emission point may change. If we know how the energy is deposited through the medium, we can choose which isotope will be more convenient to use in a particular clinical situation.

Methods

We have developed a Monte Carlo simulation code that follows in detail the motion through liquid water (the main constituent of biological tissue) of the electrons emitted by radioactive iodine nuclides (either ^{131}I or ^{125}I, which emit through different deexcitation mechanisms). The elastic collisions of the electrons are taken into account by a screened Rutherford cross section, whereas the inelastic collisions, leading to the energy loss of the electrons, are accounted for by empirical approximate stopping power formulas for high and low energy electrons.

Results

Despite the simplicity of the simulation code, the obtained dose point kernels for electrons emitted by radioactive iodine isotopes show promising agreement with available reference simulations and theoretical calculations.

Conclusions

This work shows how Monte Carlo simulations can be tuned for simple yet reasonably accurate determinations of dose distributions, of special relevance in Nuclear Medicine.

Simulation of Bragg curves of proton beams in condensed-phase materials of interest in protontherapy

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Introduction

The use of energetic ions in radiotherapy offers numerous advantages in comparison with the conventional techniques. Due to the reduced angular scattering and the maximum deposition of energy at the end of their trajectory (Bragg peak), ions can inflict great damage in an internal tumor minimizing the effects on the surrounding healthy tissues. These are the basic ideas supporting protontherapy. In order to properly perform treatments in protontherapy and to understand the cellular damage processes, a precise knowledge of the fundamental aspects involved in the energy deposition of primary ion beams in materials of biological relevance is needed.

Methods

In this work we present the simulated Bragg curves for swift proton beams, with different energies, interacting with different relevant materials in radiotherapy such as liquid water, poly(methyl methacrylate) (PMMA, $(C_5H_8O_2)_n$), or cortical bone surrogate. The depth-dose distributions are obtained with the simulation code SEICS (Simulation of Energetic Ions and Clusters through Solids), which has been developed by our research group. This code considers inelastic collisions, elastic collisions, the fragmentation nuclear reactions, and the projectile electron capture and loss processes, using the stopping power and straggling values obtained from a detailed description of the target electronic excitation spectrum, accounted for by the MELF-GOS model.

Results

Simulations for relevant energies in protontherapy (of tens and hundreds of MeV) are compared with reference simulations and experimental data for several biologically relevant materials in the liquid and solid phases, showing a good agreement.

Conclusions

This work emphasizes the importance of Monte Carlo simulations for analyzing the impact of the depth-dose distributions in the development of protontherapy treatments.

Energy-range relationships for industrial high-energy electron beam irradiators, utilising Monte Carlo modelling with realistic beams, and compared with measurements

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Introduction

Beam energy in industrial electron beams is usually found using depth-dose distributions in aluminium or polymers, utilising equations given in Annex 4 of ISO ASTM 51649 or in ICRU 35. These relationships were derived using results from earlier Monte Carlo codes, with monoenergetic electron beams.

Here, empirical relationships are derived using more realistic spectra, and the results are then compared with those from the earlier equations.

Methods

Monte Carlo calculations (EGSnrc) using a wide range of "realistic" (exponentially-modified Gaussian) spectra were used to generate a large number of depth-dose distributions in aluminium and polystyrene, from which new empirical relationships were derived linking measured range parameters R_{50} and R_p, and average and most probable energy E_a and E_p.

Measurements performed at three facilities (a Mevex linac, 1.5 – 6.5 MeV, J&J Sterility Assurance, Raritan, NJ, USA; an IBA Rhodotron, 10 MeV, Sterigenics, Denmark; a 12 MeV linac, Sterigenics, San Diego, CA, USA) for energies between 1 and 12 MeV in aluminium wedges and polystyrene stacks, were used as a validation of the method and calculations.

Empirical equations were established to relate the mean energy E_a and most probable energy E_p to the range parameters R_{50} and R_p.

Results

Residuals are shown here for measurements and calculations in polystyrene and in aluminium. An uncertainty budget is also established.

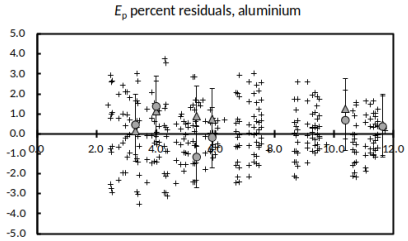

Figure: Residuals between equations identified giving (left) E_a and (right) E_p and spectra explicitly calculated using EGSnrc, for polystyrene (upper) and aluminium (lower). Circles are from measured distributions and triangles from the matched Monte Carlo calculations for those distributions.

Conclusions

These calculations and the derived empirical relationships allow a validation of the older equations, and also allow for identification of more realistic spectra for modelling actual irradiations as industry moves towards increased use of modelling techniques.

Investigation of radioactive elements and heavy metals concentration in opium with photon, neutron, and ion beam analysis methods

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Introduction

Opiums are utilized in medicine for the production of specific drugs, such as sedatives and analgesics. The potential presence of radioactive elements in narcotics exists. Afghanistan is one of the major producers of opium; unfortunately, drug traffickers mix it with lead and heavy elements in high proportions to increase their profits. The presence of heavy and radioactive elements in narcotics is a significant drawback that necessitates their identification for the preservation of patients' health. This research aims to introduce the most suitable method through nuclear analysis techniques with various radiation types.

Methods

Initially, the response of various nuclear detectors to photons, neutrons, and charged particles with different energies is optimized based on the Monte Carlo method using MCNPX and GEANT codes. This optimization is carried out for a combination of narcotics containing varying percentages of lead, heavy elements, and radioactive materials. Subsequently, practical measurements are performed by appropriately designing the detector configuration to obtain the detector response using the optimized methods.

Results

The simulation results reveal that the PIGE method with alpha particles generated from a source of americium is one of the suitable approaches for detecting lead in narcotics. In practical scenarios, by irradiating the equivalent sample of opium with varying percentages of lead using alpha particles emitted from an americium source, the detector response of the CSI (Tl) scintillation detector to the photons emitted from the sample is calculated at specific energies. This calculation is based on the formulated lead percentage.

Conclusions

The practical and simulated results of investigating various nuclear techniques for detecting lead in narcotics demonstrate that the possibility of using the PIGE method with a 5.49 MeV alpha source is superior to other methods for detecting lead, even at a minimum concentration of 5 PPM.

PyMCGPU-IR: A Novel Application for Personal Dosimetry in Interventional Procedures Using Computational Methods

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Introduction

Monitoring workers' exposure is essential to ensure safe working conditions. However, standard passive individual dosimetry has its limitations. The trend is moving towards active personal dosimeters (APDs) to increase awareness during exposure. To further improve radiation dose estimates is to use an online dosimetry application based on computer simulations without physical dosimeters. The proof of concept was developed under the PODIUM project. In this paper we present PyMCGPU-IR, one of the solutions developed in the PODIUM project for interventional radiology (IR) workplaces.

Methods

MCGPU-IR is a fast Monte Carlo simulation code written in CUDA. It adopts X-ray interaction models and material properties from PENELOPE v2014. The code is designed to provide optimum performance in GPUs. Patient and physician are represented by voxelized computational phantoms. A Microsoft Kinect™ camera was used for tracking the physicians' movements. For dose calculation, PyMCGPU-IR, a Python application for MCGPU-IR, retrieves pertinent information about each irradiation event from the patient's structured dose report and merges it with the operator's position.

Three IR procedures at St. James's Hospital in Dublin were selected to validate PyMCGPU-IR. The operator equivalent dose $H_p(10)$ was measured with an APD.

Results

Measured values ranged from 55 µSv to 12 µSv. Differences between calculated and measured were less than 8 µSv and within uncertainties. Each irradiation event's simulation time was under 2 minutes. PyMCGPU-IR provides not only $H_p(10)$, but also the eye lens equivalent dose and the effective dose.

Conclusions

PODIUM results highlight the potential of this innovative dosimetric approach for better personal dose assessment, especially in non- homogeneous radiation fields. Further developments are needed to improve the tracking of workers and to study different protection means in long procedures.

Recovering of an X-ray Spectrum from Detector Influence

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Introduction

It is well known that a measured energy dispersive X-ray spectrum differs from the original spectrum arriving to the detector. This is due to changes introduced by the detection device and by the pulse electronics during the measurement. The detection device contributes with a deformation attributed to the detector response function (DRF) which is well described in terms of physical processes of radiation diffusion inside the detector. The pulse electronics contributes in two different ways: (a) with a convoluted broadening due to an asymmetrical distribution at each recorded energy (resolution effect) which produces an uneven smoothing of the spectrum, and (b) with the pulse pile-up which introduces a distortion which changes the total counts and the shape of the spectrum. Once characterized the DRF comprising the resolution broadening effects, it is possible to recur to an unfolding algorithm to recover the original spectrum.

Methods

In this paper it is introduced a detailed description of the four steps which are necessary to recover the source spectrum from a measurement by using a set of computer codes developed in Bologna. In first place, it is applied a PPU correction algorithm on the measured spectrum which renders a corrected measure having the proper number of counts in the proper energies. Then it is computed the combined effect of the DRF (obtained with the Monte Carlo code MCSHAPE) and the asymmetrical resolution (using the code RESOLUTION) for each energy of the source spectrum. By discretizing these single energy distributions, it is possible to obtain the response matrix feeding the next step. The last step consists in the application of a robust unfolding procedure like UMESTRAT, the maximum entropy technique which takes advantage of the known a priori information and preserves the positive-defined character of the X-ray spectrum.

Results

The results are illustrated with a paradigmatic examples involving the popular SSD CdTe. The white spectrum of an X-Ray tube is determined with recovering from direct measurement. It is shown that a good description of the assymetrical resolution is essential for a good recovering.

Conclusions

A performant recovering of an X-Ray spectrum requires the combined use of several correction steps. The extent with which contributes each step is analysed and discussed. The set of codes developed at Bologna are a valid tool to make the necessary corrections and to illustrate the complex unfolding mechanism.

Thermoluminescent dosimetry planning through MNCP

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Introduction

Sealed radioactive sources of 125I are tiny seeds that are injected into organs using thin needles through the skin. These sources are being developed and manufactured at IPEN/SP. To use these sources in brachytherapy, it is necessary to perform a dosimetric characterization following the AAPM TG-43 protocol. This protocol provides theoretical and practical guidelines for calculating doses in water or equivalent materials. Experimental measurements were made using thermoluminescent dosimeters (TLDs) to calculate radiation doses. These measurements were corrected and validated by comparison with computer simulations using the Monte Carlo Method. The Monte Carlo Method is a set of algorithms that use random number sampling to obtain reliable numerical results. It is widely used in computational dose calculations and in determining photon distribution in simulated objects. The MCNP (Monte Carlo N-Particle Transport Code) is one of the codes that uses the Monte Carlo Method and has several applications.

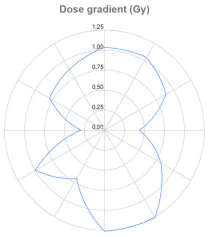
Methods

For the acquisition of the necessary parameters for the TG-43 protocol, solid water phantoms were used together with a plate that has a central space for positioning the 125I source and for radial distribution of the dosimeters. To calculate the measurement of this dose, the MCNP was used to determine the time required for the TLDs to reach 1 Gy, as described in the TG-43. program input, as well as the physical aspects of the source (emission energy, particle type, direction), the materials of all simulated structures and the expected detector response. The correction for energy dependence is given by the dose ratio in the value found in the literature is 1.049.

Results

The use of MCNP for the planning of 125I seed dosimetry shows that the results are promising, as seen in figure 1.

Figure 1: Dose gradient around the iodine seed



Conclusions

The Monte Carlo simulation with MCNP is a powerful tool in dosimetry, achieving the desired dose with the time calculated through the MCNP, in addition to being used to determine the other parameters of the TG-43.

Extensions of PenRed for Computed Tomography Simulation and Brachytherapy Treatments

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Introduction

PenRed is a highly parallel, efficient, and adaptable code for Monte Carlo simulations, written in C++ language, which incorporates the physics and functionality of PENELOPE. It is distributed as open-source code (https://github.com/PenRed/PenRed). While it is a general-purpose code, its development has focused on medical applications. With this purpose, different specific modules have been implemented to allow for the automatic simulation of computed tomography (CT) devices and brachytherapy treatments.

Methods

For CT simulation, two main modules have been implemented: a particle source that accurately simulates the movement of a CT scanner and a second module that collects photons that reach a user-specified virtual detector, generating a sinogram of the irradiated object.

On the other hand, taking advantage of PenRed's capabilities to process DICOM images, a source for brachytherapy treatment has been implemented. This source retrieves information about the seeds directly from the DICOM RT PLAN and samples the particles considering each position and its temporal weight. Moreover, a module has been implemented to calculate the kerma distribution in a user-defined Cartesian mesh. Additionally, the software generates dose-volume histograms (DVH) for each segmented organ.

Results

With the newly implemented capabilities, sinograms have been obtained for a Catphan-type phantom, and for patients using their DICOM images. Regarding brachytherapy treatments, dose distributions have been obtained for four non-clinical reference cases developed by AAPM/ESTRO/ABG/ABS and clinical cases have been verified using their DICOM plans through DVH analysis and isodose curves.

Conclusions

The obtained results demonstrate the capability of PenRed for use in the field of medical physics, as well as its reliability. Furthermore, these capabilities streamline these types of studies by automating a significant portion of the process, making it seamless and transparent to the user.

Individual Dosimetry and Monitoring

Building the foundation for a novel European Metrology Network for radiation protection via the joint network project supportBSS

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Introduction

Basic safety standards designed to protect workers, the public and the environment against the dangers arising from ionizing radiation are laid down in Council Directive 2013/59/EURATOM. As provider of dependable measurement infrastructure, metrology has a central role in implementing this directive. This task requires an international effort to meet the increasing challenges posed by stricter dose limits and new technological developments.

Methods

In the joint network project 19NET03 supportBSS, a consortium of 16 national metrology institutes and designated institutes laid the foundation for a European Metrology Network for Radiation Protection (EMN RP). The EMN RP acts as contact point for stakeholder needs and metrological improvements by initiating funded research via the European Partnership on Metrology (EPM).

Results

The EMN RP was founded in September 2021 to highlight radiation protection issues in metrology. One of its early activities was to organize a consultation workshop in September 2022 in advance of the current EPM industry call. In addition, supportBSS works continuously to underpin the European Metrology Network. A communication strategy has been established and the EMN website will soon be launched. The gaps and needs in capacity building, services and research are being identified. The latter forms the basis for the development of a strategic research agenda.

Conclusions

The network project supportBSS has worked successfully to establish a novel European Metrology Network to promote reliable radiation protection regulation. One of its foremost achievements was the founding of the EMN RP to become the single point of contact for service, research and training in radiation protection metrology.

The project 19NET03 supportBSS has received funding from the EMPIR programme co-financed by the Participating States and from the European Union's Horizon 2020 research and innovation programme. 19NET03 supportBSS denotes the EMPIR project reference.

Incorporating Uncertain Biokinetic Parameters in Stochastic Modeling of Particle Deposition Patterns in the Human Respiratory Tract for Defense and Consequence Management Applications

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Estimation of radiation dose from incorporated radionuclides rely heavily on biokinetic models as a mathematical representation of biodistribution of radionuclides. For inhaled radionuclides, reference models have been developed by the International Commission on Radiological Protection (ICRP), called the human respiratory tract model (HRTM), which have evolved from deterministic quantities given in ICRP Publication 66 and updated in Publication 130. However, structural and physiological variabilities result in uncertainties for individualized and specialized monitoring. The overall aim of this work was to conduct stochastic analysis for the updated ICRP HRTM from inhaled source term intakes as a function of radionuclide inventory and particle size distribution, solubility, and clearance for expanded inhalation coefficients, specific to the exposure source terms from nuclear security events and exposed populations.

The updated biokinetic models were reconstructed for use with realistic source terms for which an In-house code (REDCAL) was developed. As required by the inhalation pathway and as requirement for further stochastic analysis, the ICRP HRTM was reconstructed in Python programming language to calculate particle deposition fractions in each respiratory tract region under several conditions such as, but not limited to, monodispersed and polydispersed particle size distribution, and activity level. The ICRP updated HRTM deposition values were reproduced leveraging ICRP deposition methodology. To compare results with the ICRP published values, deposition fractions were computed for polydispersed particle distribution with AMAD of 5 µm for a pure light exercise level for an adult male. The results for the total deposition depicted a relative difference of 0.18% and an absolute difference of 0.15%. However, for service persons, exposed population, and individual monitoring, mixed activity level becomes important. Assuming a chronic intake for an occupational worker, the deposition values were computed using the In-house Python code and compared with ICRP published values. The relative and absolute difference in the total deposition values were 0.20% and 0.16% respectively. Overall, the reproduced deposition values demonstrated good agreement with the ICRP published values where the minute differences observed may be associated with numerical precision. Although the deposition values were broadly similar with low relative and absolute differences, the differences obtained for sex-averaged, male, and female, mixed activity levels, and intake modes are significant enough to dictate changes in the overall radionuclide distribution over time. Recent work has also demonstrated that a 3 µm particle size recommendation may be more appropriate for consequence management dose estimation, compared to the 1 and 5 µm for public and occupational recommended by ICRP. The results from dosimetric evaluation and comparative analysis will be shared.

For defense and consequence management applications, this analysis provides a base approach for further consideration of a well-defined deposition model beyond the standard reference worker and population.

Effects of resinterization on the physical, morphological and dosimetric properties of the ALOX-520 detector

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In recent decades, research has been carried out to explore new materials suitable for dosimetry, with a specific focus on their luminescent properties. One example is the development of a ceramic detector called aluminum oxide 520 (ALOX-520). The objective of this study was to conduct tests at even higher temperatures in a vacuum environment, aiming to investigate the impact of thermal treatments under these conditions on the physical, dosimetric, and morphological properties of the material. The re-sintered variant, ALOX-520T, exhibited superior dosimetric properties in terms of homogeneity, reproducibility, face homogeneity, linearity, and signal fading. From a physical standpoint, the increase in the detection threshold value of ALOX-520T could be attributed to a decrease in the sensitivity of this detector. Furthermore, unpublished studies were conducted to explore aspects such as the Optically Stimulated Luminescence (OSL) technique, including its related techniques such as Thermally Assisted Optically Stimulated Luminescence (TA-OSL) and Linearly Modulated Optically Stimulated Luminescence (LM-OSL). The results obtained from these studies aligned consistently with findings reported in the literature regarding α-Al_2O_3 ceramic detectors. X-ray diffraction (XRD) and X-ray fluorescence (XRF) analyses were performed to assess any potential alterations in the crystalline structure or composition of the material due to the thermal treatment. The results confirmed that the thermal treatment did not induce significant changes in either the crystalline structure or the composition of the material. Altogether, these results indicate that appropriate thermal treatment improved the dosimetric properties of the ALOX-520 detector without causing substantial modifications to it is crystalline structure.

Monte Carlo study of the uncertainties due to OWE positioning in a whole body counter

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Introduction

The objective of this study was to evaluate the uncertainties due to occupationally exposed worker (OEW) misplacement in a whole body counter using the MCNP6 Monte Carlo code.

Methods

The whole-body counter (WBC) of an internal dosimetry laboratory was modeled in MCNP6. The ICRP reference phantom of an adult male (RCP_AM) was positioned inside the WBC at twelve different positions along the longitudinal axis of the model at 5 cm intervals. The detection efficiency was evaluated at each position for monoenergetic photons of 100, 300, 500, 1000, 1500, and 2500 keV. The emission of photons was uniformly distributed in the soft tissues of the phantom. The position with the highest efficiency was considered the reference for in vivo monitoring, and the error for the other positions compared to the reference was calculated.

Results

The relative errors of the 76 simulated cases remained below 1.5%. Higher efficiency was found in position 6 for 100 keV and 2500 keV photons. Position 5 showed higher efficiencies for 300, 500, 1000, and 1500 keV. Position 6, where the center of the detector is located in the center of the abdominal region, was chosen as the reference monitoring position (RMP). Misplacements of 10 cm from the RMP resulted in differences of less than 2.5% for all tested energies of the female reference phantom, except for 2500 keV, where the differences were less than 5%.

Conclusions

This work shows that for the RCP_AM phantom, misalignments of 10 cm (or less) in the longitudinal axis result in errors of less than 5% for photons from 100 keV to 2500 keV distributed uniformly in soft tissues. Future work will address the evaluation of uncertainties in other phantoms and the contributions of misalignment in the frontal axis.

Design and characterization of the eye-lens dosimeter of Centro Nacional de Dosimetría according to the IEC62387 standard

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Introduction

In 2019, Centro Nacional de Dosimetría (CND) developed its own specific dosimeter for the measurement of the eye-lens equivalent dose based on thermoluminescent technology. In this study, the response to radiation of this system is evaluated following some of the type tests of the standard IEC62387, which establishes the requirements that dosimetry systems with integrating passive detectors for individual monitoring of photon radiation must satisfy.

Methods

The CND eye-lens dosimeter is made up of a single thermoluminescent LiF:Mg,Ti detector model EXTRAD TLD-100 (Thermo Fisher Scientific) with a thickness of 100 mg/cm^2 and 3 mm on each side, located between two filters equivalent to 3.2 mg/cm^2 of PTFE tissue. The set is placed in a hermetically sealed plastic case to avoid contaminants and protect it from light, and can be placed on the head with an elastic band, on the surgical cap with a safety pin or on the temple of the glasses thanks to the Velcro that incorporates. The reader used is a Harshaw 8800 plus (Thermo Fisher Scientific) and the analysis programs are those of the CND.

The irradiations of the dosimeters have been carried out in the Laboratories of CND and CIEMAT, for $H_p(3)$ values between 0.1 mSv and 1 Sv and with energies of ^{137}Cs, ^{60}Co, N series and RQR-M. The test that have been carried out are: coefficient of variation, linearity of the response with the dose, response with the energy and the angle of incidence of the photon radiation, reusability and fading.

Results

The coefficient of variation and linearity are within the tolerances in the interval 0.2 mSv-1 Sv. Response with the energy and the angle of incidence is adequate for 16 keV – 1.3 MeV and 0º – ±60º. Dosimeters are reusable until 300 mSv and fading is acceptable for up to 6 months.

Conclusions

The evaluated system complies, in the specified interval, with the requirements of the IEC62387 standard to be used in personal dosimetry to estimate the eye-lens dose in terms of $H_p(3)$.

Annual occupational doses to the lens in interventional procedures

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Introduction

New Spanish legislation published at the end of 2022 changes the eye-lens dose limit to 100 mSv over 5 years. This study presents annual occupational doses of interventional workers using eye-lens dosimeters from CND from 2020 to 2022.

Methods

Dose records in terms of $H_p(3)$ from eye-lens dosimeters used by healthcare workers classified in interventional radiology services were selected, including all type of facilities where fluoroscopy is used.

The annual accumulated dose from 2020 to 2022 official years was calculated. Administrative doses, as well as doses from lost dosimeters, bad readings, or accidental irradiations not received by the worker were excluded. No corrective factor was applied.

Doses below the reporting level (corresponding to 0,2 mSv/month) were recorded as background and treated as zero.

Results

There are currently more than 500 healthcare workers monitored with eye-lens dosimeters from CND. 80% of these workers were classified in interventional services.

A total of 989 accumulated annual doses of $H_p(3)$ from 2020 to 2022 were analyzed from 32 healthcare centers. The collective dose was 2,42 Sv, the maximum annual dose was 40,6 mSv and the third quartile of the annual doses was 5,2 mSv.

A total of 445 accumulated annual doses (45%) were below the report level, 39 (4%) were above 15 mSv, from which 22 (2%) were above 20 mSv.

Conclusions

This study shows good practices in the interventional services monitored of Spanish healthcare centers in general terms. However, the Radiation Protection service in each healthcare center shall establish the particular protocol to monitor those cases where there is risk to exceed the new eye-lens dose limit considering individual corrective factors where necessary.

The Trial of The Proficiency Testing of eye lens dosimeters in Taiwan

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Introduction

The International Commission on Radiological Protection 118 report suggests that the occupational eye lens dose is reduced from 150 to 20 mSv/year (averaged over 5-year periods). Testing the performance of dosimetry systems including the hardware, the software, and the related supporting services is very important for the first-line radiation workers to monitor the personnel exposure. The first trial of the proficiency testing of eye lens dosimeters was conducted in our study according to the American National Standard Institute (ANSI) N13.32 standards.

Methods

Eight groups of eye lens dosimeters were used in the proficiency testing. There are seven groups of thermoluminescence dosimeter systems (TLD). The other one group was optically stimulated luminescence dosimeter system (OSLD). Four testing categories and their irradiation ranges for those dosimetry performances were determined according to the ANSI N13.32 standard. Irradiation categories are both high-dose (absorbed doses in the range of 0.1–5 Gy) and low-dose dosimetry (dose equivalents in the range of 2.5–100 mSv). The categories include high- (^{137}Cs) and low-energy photons (^{137}Cs, NS40, NS150, NS80, and WS110) and beta particles (^{90}Sr/^{90}Y). Three batches of equivalent doses $H_p(3)$ reported from each labrotaries were compared according to the critera of tolerance equation ($B^2 + S^2 \leq L^2$).

Results

The results showed that the tolerance level (L), absolute of bias (|B|) and standard deviation (S) for all categories of all the dosimeters well met the criteria. The results showed that all the personnel dosimetry evaluation laboratories were able to pass the trial.

Conclusions

The first trial of proficiency testing for the eye lens dosimetric system was assessed in Taiwan. The results showed that all the personnel dosimetry evaluation laboratories can provide a reliable service for the radiation workers.

Analysis of IST-LPSR participation in Intercomparison exercises for individual monitoring services in the period 2008 - 2022

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Introduction

In this work an analysis of the results obtained by the Individual Monitoring Service (IMS) of IST-LPSR in intercomparison (IC) exercises is performed. The regular participation in IC is essential to demonstrate the reliability of the results issued and, in addition, a necessary tool to implement the quality system based on the ISO/IEC 17025 accreditation standard. In 2008-2022, the IMS participated in the following IC exercises: seven for whole body, three for extremity and four for area dosimeters, the majority organized by EURADOS.

Methods

The dosimetry system implemented is based on 2 Harshaw 6600 semiautomatic readers. For whole body monitoring a 2-element card with LiF:Mg,Ti (TLD-100) or LiF:Mg,Cu,P (TLD-100H) inserted in a 8814 holder is used to assess $H_p(10)$ and $H_p(0.07)$. For extremity monitoring a TLD-100H dosimeter is inserted in an EXT-RAD holder to assess $H_p(0.07)$. For area monitoring TLD-100 is used inserted in a 8855 holder to assess $H^*(10)$.

The IMS prepared and shipped to the organizer of the IC exercise the requested number of dosimeters for irradiation in blind conditions. Upon return, the dosimeters were readout, the dose values were assessed and reported to the organizer. A final report was received with the dosimeter number, irradiation condition (quality, angle and dose), measured and true dose values and the response (ratio of the measured and true values).

For each IC exercise the response is plotted with the corresponding trumpet curves (ISO 14146) representing the general acceptance criteria.

Results and Conclusions

The results obtained in all IC exercises (2008-2022) were within the trumpet curves with one exception for extremity monitoring that allowed for a calibration verification and correction.

The results also allowed checking linearity, response in terms of energy, angle and mixed γ-β fields, usually evaluated at type-testing. The overall results organized by dosimeter type allowed for an improved uncertainty estimation.

Improving standardization in radiation protection dosimetry and supporting reference laboratories in the European Partnership Project GuideRadPROS

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Introduction

Calibration laboratories and industrial enterprises involved in radiation protection dosimetry face significant challenges following the recent update of the ISO 4037 in conjunction with the new radiation protection quantities introduced in ICRU Report 95, the gaps and contradictions in the standards that set photon dosimeter requirements, and the lack of standards for upcoming and new technologies.

Methods

The European Partnership Project 23NRM07 GuideRadPROS launched in June 2023 will address these issues over the next three years. The project objectives are:

1. to develop harmonized X-ray spectrometry in accordance with the ISO 4037 standard series, evaluate discrepancies between measured and calculated half value layer of X-ray spectra, and produce data to update requirements for reference fields.

2. to develop guidance and training material for the calibration of dosimeters.

3. to produce guidance on validated procedures for harmonized type testing based on IEC standards.

4. to investigate new and upcoming technologies and assess future standardization needs and to produce a guidance document for the implementation of the new operational quantities of ICRU Report 95 into standards and regulations.

5. to collaborate with ISO and IEC and users of their dosimetry standards to ensure that project outputs align with their needs.

Results and Conclusions

GuideRadPROS will improve the confidence in radiation protection dosimetry, both by promoting the implementation of the ISO 4037 standard series and by assessing the impact of the operational quantities of the ICRU Report 95 on daily measurements in radiation protection. Furthermore, the outcome of this project will lead to improved and comparable procedures in calibration and type testing within Europe.

The project (22NRM07 GuideRadPROS) has received funding from the European Partnership on Metrology, co-financed from the European Union's Horizon Europe Research and Innovation Programme and by the Participating States.

Mechanistic study of the acidic aqueous solution of chrome alum as high dose and high dose rate chemical dosimeter: Steady state, pulse radiolysis and conductometry studies

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Introduction

It is crucial to have an efficient and reliable approach to ensure an optimum traceability in high dose range and high dose rate dosimetry for radiation processing (food irradiation, surgery devices sterilization…). Chemical solution dosimeters are well suited for this purpose. By using γ-irradiation and pulse radiolysis, we evaluated the performances of the chrome alum KCr(SO4)2•12H2O based on the radiation induced oxidation of Cr(III) to Cr(VI) in N2O-saturated aqueous solutions by the radiolytically produced hydroxyl radical (OH•). With combination of spectrophotometric and conductometric measurements, a mechanism has been put forward to explain the oxidation of Cr(III) leading to Cr(VI).

Methods:

The proposed mechanism involves initial adduct formation that facilitates inner-sphere electron transfer.

Results:

As far as dosimetry is concerned, this study showed that the absorbance at 350 nm of the radiation induced Cr(VI) increases linearly with the dose with a yield of G(Cr(VI))= 0.128 µmol J-1. No dose rate effect was observed up to 80 kGy min-1. This aqueous solution could be used for chemical dosimetry, mainly in the high dose range (up to 5 kGy) and high dose rate (up to 80 kGy.min-1). The main advantage of using this aqueous solution buffered at pH 4 is its equivalence to human tissue in terms of radiation absorption properties.

Conclusions:

Chrome alum aqueous solution at pH 4 is suitable for high dose and high dose rate chemical dosimetry. Based on the radiation induced oxidation of the trivalent Cr(III) to hexavalent Cr(VI) through the transient intermediates Cr(IV) and Cr(V) a chemical mechanism has been proposed in this work. This system has properties which give it special advantages for radiation dosimetry at high doses and high dose rates.

Investigation of x-ray response for flexible nanocomposite membranes of metal oxides and PVA

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In this work, flexible composite membranes of nanoparticles (CuO, ZnO, or both), poly(vinyl alcohol) (PVA), and glycerol (GL) plasticizer are fabricated of for x-ray detector applications. The nanoparticles are synthesized by a modified solvothermal technique and introduced to PVA + GL solution to fabricate the membranes. The mean sizes of nanoparticles are and , for CuO and ZnO in order. The composition of nanoparticles and membranes are investigated by energy dispersive x-ray spectroscopy and x-ray spectroscopy. Increasing nanoparticle concentration within the membranes causes their glass transition temperature to shift to low temperatures and enhances their thermal resistance. Fourier-transform infrared spectroscopy demonstrates the formation of hydrogen bonds between nanoparticles and PVA that are generated by the intermolecular and intramolecular hydrogen bonds. Impedance spectroscopy characterization reveals that the membranes hold negative temperature coefficient of the resistance. The activation energy decreases with increasing nanoparticle concentration. The composite membranes exhibit a decent response to x-ray that is proportional to its energy. The best x-ray response is for the membranes with both CuO and ZnO nanoparticles, because of their different bandgaps that cause a wide range of excitation energy to be involved. The fabricated membranes have numerous advantages such as their semiconductor features, flexibility, and feasibility of fabrication on a large scale with reasonable cost.

The potentials of white graphene (h-BN) for monitoring of gamma-ray exposure in the dose range of 2-15 Gy

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Introduction

The atomic number of an ideal dosimeter to be used in medical dosimetry should be close to that of human tissue. The h-BN obtained has an atomic number similar to that of human tissue. Moreover, the layered structure of h-BN offers more intrinsic defects that is suitable for better dose response. Therefore, the dosimetric potential of hexagonal boron nitrite (h-BN) has been studied in the gamma-ray dose range of 2-15 Gy.

Materials and Methods

A Gammacell 220 equipped with ^{60}Co gamma ray source with the mean energy of 1.25 MeV is used to expose the samples. The h-BN samples were synthesised using the chemical vapour deposition technique. The essential thermoluminescence (TL) properties including the reproducibility, TL glow curves, TL response, linearity, sensitivity and the fading of the h-BN samples were studied using the Thermo Scientific™ Hashaw TLD model 3500 reader supported by WinREMS software.

Results

This material offers excellent reproducibility accompanied with substantial fading percentage. It is worth mentioning that h-BN has a very close Z_{eff} that of a human tissue.

Conclusion

Being a chemically stable, non-toxic, wide band-gap accompanied with a considerable high thermal resistance, the h-BN offers substantial potential as the highly efficient dosimeters for medical applications.

Evaluating Dose Responses in High-Energy Photon and Electron Beams Using Badge-Type Optically Stimulated Luminescence Dosimeters with Different Badge Housings

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Introduction

Radiation workers are required to wear personnel dosimeters throughout their radiation tasks. The optical stimulated luminescence dosimeter (OSLD) is a mature and advanced technology for radiation dose measurement. OSLDs can be read repeatedly, do not require heating or annealing, and are portable instruments. Badge-type OSLDs are worn in plastic holders for convenient attachment in radiation environments, and currently, two types of dosimeter holders are used in Taiwan.

Methods

This study uses a medical high-energy linear accelerator to deliver photon and electron beams to aluminum oxide crystals as the material for badge-type optically stimulated luminescence dosimeters (Inlight™ OSLD). Two types of badge holders, OSLD hole body holder and Inlight model 2, are used for dose comparison. A batch of new dosimeters is measured for energy dependence, angular dependence, dose linearity, crystal stability, fading effect, and bleaching results.

Results

The research results demonstrate that the optically stimulated luminescence dosimeter (OSLD) in combination with two types of dosimeter holders exhibits good dose linearity for both photon and electron beams. For photon beams, the energy dependence is within 1% without a dosimeter holder, while with a dosimeter holder, the energy dependence ranges from 3% to 5%. For electron beams, the energy dependence is within 6% without a dosimeter holder, while with a dosimeter holder, the energy dependence ranges from 1% to 4%. There is significant angular dependence with or without a dosimeter holder for photon beams at angles of 60 degrees and 240 degrees. For electron beams, the maximum angular dependence without a dosimeter holder occurs at 30 degrees, while with a dosimeter holder, it occurs at 210 degrees. Initially, the dosimeter grids exhibit instability upon irradiation, but they stabilize with a fading effect of 3% after being stored for more than one month. The dosimeters can be reused.

Conclusions

There is no significant difference in the energy dependence of the dosimeter holders. However, there is a difference in angular dependence, and it is recommended to wear the dosimeter with the front side facing up. Badge-type optically stimulated luminescence dosimeters are suitable for use as personal dosimeters in high-energy radiation environments. Correct wearing of the dosimeter holder is crucial. The findings of this study can serve as a reference for radiation workers and researchers in selecting dosimeters.

Internal Dosimetry and Biokinetic models

Extracellular Decorporation of DTPA in Hepatocytes

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Sodium and Zinc diethylenetriaminepentaacetate(DTPA) salts are used for accelerated removal of internally exposed actinides from the human body. Although effectiveness of DTPA in removing these is proven, the exact mechanism of this process is still not clear. Some scientist claim, DTPA crosses the cell membranes and chelate the radionuclides such as Americium intracellularly (Grémy, et al., 2016). Various studies reject the idea of intracellular decorporation (Fritsch, et al., 2010). The objective of this literature review was to investigate the chelation mechanism of americium (Am) removal from the liver, which is a major storage site for this radioactive element, following treatment with DTPA. The aim was to gain a better understanding of the mechanisms underlying the removal of Am from the body after DTPA therapy. Hepatocytes are major Iron storage sites in the liver. Ferritin is a protein, which stores the iron in Hepatocytes. Along with iron, internalised Americium is also stored by the ferritin (Stover, et al., 1970). When DTPA is injected into the blood. It forms the stable chelate with Americium circulating the blood ($\log_{10}$Ka 26.2) (Fritsch, et al., 2010). But it also forms the chelates with other metals such as Iron, Magnesium and Copper. Elevated levels of Fe-DTPA, Cu-DTPA & Mg-DTPA are found in the urine of rats after decorporation therapy (Sato, et al., 1994). To maintain the Iron homeostasis in the body, Hepatocytes release the stored iron into the blood stream. Along with the stored Iron the Americium slowly gets released into the bloodstream. The process of glomerous filtration helps in removing Am from the blood. Additionally, it can explain the temporary increase in Americium levels in urine for a few days after the DTPA injection. Experiments to prove the hypothesis are envisaged in the future.

Acknowledgement

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References

Fritsch, P. et al., 2010. Structure of a single model to describe plutonium and americium decorporation by DTPA treatments. *Health Physics,* 99(4), pp. 553-9.

Grémy, O. et al., 2016. Decorporation of Pu/Am Actinides by Chelation Therapy: New Arguments in Favor of an Intracellular component of DTPA Action. *Radiation Research* , 185(6), pp. 568-79.

Sato, I. et al., 1994. Effects of Ca-DTPA on essential Trace metals in rats.. *International Journal of PIXE,* 04(01), pp. 59-64.

Stover, B. J., Bruenger, F. W. & Stevens, W., 1970. Association of Americium with Ferritin in the Canine Liver. *Radiation Research,* 43(1), pp. 173-196.

Developing a Biokinetic Model to Estimate Thyroid Dose Based on Individual Characteristics

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Iodine is a key component of the thyroid hormones, which regulate various essential processes in the human body. More than 90% of total body iodine is found in the thyroid gland. Several factors influence the thyroid function and daily iodine uptake, including age, disease, lifestyle, and diet. Radioactive iodine can cause severe thyroid exposure in the event of a nuclear accident. The iodine metabolism in the human body is essential for an adequate dose estimation. Biokinetic models are widely used for iodine dose estimation. Biokinetic models previously published in the literature were reviewed and compared, their advantages and disadvantages were evaluated, and a new compartmental model based on the existing ones has been developed for the studies. The ModelMaker4 program was used to implement the mathematical model. The time-dependent distribution of iodine in the body was determined, and factors influencing the thyroid function were collected. The effect of dietary iodine to the thyroid activity was investigated. If the dietary intake of iodine is less than adequate, it leads to iodine deficiency in the body. To enable the thyroid gland to maintain normal hormone synthesis, iodine uptake by the thyroid gland will increase. As a result, the uptake of radioactive iodine by the thyroid gland will also increase. However, excess iodine intake will result in less radioactive iodine in the thyroid. The effect of diseases such as hyperthyroidism and hypothyroidism on thyroid activity was studied. The effect of age was also part of the analysis. The aim of our study was to define a new biokinetic model of iodine metabolism, which considers personal characteristics, such as age-dependent thyroid uptake, disease and the effect of dietary iodine intake, the impact of which on dose estimation has been investigated.

Application of Internal Dosimetric Analyser Software Toolkit to Special Dose Assessment in the Event of Radiological Emergencies

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Introduction

The IAEA Radiation Safety Technical Services Laboratory has developed an Internal Dosimetric Analyser (IDA) software toolkit to facilitate access to dosimetric data and perform calculations related to individual monitoring for intakes of radionuclides and occupational radiation protection.

Methods

Direct ('in vivo') and indirect ('in vitro') radiobioassay methods have been developed to detect radionuclides of interest in tissues or organs of the human body or in excreta. IDA serves to correlate measurements from special internal monitoring following a real or suspected contamination incident with data obtained from the Occupational Intakes of Radionuclides (OIR) series of recommendations published by the International Commission on Radiological Protection (ICRP).

Results

The objective of IDA is to keep the internal dosimetry data in the background and allow the dosimetrist to make the necessary calculations to be able to decide: (i) whether the bioassay method and monitoring period are appropriate for special monitoring; (ii) whether the method and period will allow the recording level to be detected; (iii) whether previous intakes are contributing to the current measurement; and (iv) whether measurement uncertainties affect the dose assessment. IDA can present further information such as the minimum detectable dose as a function of the time after intake, the derived recording levels for radionuclide mixtures, committed effective dose calculations for data from air monitoring and the ISO 27048 procedure for the assessment of doses based on bioassay measurements. Isodose curves are shown that allow a quick estimate of the committed effective dose when the time of the intake is known.

Conclusions

IDA was successfully validated for functionality according to the requirements of ISO/IEC 17025.

Environmental Dosimetry, Radioactivity Measurement and monitoring

Study of radioactivity in tailings from niobium mining in Araxá city of MG - Brazil

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Introduction

This study evaluates the radioactivity in two samples of niobium tailings collected from the exploration of the iron-niobium alloy in Araxá (MG) region. The research is part of a study aimed at using waste from mineral exploration as raw material for the production of mortar in the building industry. One sample comes from the magnetic separation of the waste, considered as magnetic base, and the other from the flotation separation, considered as barite base.

Methods and results

Initially, the samples were exposed to a GM type detector, which registered a dose of 0.24μSv/h ± 0.02 and 0.33 μSv/h ± 0.06 in barite and magnetite, respectively. Gamma spectrometric analysis using a NaI(Tl) detector registered the presence of ^{214}Bi and ^{208}Tl above the background radiation in both, the barite and magnetite samples. After analyses using a HPGe detector, the barite sample was quantified as 0.24 ± 0.004 and 0.80 ± 0.003 Bq/g and concentrations of 0.17 ± 0.01 and 0.87 ± 0.01 Bq/g of ^{226}Ra and ^{228}Ra, respectively were detected in magnetite. The analyses of the results obtained using the NAA techniques showed uranium concentration of 5 ± 1μg/g and 12± 2μg/g for barite and magnetite, respectively, and thorium concentration of 70 ± 1 and 137± 2μg/g for barite and magnetite.

Conclusions

Although, the occurrence of thorium and uranium is higher in the magnetic separation tailing sample, the activity of ^{226}Ra is higher in the flotation wastes sample. This can be explained by the affinity of ^{226}Ra for barium (W. Dyck and j. R. Jonasson, 2000), which, according to FRX analysis of the wastes (F. S. Mazzaro, 2022), has a much higher BaO content in the barite-based sample than in the magnetite-based sample. According to the results, the tailing does not represent a radioactivity risk to the public exposure dose (CNEN NN 3.01, 2014). Nevertheless, the presence of ^{226}Ra should be investigated , as it is a source of radon gas exhalation, which can be a risk factor in the use of tailings (N. A. O. SCIENCE, 1999).

Design of a low dose rate calibration facility for environmental radiation protection dosimetry

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Introduction

In normal situations, the natural *H**(10) rates measured in France in the environment represent on average a few tens of nSv/h. The calibration or verification of the devices used for these measurements must be performed with *H**(10) rates close to those to be measured. In order to reach a level of uncertainty compatible with the metrological needs. Low background facilities are therefore necessary, i.e. lower by a factor of about 10 compared to the natural background.

Methods and Results

Inspired by an existing Japanese facility and following the main specifications of the ISO FDIS 20956 standard, the LNHB decided to set up a photon beam within a shielded box (1mx1mx1.2m) in which the natural radiative level is reduced by at least a factor of 10. The steps of the installation and the characterization of the photon beams within this shielded box are described. The identification and the spectrometric characterization up to 2 MeV of the components of the natural radiative background allow choosing 25 mm thick lead walls, by means of Monte Carlo calculations. The calculations show a theoretical decrease of almost 2 decades of the background inside the box. The calculation of the theoretical *H**(10) rate led to install two ^{60}Co photon sources of 50 and 300 kBq. The collimator opening gives a beam radius of 15 cm at the reference plane located at 40 cm with a scattered radiation component of about 15% at the measurement point and a profile varying by about 18% between the edge and the center of the beam in terms of dose equivalent. This collimator would be optimized to lower these values. The traceability of the dose equivalent measurements to the French primary reference in terms of air kerma is achieved by calibrating a BERTIN type 6150AD survey meter in a collimated photon beam with higher dose rates.

Conclusions

The results of the modelling are compared to the measurements and the uncertainty budget is evaluated following the ISO 13005 guide method.

Estimation of H*(10) and e using the Hp(d) detectors of the UKHSA personal TLD

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Introduction

UKHSA issues thermoluminescence dosemeters (TLDs) to assess occupational exposures to individuals. Its body TLD features two ^{7}LiF:Mg,Cu,P elements that accurately measure $H_p(10)$ and $H_p(0.07)$ in mixed photon/electron fields with an energy range from a few keV to a few MeV. However, interest has been expressed in employing the device differently, to estimate either $H^*(10)$ or E; potential applications would be in workplaces or locations such as the boundaries of licensed sites, where doses to the public may be of interest. But, because the dosemeter was not designed to measure these quantities, its performance is unknown.

Methods

To address this, the Monte Carlo code MCNP6 has been used to model the $H^*(10)$ and E responses of the TLD for different photon fields in various scenarios of potential operational / public relevance. These calculations are described in the current paper, with the resulting energy-dependent response relationships presented and discussed.

Results

The relative response profiles were found to be fairly flat at energies above a few 10s of keV. However, correction factors were derived to improve the overall response characteristics, given the standard calibration of the UKHSA TLD to $H_p(d, 0°, g: 662\ keV)$. The resulting performances of the dosemeter are then compared against the relevant IEC standard.

Conclusions

The UKHSA personal dosemeter may be used in some situations to provide reasonable estimates of ambient dose equivalent and effective dose. In the wider context, the research also explores the general issues behind using a personal TLD as an environmental dosemeter or to estimate alternative dose quantities, possibilities that could be of significant benefit in circumstances where obtaining results otherwise might be problematic.

Evaluation of adsorbent materials for chemical elements control in acid uranium mine drainage

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Introduction

It is known that acid drainage is an environmental concern in several mining regions, especially after the closure of activity in the mine, both due to the acidity of the water and the high content of metals that are leached.

Methods

The purpose of this work is to study the use of different adsorbent materials – zeolites and modified starch - in contact with water from acid mine drainage basins, from the region of Poços de Caldas/MG - Brazil, with the aim of objective of proposing an alternative for the treatment of this water, aiming to reduce the concentration of chemical elements of interest, with emphasis on manganese (Mn), iron (Fe) and aluminum (Al). Controlling acidity in water is essential to remove uranium from it, making it suitable for release into the environment. For this work, the adsorbent materials were characterized by X-ray diffraction (XRD) and X-ray fluorescence (XRF). They were then contact with water obtained from basins formed by acid drainage in the deactivated uranium mine. After contact for 24 hours pH measurements were taken, and the waters were characterized using the Inductively Coupled Plasma Optical Emission spectroscopy (ICP-OES) and Atomic Absorption Spectroscopy (AAS).

Results

It was observed that the natural adsorbent material (zeolite) completely removed the Fe element from the water, in addition to having demonstrated better Al adsorption performance than the other material tested. Promising adsorption results for Mn were not obtained.

Conclusions

The removal of elements by adsorption made it possible to increase the pH of the water, favoring the associated use of techniques for the selective removal of uranium, in the process of remediation of the contaminated environment.

Implementation of numerical method based on Artificial Intelligence for Identifying Behavioral Patterns in Dosimetry Measurements

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Introduction

This contribution is developed through collaboration between the Department of Physics at the University of Cordoba (UCO) and the Ionizing Radiation Dosimetry Unit into the Energetic, Environmental and Technological Research Center (CIEMAT) in Spain. The main objective of this work is to implement unsupervised artificial intelligence (AI) algorithms methods in order to find behavior patter in both thermoluminiscence (TL) glow curves and gamma spectra measurements of germanium detector.

Methods

Several algorithms methods, in order to identifies clusters of data points, based on their proximity to each other and their density within the dataset (DBSCAN algorithms) and/or AutoEncoders, that are an artificial neural networks that learns to compress and then reconstruct data. These AI methods are widely used because have shown high capability for managing a large volume of data that are implemented in the following two areas:

1. TL glow curves obtain from dosimetry services and TL material characterization and analysis laboratories.

2. Gamma spectra of environmental samples measurements of Cinderella Germanium detector, measured in the particle station of Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) placed in Portugal, (PTP53).

Results

Finally, an automated tool, developed in Python codes based on AI, is implemented that takes experimental data, learns from it, and is capable of classifying these measurements to clusters, without the need for prior technical supervision.

Conclusions

So that, this work presents an automated quality control system capable of grouping measurements without prior supervision and of differentiating y analyzing the intrinsic information of the TL curve and gamma spectra themselves.

How to select a dosimeter?

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Introduction

This work proposes a new TLD selection method. When analyzing the TLD 100 dosimeter, due to small size and ease of "cracking", the range of use must be considered in selection, as an internal crack means that light resulting from radiation interactions with the dosimeter is not transferred to the TLD Dosimeter reader proportionally and must be discarded.

Methods

142 TLD-100 crystals were irradiated with a dose of 5 Gy and evanescence time of 15 hours. The spectra of the crystals were obtained individually in Victoreen model 2800 reader. The irradiation was repeated three times, using a styrene plate, which has 288 TLD-100 irradiation positions with space for 72 seeds (Figure 1). The error of the CNC, the equipment used to manufacture the irradiation plate, is of the order of 0.1%. Only the peak range of iodine-125 irradiation was chosen, formed in the temperature range of 100°C and 200°C.

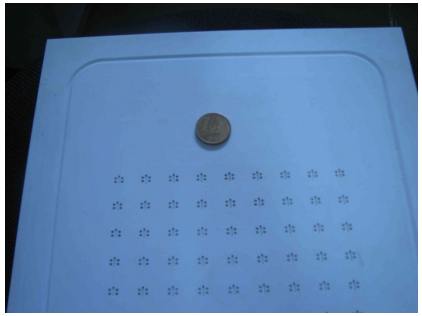

Figure 1 – Styrene plate used to irradiate the crystals

Source: ZEITUNI, C.A, 2005

Results

Dosimeters that simultaneously presented a maximum of 15% of standard deviation and 15% of deviation from the mean were considered acceptable. The values of 15% were arbitrarily chosen, just to guarantee a pre-selection of the crystals to minimize the number of crystals to be used, guaranteeing the use of the considered best of lot acquired by the Institute. The dosimeters that were within the acceptable range's uncertainty values were placed in a plastic box, separating them individually for tracking.

Conclusions

The proposed methodology using a cutting parameter and an automatic reader, such as the Harshaw 5500, the pre-selection of crystals can be reduced to just over 4 measurements of 1 hour each. And considering the thermal "burning" time of the crystal, plus its irradiation, the complete measurement takes just over four working days.

Detector-specific separation of spectral components from repetitive measurements in environmental radiation monitoring

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Introduction

Gamma-ray spectrometers for environmental radiation monitoring routinely record short-duration spectra. Under normal conditions, these spectra are the sum of a constant background plus photo-peaks from natural gamma-ray emitters, their resulting bremsstrahlung and Compton scattering radiation. For each monitor, the constant background is specific to the monitor components and their geometry, the detector crystal type and size, and the composition of the soil and of the surroundings. On the other hand, the spectrum of each natural emitter also depends on the aspects above, but also has a variable intensity owing to the varying Radon emanations.

Methods

In this context, for each spectrum we measure the counts in a set of regions of interest (ROIs) that characterize the intensity of natural emitters. Then, for each channel, the counts in each ROI constitute the coefficients of an equation, where the unknowns are the spectra of the natural emitters and of the constant background. After repeated measurements, we can construct an overdetermined system of equations that is solvable as a non-negative least-squares problem.

Results

As a result of the least-squares minimization we obtain the separate spectra of the constant background and of the most relevant natural gamma-ray emitters.

Conclusions

This method allows to separate the components contributing to the spectra measured by each monitor, without need of dedicated simulations that would be too specific and unpractical owing to the variety of hardware and sites in the detection network. The resulting spectra can be used to improve the characterization of each monitor and to improve capability to detect radiation of artificial origin, which will stand out from the recurrent components.

Analysis of radon progeny presence in LSC vials for their re-utilization depending on the vial's material

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Introduction

Liquid scintillation counting (LSC) is an effective and efficient method for radionuclides measurement. LSC is an analytical tool suitable to be applied in analysis with low levels of radiation. Hence, this technique is frequently used in the measurement of natural series radionuclides, environment monitoring and studying the rate of processes in the environment. This measuring method uses vials as containers to encapsulate the water samples that contain the radionuclides. In case of cleaning the vials to re-use them, due to the low levels of radiation that are involved in environmental measurements, some aspects, as the material of the container, may influence the accuracy of the following LSC measurements. The samples analyzed in this work are vials that used to contain water samples with radon, which is a natural radionuclide. The work focusses on characterizing and quantifying the possible differences arising if either plastic vials and plastic vials coated with Teflon are rinsed for cleaning them and re-used for new radon water measurements.

Methods

To validate re-using LSC vials after their first measurement, the existence of radionuclides in each type of material, after emptying and rinsing the containers, is quantified. This evaluation assesses the presence of radon progeny, performing for that a measuring process by using a gamma spectrometry iodide detector.

Results

This work presents the counting results for each type of container material and evaluates the convenience of re-using the vials after their first use. For this, the number of rinsing steps, together with an estimation of the radon concentrations that will be acceptable to be measured in further tests, are discussed.

Conclusions

Considering the radon loss quantified for each type of material, together with their different costs, the most suitable material, depending on the conditions of the measurement, can be chosen.

Studying the viability of using gamma spectrometry detectors to monitor in real time the presence of ^{234}Th in the environment in presence of variable natural radioactivity

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Introduction

The Gamma Spectrometry Surveillance Network of Catalonia consists of different types of scintillation gamma spectrometry detectors for the continuous and real-time automatic measurement of environmental radiation. The network has a total of 36 monitors registering spectra every 10 minutes: 24 direct measurement monitors (13 $LaBr_3$(Ce), 6 SrI_2(Eu) and 5 NaI(Tl) detectors), 10 particulate filter monitors (9 $LaBr_3$ (Ce) detectors and 1 SrI_2(Eu)) and 2 river water monitors. A study for the viability of detecting ^{234}Th in the environment has been performed. While ^{137}Cs is one of the main indicators in a nuclear disaster, ^{234}Th is a main indicator of NORM (Naturally Occurring Radioactive Materials) contamination outside controlled areas such uranium mines or uranium processing plants. Being able to monitor this isotope in real time would allow to implement surveillance plans in these locations.

Methods

For this study a 2"x2" $LaBr_3$(Ce) and a 2"x2" SrI_2(Eu) detectors were used for laboratory measurements. Moreover, one station composed by two 2"x2" $LaBr_3$(Ce) shielded detectors (one pointing up and other pointing down) in direct measuring configuration was used for field measurements. A self-developed method, based in the spectral regions of interest analysis, for the automatic and real-time quantification of the activity concentration of artificial and NORM isotopes has been applied. The activity concentrations uncertainties, as well as the corresponding detection limits, were calculated applying the ISO-11929 standard.

Results

The method achieves the subtraction of the variable natural contribution, making it possible to quantify ^{234}Th when a source of ^{234}Th is placed next to the detector, remaining in a zero-activity concentration when there is no presence of this isotope.

Conclusions

The results confirm the viability of using the spectral regions of interest analysis based method to detect presence of NORM isotopes which have a similar behavior as the artificial radioisotopes in the environment.

Natural radioactivity in the rocks of the main quarries in Belo Horizonte- MG, Brazil

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Introduction

The radioactive decay series of uranium (^{238}U) and thorium (^{232}Th), the main element responsible for natural radiation exposure is radon (Rn) and its progeny, corresponding to 42% of the total dose that humans receive annually. The great concern about Rn and its progeny is due they are the major cause of lung cancer in non-smokers. The knowledge of Rn concentrations in rocks is of great importance for taking prophylactic measures, such as reducing exposure time at that site in indoor and/or outdoor environments. Belo Horizonte has a predominance of archean rocks that make up the Belo Horizonte Complex and supracrustial sequences of paleoproterozoic age of the Minas Supergroup. The main objective was to know the concentrations of the main radionuclides of natural origin by two analytical methods.

Methods

The city of Belo Horizonte has thirty-six quarries. Thus, four of these quarries that were deactivated were selected to be studied in this work, which are, Lagoinha, Pompeia, Prado Lopes and Engenho Nogueira. Two Methods were used to determinate U and Th by Neutronic Activation Analysis (NAA) and ^{226}Ra, ^{228}Ra and ^{40}K using Gamma spectrometry of solid samples. The samples were prepared as following: first they were pulverized and packed in 1kg sample holders and then the secular equilibrium time of 30 days was awaited.

Results

The Neutronic Activation Analysis results were, for ^{238}U ($\mu g.g^{-1}$): Lagoinha 3 ± 1; Pompeia: 3 ± 1; Prado Lopes (A): 2 ± 1; Prado Lopes (B): 2 ± 1; Prado Lopes (C): 4 ± 1; Engenho Nogueira: 4 ±. According to the reference organization UNSCEAR, the median for ^{40}K, ^{238}U and ^{232}Th are, respectively, 400, 35, and 30 Bq kg^{-1}. The Activity concentration ($Bg.kg^{-1}$) of ^{226}Ra, ^{228}Ra and ^{40}K were: Lagoinha 30.3, 81.8 and 1166.8; Pompeia 33.3, 36.9 and 715.4; Prado Lopes (A) 18.2 171.1 and 1149.7; Prado Lopes (B) 26.5, 114.8 and 1192.3; Prado Lopes (C) 26.9, 101.4 and 997.4; Engenho Nogueira 82, 91.2 and 1400.6, respectively for each sample.nIn this way, all the results of ^{40}K (analyzed by gamma spectrometry) and ^{238}U and ^{232}Th (analyzed by NAA), are above the limit established by UNSCEAR. The results of ^{238}U for each type of rock obtained by NAA were not consistent with those of gamma spectrometry, indicating the existence of a radioactive imbalance. The results of ^{232}Th for NAA indicate coherence with the results of gamma spectrometry, confirming the expected for radioactive balance. Studies are being conducted to better assess the real imbalance between Uranium and its decay products. The observed imbalance is usually due to geochemical causes that occur in the geological history of the environment.

Conclusions

This work achieved, through the method of analysis by Spectrometry Gamma and by NAA, the distribution of natural radionuclides in the rocks of different outcrops of Belo Horizonte, which were used as quarries in the years beginnings of construction of the age of Belo Horizonte. The high values are due to igneous rocks of the granite type that directly influenced the concentration of primordial nuclides analyzed in this study as seen in the literature previously studied. Were admitted then because of the granite paving used on those streets. The conclusion still depends on carrying out studies on more samples and on petrographic studies of rocks from quarries and rocks. The information obtained will contribute to the composition of a radiometric database environment in Belo Horizonte.

Radon exhalation in different granulometries of granites from Belo Horizonte- Brazil

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Introduction

UNSCEAR (2000) estimates that the annual average effective dose received by the world population is 2.40 mSv, from Rn and its decay products being the most important human exposure from natural sources. The World Health Organization (WHO) recommends that member countries implement national mapping programs to determine areas prone to an increased risk of radon exposure, preferably through geological and geographically based studies. One factors that must be analyzed in the study of Rn is the exhalation factor related to the granulometry of the source. Thus, the present work aims to study the different granulometries of outcropping rocks in regions of natural radiometric anomalies in the city of Belo Horizonte.

Methods

The samples were selected from a gamma-spectrometric survey carried out by a BGO detector, RS-230. Where was noted a radiometric anomalies (variations above 400 CPS) five groups of granites rock samples were collected from the region for study in a closed circuit at the Natural Radioactivity Laboratory (LRN) of the Nuclear Technology Development Center (CDTN). According to national and international recommendations and the main risk protocols, such as UNSCEAR (2000) and EPA (2009), radon exhalation is being studied through radon concentration with AlphaGuard (AG), an ionization chamber detector. The rock samples were crushed and pulverized in different granulometries, these being 350#, 16#, 4#. Each sample remained in closed circuit for 3 days and ran 3 times, in mode: 10min/flow. The samples were named according to the place of withdrawal. The radon exhalation was calculated by

Results

The preliminary results first showed a limitation of the method for granulometries below 350#, this, because the air flow passing through the tube pushes the sample column, reducing the passage of air at the ends. Despite this, the authors report the results (Table 1) of rocks from one location (PPD – from Bahia Street, a well-known street in the center of the city, where several people pass each day) are higher than samples collected on quarries.

Sample	Sample	Granulometry	Radon concentration (Bq/m^3)	Rn exhalation ($Bqs^{-1}m^{-2}$)
Bahia Street (Group A)	1A	Powder (350#)	1490,24	0,00349
	2A	Gravel (16#)	9380,89	0,00063
	3A	Sand (4#)	6548,83	0,00088
Prado Lopes Quarry (Group B)	1B	Powder (350#)	447,22	0,00105
	3B	Gravel (16#)	731,77	0,00010
	4B	Sand (4#)	1602,22	0,00011
Lagoinha Quarry (Group C)	1C	Powder (350#)	231,5	0,00054
	3C	Gravel (16#)	808,5	0,00011
	4C	Sand (4#)	810,5	0,00005

Table 1: Results

Conclusions

The first results were able to indicate the best way to make a closed circuit of radon exhalation in different granulometries. So far, the results have been as expected: finer granulometries tend to exhale more radon. Other parameters will be analyzed such as the chemical composition of uranium and thorium of the sampled rocks. It is also expected to assemble a map of the internal dose of radon, considering the inhalation of this gas and its progeny, and finally, to confirm that some anomalies are in fact due to local geology or if they come from human action in the paving of the streets.

Investigation of dietary supplements composition using kayzero neutron activation analysis at the Training Reactor VR-1

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Introduction

Low-power nuclear reactors provide useful research techniques that can be utilized for monitoring the natural environment and investigation of environmental, biological, and geological samples, historical items, and archaeological artefacts. For the study of sample composition, impurities, and trace elements compositions, the radioanalytical technique called neutron activation analysis (NAA) can be employed.

Methods

In recent years, the comparative method of NAA has been successfully employed at the Training Reactor VR-1 of the Czech Technical University in Prague to investigate the composition of various historical and geological samples as well as medicinal pills. The next step in the development and utilization of NAA at the VR-1 reactor includes the implementation of kayzero neutron activation analysis (k_0-NAA), which will further expand the experimental capabilities of the reactor. Therefore, this contribution focuses on the study of dietary supplements composition using k_0-NAA. The analysis encompasses the dietary supplement pills of different brands available on the market. All pills were irradiated together with the gold ultimate etalons (Cd ratio method) in the vertical channel of the VR-1 reactor at the nominal power (80 W), and neutron field characteristics were measured using several activation monitors.

Results

By employing k_0-NAA, the amount of Zn, Mg, Ca, and K in the investigated pills was successfully determined, and the obtained results are well consistent with the values declared by the producers. Additionally, the amount of Na, which is typically presented in pill filler, was also measured. Selected results obtained through k_0-NAA were subsequently validated using the comparative method of NAA.

Conclusions

The k_0-NAA was utilized for the first time at the Training Reactor VR-1. The results obtained using the k_0-NAA method are promising and show clearly that the low-power Training Reactor VR-1 is an excellent tool for the NAA experiments. The k_0-NAA has great potential for multi-elemental quantitative analysis, and it will be crucial for future analysis of e.g., environmental samples and objects of cultural heritage at the VR-1 reactor.

Evaluation of Radiological Risks in Negative Ion Healthcare Products Containing Naturally Occurring Radioactive Materials

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As with other life forms, humans are continually exposed to ionizing radiation from natural radionuclides, including from terrestrial media, building materials, water, air and food. The study investigates commercially available negative ion healthcare products, 55 samples of body patches, and negative ion sanitary pads investigated in this study. Evaluations are made using gamma-ray spectroscopy and Geant4 Monte Carlo simulations. Observed to contain naturally occurring radioactive material (NORM), evaluations are made of the radiological risk arising from the use of these as items of everyday wear. Organ doses from these were simulated using the MIRD5 mathematical female phantom, with the incorporation of dose conversion factors (DCFs). At 65 ± 13, 273 ± 34, and 211 ± 31 Bq, for ^{238}U, ^{232}Th, and ^{40}K respectively, item code S21 was found to possess the greatest activity, while item code S34 was shown to have the least activity, at 3 ± 0.7 and 08 ± 3 Bq, and again for ^{238}U and ^{232}Th, respectively. Sample code S37 recorded least activity, at 18 ± 4 Bq, for ^{40}K. Wearing these particular products results in an annual effective dose of 0.35 mSv/y, assuming they are worn continuously for 24 hours a day. Despite this, the effective dose incurred from their usage remains below the annual public limit of 1 mSv set by the International Atomic Energy Agency (IAEA). However, it is important to note that with potential for external radiation exposure, prolonged use of such consumer products may raise concerns and lead to unnecessary radiation exposure.

Monitoring Natural Radioactivity in Groundwater: The Protocol Applied in The Metropolitan Region of Belo Horizonte, Brazil

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Introduction

Radionuclides from uranium and thorium series are commonly found in groundwater of regions characterized by a granitic-gneiss basement, such as the Metropolitan Region of Belo Horizonte. This study aims to develop a comprehensive protocol for evaluating the radioactive element distribution in groundwater – U_{total}, ^{234}U, ^{238}U, ^{232}Th, ^{226}Ra, ^{222}Rn, gross α and gross β – in accordance with the Brazilian Consolidation Ordinance No.5/2017.

Methods

Physicochemical parameters in-situ were measured by Ultrameter. Inductively Coupled Plasma Mass Spectrometry determined uranium and thorium concentrations. The activity concentrations were determined using Alpha Spectrometry for ^{234}U, ^{238}U and ^{234}U/^{238}U ratio; Radon emanation with RAD7 for ^{226}Ra; RAD7 for ^{222}Rn; and Gas Flow Proportional Counter for gross α and gross β, respectively.

Results

Hardness and Total Dissolved Solid levels were found to meet the regulatory demands. However, two samples showed elevated acidity levels beyond the recommended limits. The uranium results suggest stable systems aquifers under normal reduced or oxidized environments, with one exception where a point was identified as a down-dip from forming accumulation. The highest ^{232}Th value was 0.099±3% μg·L^{-1}. The activity concentrations ranged from 6.5±0.7 to 230±4 Bq·L^{-1} for ^{222}Rn; 2.0·10^{-2}±3.9·10^{-2} to 6.0·10^{-2}±3.9·10^{-2} Bq·L^{-1} for ^{226}Ra; 0.10±0.03 to 0.39±0.04 Bq·L^{-1} for gross β and 0.04±0.03 to 0.54±0.05 Bq·L^{-1} for gross α.

Conclusions

The analysis protocol adopted fulfilled the Brazilian regulatory requirements. The measurement system for ^{226}Ra using ^{222}Rn emanation proved to be effective. It is important to note that two samples exhibited ^{222}Rn activities concentrations exceeding the Euratom limit of 100 Bq·L^{-1}, with only one sample falling below the USEPA limit of 11.1 Bq·L^{-1} for drinking water. This emphasizes the importance of implementing dedicated regulations in Brazil for monitoring levels of radon.

The new deep and surface soil transfer model in the GENII-LIN multipurpose health physics code

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Introduction

Some years ago, we strated developing a multipurpose health physics code in the aim of the to provide a reliable computational framework with capabilities for retrospective and prospective calculations of radiation dose and risk to individuals or populations from radionuclides released to the environment, and from pre-existing environmental contamination.

The code can handle a large variety of acute and chronic releases to air, deep end surface water, deep and surface soil and pre-existing contamination of soil, surfaces, and environmental media.

Methods

At the very beginning of the development, the nuclide transfer model through soil could handle only exposure to residual contamination from long term activities and from waste form degradation. Short life nuclides were intended absent or at equilibrium with long life parents. In a previous work [1], we introduced a new soil transfer model, that accounted short life nuclide contributions correctly. In the following years the model was significantly developed by increasing the number of soil layers and compartments and by revising both physical and numerical modeling of soil transfer processes [2]. In these years the model has been further enhanced to cover exposure scenarios from terrestrial and animal food ingestion.

Results

The new soil transfer model development is almost complete. The computational module is correctly working and well embedded in the GENII-LIN framework.

Conclusions

The GENII-LIN has acquired new capabilities and a wider number of contamination and exposure scenarios can be effectively studied.

[1] Teodori, F., 2017. A new nuclide transport model in soil in the GENII-LIN health physics code, Radiat. Phys. Chem. 140, 146–149.

[2] Teodori, F. 2020, The latest development and the new extended capabilities of the GENII-LIN soil transfer model, Radiat. Phys. Chem. 174: 108949.

Naturally Occurring Radioactive Materials in Dentures and Crowns: Potential Hazard Evaluation

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Traditionally, acrylic plastic has become the primary material for modern dentures, while porcelain was also commonly used until the 1980s. Manufacturers introduced uranium as an additive to the porcelain powder used in denture production. The purpose was to utilize the fluorescence of uranium to closely imitate the appearance of natural teeth under various lighting conditions, both natural and artificial. Uranium offered an advantage over alternative materials because its fluorescence remained unaffected by the high temperatures required during the production process. According to National Council on Radiation Protection and Measurements (NCRP Report 95), it appears that manufacturers discontinued the practice of incorporating uranium into porcelain dentures around 1990 or thereabouts, due to the radiological risk. This study investigated the concentration of uranium and potassium levels in 20 samples of acrylic resin teeth set that are commercially available. Assessment is made of the radiological risk posed by the use of such products, internal exposure dose being the particular focus. Radiological evaluations are made using High purity germanium (HPGe) spectrometer and IdentiFinder Survey Meter. The study recorded radioactivity levels ranged from 0.18 ± 0.05 to 11.2 ± 1.4, and 2.5 ± 0.4 to 43.2 ± 8.4 Bq/g, for ^{238}U, and ^{40}K respectively. The radioactivity concentration of uranium in these particular samples exceeds the exemption limit at 6 Bq/g, based on the Nuclear Regulatory Commission regulations (2003), 10 CFR 40.13a. Wearing these particular products results in an effective dose of 1.314 mSv/y that exceeds the exemption public limit of 1 mSv/y established by the IAEA-SSG36, assuming they are worn continuously for 24 hours a day. These results are highly recommended for the regulatory bodies for prohibiting these particular products from being used.

Measurement of Natural Radioactivity in Soil and Vegetation Samples from Farming Lands and Estimation of their Health Effects

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The present work aims to give an insight about the natural radioactivity levels in farming soil and vegetation in addition to their effect on human health. The investigative study was conducted on one of the farms and presented the natural radioactivity level (Ra-226) during the routine screening of soil and groundwater in farms. This study was conducted on soil samples in order to recognize the possible source of any potential elevation, through investigating uranium series disequilibrium. This will explore the possible radionuclides uptake by vegetation samples grown in that soil and to evaluate the possible health risks due to ingestion. The soil samples were oven dried, weighed, and sealed in Marinelli Beakers whereas the vegetation samples included the edible parts only after complete dryness. The water content for each vegetation sample was determined using air-flow drying oven (at 60 C). All the samples were stored and measured after one month to attain secular equilibrium between Ra-226 and its progenies. The determination of gamma-emitting radionuclides in food and samples was performed using high purity germanium (HPGe) gamma spectroscopy (Canberra, USA). The mean activity concentrations for most of the natural radionuclides in the soil samples were within global average (UNSCEAR). Likewise, the mean values for Th-232 and K-40 were comparable to local values. The investigation of the geochemical behavior of U-series between U-238 and its daughter Ra-226 in soil was also presented in this study. The background samples showed activities comparable to the values reported by Al-Sulaiti et al. (2010; 2012) and Ahmad et al. (2019). Their (Ra-226:U-238) ratio indicated slight disequilibrium which can be considered as natural behavior. On the other hand, fertilizer samples had normal activities for Ra-226 and U-238. In the present work, the affinity and radionuclide uptake of the investigated vegetations were studied and reported. This could be extremely useful for efficient use of vegetations as a bioindicator for soil contamination as well as bioremediation agent in case of any soil contamination occurring. Moreover, the hazard indices as well as the annual effective doses (due to natural radioactivity) from soil samples were evaluated and compared to UNSCEAR 2000's global average values. Furthermore, the gamma absorbed dose rate in the farm and the committed effective dose (due to ingestion) for all the investigated radionuclides were determined and compared to the reference levels covered in the IAEA GSR and FAO/WHO. Further investigation is required by conducting detailed biogeochemical studies of U-Series (e.g., Ra-226/Ra-228, Th-232/U-238, Th-230/Ra-226, etc.). Future work on this topic should therefore concentrate on the following areas: a- Plant species uptake differences. b- The effect of calcium and other cations on radium uptake. c- The chemical forms of radium in soil and in plants and the differences in availability for radium isotopes, d- The effect of organic matter in soil on radium availability for plant uptake, e- the effect of soil pH on Ra-226 uptake and f- measurement of the farmer's occupational radiation doses using personal dosimetries.

Thermoluminescence glow curve analysis of $GdAlO_3$:Dy beta induced

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This paper reports thermoluminescence glow curve analysis of dysprosium trivalent ion doped gadolinium aluminate ($LaAlO_3$:Dy^{3+}) beta irradiated. Samples of $GdAlO_3$:Dy^{3+} were characterized by X-ray diffraction (XRD) technique. The $GdAlO_3$:Dy samples were irradiated using a Sr-90/Y-90 source and it showed an intense peaks centered at 155°C with a shoulder peak at higher temperature range (270°C). Three experiment techniques including variable heating rate (VHR), peak shape (PS) method, and computerized glow curve deconvolution (CGCD) technique were employed to determine TL glow curve kinetic parameters. Analysis of the main dosimetric peaks through the techniques mentioned above indicates that activation energies (E) and pre-exponential factor (s) are in the range of 1.4–1.6 eV and 1.12×10^{15}–1.71×10^{16} s^{-1}. Additionally, it is found that the temperature of the glow peaks shifts toward the higher temperatures and the TL intensity decreases as the heating rate increases. Results indicate analysis of the TL glow curve $GdAlO_3$:Dy help to understand as dosimetric material.

Thermally and optically stimulated luminescence of $GdAlO_3:Dy^{3+}$ beta irradiated

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This paper reports experimental results of dysprosium trivalent ion doped gadolinium aluminate ($LaAlO_3:Dy^{3+}$) using thermally stimulated luminescence (TSL) and optically stimulated luminescence (OSL) techniques. Samples of $GdAlO_3:Dy^{3+}$ were irradiated to beta doses, in air, from 1.1 Gy up to 44 Gy and then were analyzed using both TL and OSL techniques to determine their luminescent properties. Luminescent phosphors show an intense thermoluminescent glow curve located at around 155°C being exposed beta radiation effect with a shoulder centered at higher temperature range. Meanwhile, OSL decay curve concists a fast, a medium and a slow component. TL and OSL response as a function beta radiation dose was linear in the studied dose interval (from 1.1 mGy up to 44 Gy). The present results, it is concluded that $GdAlO_3$:Dy show interesting luminescent behavior suitable for beta radiation monitoring.

Dosimetry in **S**pace **A**pplications

Exploring Single Event Effects (SEE) of Protons and Carbon Ions: Bridging Knowledge Gaps and Establishing Benchmarks

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Introduction

Single event effects (SEEs) pose significant challenges to the reliable operation of electronic devices in space and particle accelerator environments. Proton and carbon ions are among the most common energetic particles encountered in these environments and can induce SEEs through their interaction with semiconductor materials. The rate of SEE is typically estimated using the Linear Energy Transfer (LET) concept. However, instead of focusing on LET, which is a deterministic measure, we should use stochastic quantity considering the energy deposited by each individual event. Microdosimetry, which calculates energy loss along each specific tracks, is a better method for predicting microelectronic failures caused by SEEs.

Methods

Our objective was to accurately evaluate the SEEs for both Proton and Carbon Ions. We employed G4SEE, a GEANT4 Monte Carlo user code, to fine-tune various parameters such as target size, physical models, and scoring techniques. A multi-layer pure silicon cylinder with a sensitive volume (SV) was defined to score various quantities.

Results

Through our analysis, we discovered that the thickness of the sensitive volume, significantly impacts the lineal energy spectra. In the case of a 10,000 nm thickness, Protons did not produce secondary particles above 10-15 MeV-cm^2/mg. However, Carbon ions had a higher value of around 30-35 MeV-cm^2/mg, about three times more than Protons.

Conclusions

This study will help fill the data gap regarding SEEs caused by Protons and Carbon ions. It will serve as a benchmark for future research on Carbon ions and their impacts. Moreover, with the installation of a new heavy ions therapy unit at Taiwan, this study will facilitate the testing of electronic components with heavy ions and the development of Standard Operating Procedures (SOPs) for SEE.

Preliminary characterization of shielding materials for space missions

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Introduction

Space exploration has been one of the most ambitious missions of humankind since the 50's decade. Traditionally, chemical propulsion systems have been widely used in space vehicles as the space shuttle, but the development of nuclear fission power systems for space exploration has been of interest to several space agencies as NASA or ROSCOSMOS, which have studied different projects with the aim of using nuclear energy as a propulsion system.

The purpose of this work is to evaluate by Monte Carlo simulations the performance of different basic radiation shielding configurations, materials and thicknesses, to be used in a space vehicle, analyzing the potential ambient equivalent dose received during a space mission. The PHITS (Particle and Heavy Ion Transport code System) code has been used.

Methods

The cosmic radiation that the spacecraft would find on a mission has been studied together with the radiation from the nuclear reactor. Different shielding configurations were simulated to choose the most adequate design. Using lead, polyethylene and iron, the necessary shielding has been evaluated to estimate its required thicknesses, depending on the admissible occupational dose. Each configuration is being simulated in different scenarios.

Results and conclusions

From the simulation results obtained, the performance of different shielding design configurations allows to identify the best one. It could be used as an input to the design of the spacecraft.

Charge Distribution Effects in Active Radiation Shielding

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Introduction

Astronauts who embark on interplanetary space missions will be exposed to harsh radiation environments, resulting in the potential for increased risk of exposure induced death. Shielding highly-energetic, heavy charge particles through passive shielding can create more dangerous secondary particles that present increased risk. For longer duration missions passive shielding is less viable, so another method has been examined: active radiation shielding. Active radiation shielding utilized electromagnetic fields to redirect the radiation around the crew volume. A properly optimized active shielding configuration would add much less mass than the passive shielding approach and lead to greater shielding efficacy on a per unit mass basis. ASPP propagates particles through electromagnetic fields and can be used to estimate particle fluence reduction factors in different structural configuration as well as can be run in CPU or GPU mode, enabling rapid evaluation of candidate active shielding configurations. Due to the assumption in ASPP that the charge is uniform, this leads to inaccuracies in the fluence reduction estimate, and the power required to create the electric field. The purpose of the present study is to model the charge distribution for a specific active shielding configuration.

Methods

The configuration examined is a mixture of 18 positively charged plates and 8 negatively charged rods around the crew volume. The simulation was conducted using COMSOL to generate the charge density and the Levenberg-Marquardt method in python for the fit.

Results

Functional fits were created for a single set of 3 plates and a rod with an assumption of 3-axis symmetry.

Conclusions

The functional fits in the future will be input into ASPP to determine the change between the uniform and nonuniform models. The functional fits match relatively well to the COMSOL simulated data.

Dosimetry in Radiological and Nuclear Emergencies and accidents

Python-based program designed to simulate the effects of nuclear detonations

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Introduction

This paper describes in detail a Python-based program designed to simulate the effects of nuclear detonations anywhere in the world. The user-friendly interface of the program allows users to easily specify various parameters, including the explosive yield and height of burst, providing them with a comprehensive visualization of the resulting effects in a map and an Excel spreadsheet containing all the necessary data.

Methods

The program employs several methods to calculate the prompt effects of a nuclear detonation, including the use of Brode´s equations to determine blast overpressure, as well as a wide range of data from *The Effects of Nuclear Weapons* for the calculation of heat and acute ionizing radiation.

To determine the fallout gamma pattern, the program employs the equations provided by H.G. Norment. These calculations take into account critical factors, including the stabilized cloud properties and the fallout onset time, the fallout arrival time, and additional correction parameters to determine the gamma ray exposure rate.

Results

The accuracy and comprehensiveness of the program make it an invaluable tool for studying and understanding the potential impacts of nuclear detonations. It has practical applications in disaster management and emergency planning, and its educational and research value is undeniable. Moreover, it provides policymakers and researchers with a comprehensive tool to model nuclear detonations accurately.

Conclusions

This program represents a significant contribution to the field of nuclear weapons effects research. Its user-friendly interface, comprehensive feature set, and accurate calculations make it an essential tool for policymakers, researchers, and anyone seeking to understand the potential impacts of nuclear detonations. It is a helpful code that advances on our knowledge and understanding of this critical topic, making it an indispensable tool for the field.

Feasibility study of using earbuds and wireless headphones for retrospective dosimetry

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Introduction

Luminescence dosimetry could be an essential tool in retrospective dosimetry for assessing an absorbed dose after a radiological overexposure. Mobile phone components are useful proxies for measuring the amount of dose an individual has received. Different research groups have extensive experience in characterising different elements of mobile phones (i.e. electronic components, display or touch screen glass) for physical retrospective dosimetry. However, so far these techniques are frequently destructive. This implies that, in case of a dose assessment, the phones can no longer be used, which is a major issue in terms of the acceptance within the population due to the destructive loss of the mobile phone and potential emotional damage. In order to overcome this problem, alternative materials need to be sought and further research is necessary on cheaper electronic devices.

Methods

Earbuds and wireless headphones have become quite popular and are often carried closely to the body (i.e. from commuters in public transports) or may be found in personal bags. These low-budget electronic devices might potentially be better accepted by the general population compared to high-price objects, such as an expensive smartphone. Additionally, these devices neither store any personal data (contacts, notes, documents, etc.) nor personal pictures and can be replaced easily. On the circuit boards of these items, electronic components, such as surface-mounted devices (SMDs), were found and a standardized optically stimulated luminescence (OSL) measurement protocol was applied in this study.

Results and Conclusions

The results of a dose recovery test after x-ray irradiation are presented. Unexpected challenges concerning signal fading of the sampled SMD components are discussed. Generally, these low-budget electronic devices are potentially suitable for dose assessment and an alternative fortuitous retrospective dosimeter.

Investigating luminescence signals of dietary supplements and electronic devices for emergency dosimetry

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Introduction

In case of a large-scale radiation incident (e.g. a nuclear accident or a terrorist attack with a dirty bomb), thousands of people could be exposed to an unknown amount of ionizing radiation. In such a situation there will be a need for a fast method of assessing the absorbed doses in order to implement a triage, i.e. segregation of victims according to the degree of injury and need of immediate treatment. The general public is not equipped with dedicated radiation dose monitors (i.e. personal dosimeters). For that reason, in recent years scientists have been investigating various personal objects and items, as the mobile phones, that are kept closely to a human body, to use them as so-called emergency dosimeters.

Methods

Generally, one of the methods which is used for emergency dosimetry is the luminescence technique, as thermoluminescence (TL) or optically stimulated luminescence (OSL).

One disadvantage of using electronic parts of mobile phones, that the preparation of the samples generally destroys the objects. That is why emergency dosimeters should not be too valuable objects. One group of materials which fulfill this requirement are different types of pharmaceuticals or dietary supplements. The samples may be prepared quickly and the unit value is negligible. Another option might be some parts of electronic devices, such as memory RAMs from laptops (often transported in personal bags) which are less valuable than mobile phones.

Results and Conclusions

The aim of the work was to investigate OSL properties of various dietary supplements, especially these containing magnesium compounds, as well as the electrical parts (resistors) found on the circuit board of a laptop. The measurements of such luminescence properties as reproducibility, dose response, signal stability (fading) were performed. Results indicated that most of the investigated samples show an OSL signal with sufficient intensity for accidental dose estimation.

EURADOS Intercomparison of age-dependent thyroid phantoms for thyroid monitoring in nuclear or radiological emergencies

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Introduction

According to 2020 updated Strategic Research Agenda (SRA) of the European Radiation Dosimetry Group (EURADOS), one of the identified research areas focused on improving the calibration of in vivo monitoring techniques for children, particularly in cases of emergencies. Linking with this challenge, members of the WG7 Task Group on “Internal Dosimetry for Emergency” organized an intercomparison exercise for comparing different age-specific thyroid neck phantoms for in vivo monitoring of ^{131}I in the thyroid, specifically targeting children and adults.

Methods

Before starting the exercise, a technical questionnaire for information gathering and a measurement protocol were agreed. Measurements were carried out with the same germanium detector (BEGe) at the CIEMAT Whole Body Counting Laboratory. Three geometries of measurements were agreed for comparing efficiencies at short (2 cm), medium (10 cm) and long (15 cm) detector-phantom distances. Detection limits were calculated using blank vials. Each participating laboratory was allowed to send technicians to CIEMAT for performing the measurements.

Results and Conclusions

Once the intercomparison started and prior to the commencement of the measurement campaign, the participants submitted the technical questionnaire with specific data about their phantoms and calibration and measurement procedures. After analyzing the information received it was confirmed significant variations in the design of the phantoms. Such differences highlight the necessity of harmonization in this field. Regarding the intercomparison measurements, a comparative study has been conducted on the efficiency values obtained by the participants for each age group in the three defined geometries. The results analyzed revealed significant variability in the efficiency values, particularly at short and medium detector-phantom distances, where discrepancies can reach up to 50%. Upon concluding the exercise and disseminating the results, it will be essential to establish a consensus regarding the design of reference age-dependent thyroid phantoms in order to standardize calibration and measurement procedures for enhanced accuracy and harmonization.

Thyroid monitoring of exposed population at risk of intakes of radioiodine isotopes due to a nuclear or radiological emergency

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Introduction

The main objective of this work is to implement a new methodology in the CIEMAT Whole Body Counter to improve the capabilities for in vivo monitoring of the population internally exposed by intakes of radioiodine isotopes as a consequence of nuclear or radiological emergencies.

Methods

A Broad Energy germanium (BE Ge) detector was calibrated using a family of age-dependent thyroid-neck phantoms that simulate thyroids of 1, 5, 10, 15 year-old children and (male and female) adults, based in ICRP Publication 89 and ANSI 13.44 Standard.

The calibration of the BE Ge detector for all neck phantoms was performed with the same counting geometry, centered under the BE Ge detector and at the same distance of 15 cm. Using same counting parameters allows to compare efficiency curves of thyroid monitoring depending with age. The in vivo measurements with the BE Ge detector allow to identify X rays and gamma emissions between 10 to 1000 keV with a great resolution and to quantify activities of radioiodine isotopes in the thyroid of exposed population.

Results

Calibration curves have been obtained for different sizes of the thyroid, depending with age. This study of counting efficiency using the main energies of the most important radioiodine isotopes result in accurate activity calculations. Detection limits were obtained for each radioiodine isotope, using blank phantoms of each age.

Conclusions

This work presents an improvement in the calibration of the BE Ge detector using age dependent neck-thyroid phantoms for thyroid monitoring of exposed individuals (workers and members of the public), allowing the detection and quantification of incorporated radioiodine isotopes in a nuclear medicine frame or in case of accident of a nuclear reactor.

Comparison of dose measurements using environmental and personal dosimeters in real scenarios to deal with radiological and nuclear emergencies

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Introduction

The assessment of dose rates with environmental dosimeters takes usually much longer than with personal dosimeters. From 2006 to 2010, 25 locations were simultaneously monitored every 2 months with environmental and personal dosimeters in Ciemat. This study compares the results of both types of detectors with the aim to show how personal dosimeters can be used as environmental dosimeters to deal with radiological and nuclear emergencies, when rapid dosimeter processing is essential.

Methods

Simultaneous dose measurements were performed in the period 2006-2010 at 24 environmental and area stations using the two thermoluminescence (TL) dosimetry systems of the Ciemat External Dosimetry Service (EDS), both accredited by ISO 17025 (Romero, A.M, et al., 2016):

- Environmental dosimeters: based on LiF:Mg,Cu,P detectors (model GR-200 from Conqueror electronics), calibrated in terms of $H^*(10)$ and processed in a reader Harshaw 5500, where the response to the ionizing component of secondary cosmic radiation (SCR) was estimated in the IC2014env intercomparison (Dombrowski, H., et al., 2017), and

- Personal dosimeters: based on $Li_2B_4O_7$:Cu and $CaSO_4$:Tm detectors (model UD-802 from Panasonic), calibrated in terms of $H_p(10)$ and processed in a reader Panasonic UD-710.

One of the monitored stations was inside an 11 cm thick lead shield, where the fraction of the ionizing component of secondary cosmic radiation (SCR) is determined (García-Talavera, M., et al., 2007) in this work.

Results

The UD-802 and GR-200 dosimeters showed a similar behavior for all stations, but the SCR response of the UD-802 was significantly lower than GR-200, which markedly affects the free field dose evaluation. Thus, the response of dosimeters to the SCR ionizing component strongly depends on the dosimetry system. Therefore, evaluation of dose response $H^*(10)/H_p(10)$ was made by dose subtraction of the ionizing component of SCR. The final $H_p(10)$ dose values measured with the personal dosimeter were found to be around -13% lower than the $H^*(10)$ dose measured with the environmental dosimeter.

Conclusions

This study provides a way to use your own personal dosimeters as environmental dosimeters, which is essential when large numbers of dosimeters need to be processed in a short time, such as radiological and nuclear emergencies.

Event reconstruction model of Ru-106 release from October 2017 using the HYSPLIT and JRODOS-MATCH models

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Introduction

Accidental and purposeful releases of hazardous substances in populated areas are a significant concern for all people responsible for the security of society. Apart from prognosis and diagnosis of the radiological situation, a necessity arises to create a model based on measurements of the concentration of dangerous substances by the extensive network of sensors that can indicate the probable source term. In October 2017, a European network that monitors atmospheric radioactive contamination measured Ru-106 air concentrations. One of the singularities of the hazardous event was that the location and the release rate of the source were unknown at the time when the first detections were registered. The source's location should be found as soon as possible and accurately.

Methods

HYSPLIT 4.0 used the location of the monitoring stations as input for four types of backward trajectory models to locate possible source terms. Each model applied different vertical motion methods to obtain path lines of traveling air mass and Ru-106. JRODOS calculations were performed using the in-built MATCH model feature for the forward concentration atmospheric dispersion model. It was found that the model accurately predicts the build-up of concentration levels along the plume path lines.

Results and Conclusions

After performing these simulations, it was found that European Russia is the most probable source term region. The MATCH model simulation was run separately for five possible source terms, with 106-Ru release with 280TBq activity on 25-26th September 2017. Subsequently, the source term parameters were analyzed: emission level and date of unexpected event occurrence. The values from the performance tests showed the possible location of the source term to be the MAYAK Nuclear Facility in Russia. The results and conclusions obtained coincide with those of the publications and reports on the 106Ru event topic published by IRSN.

Dosimetry of Radon Exposures

Radiometric study in indoor environments: radon and gamma monitoring

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Introduction

Environmental ionizing radiation comes from natural and artificial sources. Among both, radon and its progeny stand out due its correlation with lung cancer. Therefore, the World Health Organization (WHO) encourages its monitoring. The ideal radon concentration is up to 100 Bq/m^3, and levels above 300 Bq/m^3 are considered worrying. This work aims to present the results already obtained from a radiometric study in internal environments of Belo Horizonte city in Brazil.

Methods

According to WHO recommendations, alpha radiation from radon was measured using long-term solid state passive detectors with CR-39 resin. The detectors were exposed in indoor environments for approximately three months. Ambient dose (h*(10)) from gamma radiation was estimate with LiF TLDs: Mg, Cu, P (MCP). The study points were chosen based on the spatial distribution of the sites. Resident people voluntarily adhered to a Radon Indoor Monitoring Campaign.

Results

For the monitoring campaign, 500 detectors were delivered. Radon concentration (Bq/m^3) and the respective percentage of results ranged from 0-50 (60,8%), 50-100 (20,7%), 100-200 (12,5%), 200-300 (3,1%) and above 300 (2,9%). The resulting risk level (high, medium or low) was communicated to the house residents. The suggested action to mitigate radon was mainly to improve the ventilation in the environment and investigate the radon source. Among the selected sites, 300 of them were also monitored from gamma radiation in order to estimate h*(10). The results ranged from 0.7 to 3 mSv/year; these results match with literature ambient dose values.

Conclusions

Regarding radon concentration in the studied sites, 18.5% were above 100 Bq/m^3, requiring attention and mitigation measures to be taken. Furthermore, monitoring made possible to identify situations with high and intermediate risk. It is crucial to continue this work, especially in countries such as Brazil, where radon culture isn't established yet.

Radon chamber operation and sensitivity analysis of air radon detectors

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Introduction

The exposure to radon gas of workers and the population in enclosures is regulated by European directive 2013/59/EURATOM, recently transposed into Spanish legislation (Real Decreto 1029/2022). Likewise, these regulations have been reinforced by the protection measures against radon detailed in the Technical Building Code (CTE, Real Decreto 732/2019).

Legislative requirements and the increase in demand for radon measurements in air have prompted the setting up of laboratories and accredited entities for this purpose. To guarantee the quality and reliability of the results offered, it is essential that these entities participate in intercomparison campaigns for the detectors used, as required by the UNE-EN ISO/IEC17025 standard. In this context, through funding from the GENERALITAT VALENCIANA (IDIFEDER/2021/047), a 1 m3 radon chamber has been purchased to verify radon measurement techniques in air. One of the main objectives of this research is the implementation of the radon chamber while the second objective is to analyze the sensitivity of radon detectors in air.

Methods

Radon chamber tightness has been analyzed according to ISO 11665-13, the operation of the ventilation by the chamber solenoid valves and radon removal system by activated carbon. An intern intercomparison of integrating detectors was conducted at ISIRYM, UPV for detectors analysis though the participation of four groups. Likewise, the sensitivity of continuous detectors to changes in radon concentrations in air has been analyzed by comparing with reference.

Results

The correct operation of the camera has been validated according to experimental results: tightness, ventilation, and radon removal. The detectors are in good agreement with each other when compared to the radon concentration measured by the reference detector. Those detectors that operate with a low temporal resolution may tend to smooth out the fast variation of the concentration.

Conclusions

This investigation has allowed the implementation of the camera, verifying the correct operation of its systems. In addition, the sensitivity of the detectors is analyzed, obtaining a good response to the concentrations exposed.

The Effect of Radon Concentration on Integrated Exposure for Passive Detectors Measurements

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Introduction

The UKHSA passive radon diffusion detectors are integrated exposure devices, i.e. the measurement results are the average of all recorded radon concentrations. However, the unwarranted misconception within radon professionals exists that different concentrations of radon impacts the outcome of measurements for such devices. A peculiar case is the intercomparison exercise at which detectors are exposed to high radon concentrations. Therefore, the comment of participants is that integrated exposure at thousands of Bq/m^3 over days is not the same as at tens of Bq/m^3 over months. In this study, passive detectors were exposed to a variety of radon sources to evaluate the effect of radon concentration on the final integrated exposure results.

Methods

Groups of 15 detectors were exposed to various radon activities to reach equal integrated exposure of 37kBqhm^{-3}. Low, medium and high radon activities were provided by sources of a granite stones, flow through set-up or watch dial all monitored with Alphaguard or ATMOS 12DPX systems. All instruments were calibrated against a primary source traceable to CHUV, Switzerland. Images of etched detectors were recorded and analysed using UKHSA system. Statistical analysis was performed using Data Analysis Tools (Microsoft Excel 365).

Results

The results, based on statistical group analysis, show that there was virtually no difference in the exposure results taken at various radon concentrations. Similar results were obtained for groups with exposures to two different radon concentrations or at different equilibrium factors. The only exception was for a very low radon concentration, but that may be due to the limitation of both active and passive devices reaching their low level of detection limit.

Conclusions

The experimental evidence proved that passive diffusion radon detectors are truly integrated exposure measurement devices. Therefore, it opposes any claims that radon concentration can impact on its final, recorded measurement values.

Evaluation of thoron concentration in an underground gallery of a labor building

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Introduction

The main source of radiation exposure is ^{222}Rn (half-life, $t_{1/2}$, ≈ 3.83d), a member of the ^{238}U decay series; ^{219}Rn ($t^{1/2}$ ≈3.92s), from ^{235}U decay series; and ^{220}Rn ($t^{1/2}$ ≈54.5s), that belongs to the ^{232}Th decay series (hence known as thoron). The importance of the radon study is due to the fact that it is radioactive and it is the second leading cause of lung cancer, according to the World Health Organization (WHO). Because it is a gas, and because it is present in soils and rocks, it tends to accumulate indoors and pose a health risk. A previous study identified the radon concentration of 541.6 Bq/m^3 in an office, located in the basement of a work building, being above the value recommended by the WHO (100 Bq/m^3). The objective of this work was to search for the origin/source of radon in that building, analyzing the thoron in the gallery below it, where there is the presence of earth, uncoated walls, humidity and little air circulation. As thoron is detectable and has a very short half-life, its detection in an environment indicates proximity to the source.

Methodology

The building houses the administrative service and has no radioactive sources. The structure consists of two floors (basement and ground floor) and a gallery with an unbuilt area; the first floor/ground floor of the space has 18 offices and 4 bathrooms; The basement has 8 offices and 2 bathrooms. To perform the measurements, the Electronic Radon Detector (Rad7) DURRIDGE Company Inc. The “sniff” function allows measuring the thoron, tracking and identifying its entry into the environment. The equipment was installed and put into operation in the “sniff” function, in cycles of 5 minutes in each of them. The gallery has 45x3 m, the points chosen were: (4 points) along the gallery, (2) observed cavities, (1) wall with coating, (1) wall without coating, (1) ceiling, (1) floor, and (1) entrance of the gallery.

Results

The measurements in the gallery ranged from 92.5±185 to 5740±927 Bq/m^3 and the BG null. Presenting, thus, points with values considered highand above the recommended.

Conclusion

The evaluation of the concentration of thoron indicates, apparently, the building materials being the main source of radon and thoron,and not the mound of earth, as could be hypothesized. Therefore, mitigating measures in order to preserve the health of workers may be adopted.

Methodology for radon dose assessment in tourist caves

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Introduction

The recent publication of the Royal Decree 1029/2022 on Health Protection against Ionizing Radiation, which entails the adaptation to Spanish regulations of the European Directive 2013/59/Euratom highlights the need to carry out measures to assess the dose due to the presence of radon gas in workplaces, especially in those where the probability of finding doses greater than 6 mSv is probable, such as tourist caves, spas and/or underground places where work activities are carried out.

Methods

In our Laboratory of Environmental Radioactivity (LaRUC) we have developed a methodology to carry out said value based on two technologies: The first using CR-39 detectors and the second by continuous measurement of the radon concentration. In the commination that is presented, they are developed in detail, showing the advantages and disadvantages of both. Likewise, data of its application to specific cases are provided.

Results

The results presented are the estimation of dose in a tourist cave using both methodologies. Although the average radon concentration over the exposure period obtained using both methodologies is equivalent, the dose calculation considering the worker's duration of stay in the cave may exhibit noteworthy variations.

Conclusions

The conclusions of the study suggest that precise evaluation of the dose received from radon requires controlling and monitoring the time and duration of workers' stay.

Study of the use of wallpaper to mitigate radon exhalation from building materials

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Introduction

Radon gas is known to exhale from the ground and can enter and accumulate inside buildings. This is why many countries set radon limit concentrations and propose mitigation techniques to prevent radon from entering buildings. However, radon can also exhale from building materials, e.g. cement, bricks, marble or tiles. Although radon from building materials is usually minor, and with good ventilation concentrations are kept low, there may be cases where this is insufficient. Therefore, this work has investigated how to prevent radon from passing from building materials into indoor spaces using wallpaper.

Methods

The diffusion coefficient of various types of wallpaper with different characteristics has been calculated. All wallpapers have a grammage of 170-180 g/cm^2, but the materials from which they are made vary. Thicknesses are between 176 and 471 µm. The reduction in radon concentration achieved by using wallpaper has also been measured. Configurations of 1 and 2 layers of wallpaper have been tested, as well as adding an aluminium film between the two layers of wallpaper.

Results

For two of the wallpapers, good results are obtained with a single layer of material, the radon reduction being more than 90% and the diffusion coefficient around 10^{-11} m^2/s. When a second layer of material is applied to these wallpapers, the radon reduction increases to more than 98% and the diffusion coefficient decreases to 10^{-12} m^2/s. However, for the other two wallpapers, with one layer, radon reductions between 9 and 20% are obtained and the diffusion coefficient has a value between $8{\cdot}10^{-11}$ and $1{\cdot}10$-10^{-10} m^2/s. When a second layer of paper is applied, the radon reduction increases slightly (between 10 and 32%), but the diffusion coefficient remains the same. By adding an aluminium foil between the two layers of wallpaper, for all materials, a radon reduction of more than 98% and a diffusion coefficient of around 10^{-12} m^2/s is obtained, achieving a considerable improvement in the results for two materials.

Conclusions

These results show that wallpapers have the potential to act as radon barriers to protect indoor spaces from radon exhalation from building materials by using these products.

Study of radon progeny inhalation protection by using facial masks

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Introduction

Radon exposure is the second-leading environmental cause of lung cancer, therefore finding ways to reduce the radon inhalation dose is a priority objective. Inhalation dose is calculated considering two contributions, the radon gas on the one hand and its progeny on the other. This paper studies the effectiveness of face masks (surgical masks, FFP2 and FFP3) to reduce the contribution of radon descendants that pass into the respiratory tract and thus reduce associated inhalation dos**es.**

Methods

To analyze the radon filtering potential of these masks, a continuous radon monitor has been used to estimate the radon concentration and the Potential Alpha Energy Concentration with and without facial masks. The data registered by this monitor, together with an error minimization algorithm developed in Matlab®, allow the Equilibrium Equivalent Concentration to be calculated.

Results

These results make it possible to compare the inhalation doses received by a person not wearing or wearing different types of masks, obtaining a dose reduction of 64% for surgical masks compared to the study without mask, a reduction of 71% for FFP2 and 72% for FFP3 masks.

Conclusions

This important dose reduction based on the use of a facial mask, offers an important measure of easy and economical protection of all those people who are exposed to radon.

Computational **D**osimetry and **P**hantoms

Computational Personal Dosimetry: Status and New Applications

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Introduction

Large uncertainties still exist in individual monitoring of workers exposed to external ionizing radiation. In an attempt of reinventing personal dosimetry by leveraging the most recent evolutions in computer simulations, artificial intelligence and computer vision, the PODIUM project was set up.

Methods

The objective was to improve personal dosimetry by an innovative approach: the development of an online dosimetry application based on computer simulations without the use of physical dosemeters. Operational and protection quantities can be calculated based on the use of modern technology such as personal tracking devices, flexible individualized numerical phantoms, machine learning and scanning of geometry set-up.

Results

In PODIUM the methodology was applied and validated for two situations: neutron workplaces and interventional radiology. Thanks to depth cameras and person tracking algorithm, we captured the real movements of exposed workers and transferred this to the calculation application. Several validation and test measurements were performed. Personal doses could be calculated within acceptable simulation times, just based on captured movements of the workers and information of the radiation fields.

Conclusions

After the PODIUM also other applications are being researched, like for extremity doses in nuclear medicine workers. By developing tailored computer vision recognition models, we were already able to track syringes, hands and fingers on camera images with good accuracy. These are translated to computational phantoms, and further transferred into Monte Carlo simulations. As such, the distribution of the doses can be known across the hands. This procedure is also very useful for optimizing the working procedures of the staff. Such ALARA application is also one of the main focus points in yet another application, the decommissioning of nuclear installations. In this presentation, some highlights and novel developments of the different applications will be shown.

Anatomically Predictive Extension, a new realistic extension of partial CT scans of pediatric patients

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Introduction

More than 60% of cancer patients receive radiotherapy treatment. While modern treatments can deliver a localized radiation dose to the tumor, healthy tissues at distance are inevitably exposed to scatter radiation that has been linked to late health effects such as second cancers and cardiovascular disease. Quantifying the radiation dose received by tissues beyond the target is critical for research on such late effects, which help inform current clinical practice. However, the typical radiotherapy planning CT only covers part of the body near the target and the organs of interest for late effects research are not always included. Thus, the aim of this study was to develop a method for extending a partial-body CT scans in order to estimate organ doses.

Methods

Software was developed which takes as input a user-provided partial-body CT scan and associated organ contours. The output is an extended body CT scan with organ structures which we refer to as the Anatomically Predictive Extension (APE). The method uses a library containing images of 359 pediatric patients. Image registration is performed through comparison of the patients' skeletons. The images showing closest similarity are appended to the original CT and a new structure file is written.

To test the APE method, CT scans for three patients from the library were extracted, with a portion removed and then extended using APE. Radiotherapy plans were simulated using Monte Carlo code XVMC onto both the original and APE patients, with the original serving as ground truth.

Results

Three example APE patients were created: (1) head CT for a simulated brain tumor extended to chest; (2) superior chest CT for simulated Hodgkin's lymphoma extended to inferior chest; (3) pelvic CT for Wilms tumor extended to superior chest. In all cases, calculated organ doses showed good agreement between the original and APE patients. The mean relative error calculated for 40 organs was ~6%.

Conclusions

The APE method will be useful for estimating radiation doses to peripheral organs in support of research on late effects following radiotherapy.

Chances and challenges of machine learning in computational radiation dosimetry

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Introduction

Artificial Intelligence (AI) and machine learning (ML) are increasingly used in medicine. In order to establish a solid framework for certification of the AI performance criteria of explainability, robustness and uncertainty, PTB has started the Metrology for AI in Medicine (M4AIM) program. AI-based methods have been first used for dosimetry in nuclear medicine [1]. Applications of ML in external radiotherapy [2] [3] have recently also been reported.

Methods

Two of the three M4AIM projects related to dosimetry study the potential of ML-augmented Monte Carlo radiation transport and track structure codes to accelerate simulations and the associated uncertainties. The use of ML is expected to improve the limitations of previously reported analytical approaches [4,5]. Faster simulations can be achieved by ML relations between primary particle interactions and the final pattern of energy transfer points including interactions of electrons. On the fly ML of variance reduction strategies is also investigated.

Results

In parallel to exploring suitable architectures of neural networks, the work has focused on producing comprehensive reference data (as a prerequisite for training and testing) and on developing tools for assessing their quality. As a byproduct, a number of publications of simulation studies with biased and faulty results have been identified.

Conclusions

ML-augmented Monte Carlo simulations appear to have a high potential for detailed simulations in real-time. Obtaining reliable reference data by simulations remains one of the big challenges for the fruition of this enormous potential.

Acknowledgement

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References

[1] Arabi H, Zaidi H. European J Hybrid Imaging 2020;4:17.

[2] Götz TI et al., Phys Med Biol 2020;65:035007.

[3] Mentzel F et al. Cancers 2023;15:2137.

[4] Alexander F et al. Phys Med Biol 2015;60:9145–56.

[5] Ramos-Méndez J et al. Phys Med Biol 2018;63:235015.

Simulation of radon progeny deposition in human airway applying Computational Fluid Dynamic

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Introduction

Exposure to radon and its progeny is a significant risk factor for human health, being the second largest responsible for lung cancer incidence worldwide, according to the World Health Organization. Radon progeny are solid particles of positive electrical charge emitters, predominantly from alpha radiation. A fraction of these products attaches to aerosols present in the air, and another fraction remains free or agglomerated. When inhaled, these particles deposit in the respiratory tract, constituting a dose source of ionizing radiation.

Methods

To better understand how these particles deposit in the respiratory tract, we developed a computational model of the upper airway - based on anthropometric measurements taken from the reconstruction in three dimensions of a computed tomography and information from the literature - and then simulated particle deposition using Computational Fluid Dynamics (CFD) methods in *Ansys R18.0 Academic software,* which allowed us to simulate the deposition of not attached and attached particles with diameters of 1×10^{-7} and 2.5×10^{-5} cm, respectively.

Results

The air speed behavior on the airway walls in the three meshes of different refinements showed similar results. The injected particles velocity at the entrance was 3.1 m/s. The maximum velocity of the attached and not attached particles, in the three meshes, ranged from 5.1 to 5.3×10^{2} m/s and from 4.8 to 5.3×10^{2} m/s, respectively. As expected, speed of air flow increased as it passed through regions of decreasing diameter, leading to higher turbulence in bifurcations and other meeting points. The speed increases according to the air path in the geometry; this phenomenon was due to the Venturi effect. The places with the highest speed or turbulence are the most conducive for particles to deposit, as well as meeting/curve points.

Conclusions

The results suggest that CFD is a promising tool for to simulating radon decay product deposition in the respiratory tract. Further studies using this technique could deepen our understanding on the mechanisms of radon-related lung cancer.

Age-dependent dose assessment for ^{177}Lu and ^{161}Tb in pediatric Targeted Radiopharmaceutical Therapy

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Introduction

Targeted Radiopharmaceutical Therapy (TRT) is one of the most intensively developing directions of nuclear medicine. TRT has a limited therapeutic role in the management of pediatric cancers, however, it is envisaged that it will play a major role in the future. The main aim of this work was to evaluate the impact of the pediatric patients´ dependent anatomy on their organ absorbed doses, considering ^{177}Lu and ^{161}Tb.

Methods

Dosimetry assessment was performed through Monte Carlo (MC) simulations using the PENEOLOPE program, with the pediatric ICRP reference computational phantoms, namely 10 and 15 years female phantoms. After a successful MC validation, the dose assessment was performed by calculating organ S-values for ^{177}Lu and ^{161}Tb.

Results

The dosimetric assessment of ^{177}Lu and ^{161}Tb highlights the potential benefit of ^{161}Tb. The β- S-value of ^{161}Tb was slightly superior comparatively to ^{177}Lu, in self and cross-irradiations assessment, due to a higher β- energy of ^{161}Tb. The Internal Conversion (IC) and Auger electrons present higher dosimetric efficacy in ^{161}Tb, showing at the same time an higher self-irradiation and lower cross-irradiation, with respect to ^{177}Lu. In cross-irradiation, the γ photons show an higher S-value because of their high mean free path. The dosimetric effect of the emitted particle types on the different organs reflected the S-value variability observed in this work. The S-values were mainly higher for the 10y phantom, presumably due to different morphology and lower distance between organs, with respect to the 15y phantom.

Conclusions

The absorbed dose calculations demonstrate that ^{161}Tb has a good dosimetric performance and is a promising candidate for TRT leading to a better therapeutic outcome, which reinforces results from other studies that compared ^{161}Tb with ^{177}Lu. In addition, the presence of a lower energy gamma emission for ^{161}Tb with respect to ^{177}Lu, could be attractive for imaging purposes in pediatric patients.

Data Science Pipeline for Development of Patient-Specific Phantoms and S-value Calculation in Radiopharmaceutical Therapy

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Introduction

In recent years Radiopharmaceutical Therapy (RPT) received renewed and increased attention, demonstrating high accuracy to target tumour cells with minimal toxicity to healthy tissue. The aim of this work was to develop a Patient-Specific Phantom (PSP) and perform dosimetric calculations by comparing results with the ICRP reference adult female phantom (ICRP-AF).

Methods

Clinical SPECT/CT images representing a female patient treated with ^{177}Lu-DOTATATE were acquired and segmented using state-of-the-art specialized software, i.e. Pinnacle TPS and 3DSlicer. In addition, a pipeline was developed using Python, employing data science libraries/modules. This pipeline analyzed image data and produced a voxel phantom file for Monte Carlo (MC) dosimetric calculations using the PENELOPE2018 program. Absorbed Fractions (AF), Specific AF (SAFs) and organ S-values were calculated in PSP and ICRP-AF, and were then compared considering liver as the source organ, and self- and cross-irradiation. The target organs considered were the lungs, breast glandular tissue, esophagus, spleen, stomach wall, kidneys, pancreas and urinary bladder wall.

Results

^{177}Lu emissions were considered for the comparison, i.e. beta, internal conversion and Auger electrons and gamma and X-ray photons. The mean relative differences between both phantoms were 508 and 770% for AF and SAF, respectively. Mean relative difference between the S-values obtained for both phantoms was 250%, ranging from 21 to 1982%, respectively.

Conclusions

As expected, the differences obtained between the two phantoms reflect the unequal patient individual anatomy, e.g. PSP has much higher liver mass than ICRP-AF. This ongoing PSP is underway to improve the accuracy of image-based and personalized dosimetry calculations in organs and other substructures of the body, also taking into account real radiopharmaceutical distribution. This is essential to minimize healthy tissues radiotoxicity and improve therapeutic outcome.

Fetal dose assessment and the Taiwanese pregnancy phantom validation for occupational exposure in nuclear medicine

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Introduction

In nuclear medicine, the critical workers who may receive the most exposure are radiologists. For pregnant workers, possible radiation doses and risks to their fetus are important concerns. In ICRP 103, it is recommended that the employer should ensure that additional dose to the fetus do not exceed approximately 1 mSv for the remainder of the pregnancy. Generally, the radiation dose received by the fetus cannot be directly measured. The purpose of this study is to confirm the accuracy and applicability of using the Taiwanese pregnancy phantoms, and to establish a standardized process for fetal dose assessment.

Methods

This study measures the uterine dose (fetal dose) of the Taiwanese pregnancy phantoms and compared it with the dose from MCNP simulation, including mono-energy photon (^{137}Cs) and X-ray (standard quality RQR 8). Besides, pregnant phantoms were placed at a common working distance in the department of nuclear medicine in hospital. The workplace environmental dose rates and the one-month doses results from the abdominal surface, uterine region, general personnel doses were collected and analyzed.

Results

The measured results from TLD are similar to simulation and the uterine dose conversion coefficients (DCCs) showed that the average error of different gestation periods was 13.18%. In early pregnancy, uterine dose at 3-months pregnancy was the highest of the four gestation period (<1, 3, 6, 9 months) and the uterine DCCs of the MCNP simulation is slightly higher than the uterine DCCs calculated by the experimental measurement.

Conclusions

The 3-months pregnancy can be used as a representative gestation period for conservative calculation of fetal dose. An abdominal badge is recommended for a pregnant worker to wear on the abdominal surface in early (such as 3-months) pregnancy for a period and to use uterine DCCs to estimate the fetal dose in order to determine whether follow-up workers needed to adjust their work environment during pregnancy.

Investigation of the correlation between technical parameters in pediatric digital radiographic images utilizing the CDRAD Contrast-Detail Phantom

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Introduction

The quality of a radiographic image plays a crucial role in visualizing and distinguishing nearby structures. Technical factors such as spatial resolution, contrast resolution, linear transfer modulation, and noise all contribute to image quality. The assessment of spatial resolution and contrast resolution in digital radiology can be achieved using the CDRAD contrast-detail phantom. This phantom consists of an acrylic plate containing holes with diameters ranging from 0.3 to 8mm ± 0.03mm, with each line associated with a column of holes of the same size, but with varying depths. Children are more sensitive to radiation with a longer life expectancy. Conducting this study in a pediatric environment makes it possible to examine the relationships between different techniques due to the large variation in size among children. This variation leads to a wide range of voltage and current settings. However, it is important to note that these variations can potentially increase the radiation dose to the patient without necessarily improving image quality. Therefore, the primary objective of this study is to evaluate the correlation between technical factors and image quality in pediatric protocols for digital chest radiographs.

Methods

Measurements were performed at a large pediatric hospital in Curitiba, Brazil, using a dedicated pediatric X-ray machine, the Shimadzu Flexavision. The standardized pediatric chest protocol was used for all exposures. Voltage variations from 60 to 85kVp and current settings from 0.5 to 10mAs were used. To simulate the thickness of a pediatric patient, five polymethylmethacrylate (PMMA) plates were used, each 1 cm thick. The CDRAD phantom was positioned in three different positions for each technique: below, in the middle, and above the PMMA plates. Measurements were consistently conducted on the same equipment, with three repetitions performed for each technique. Subsequently, specific software was used to detect the number of visible points in the obtained image, enabling the creation of a contrast-detail curve. This curve serves as a visual representation of the relationship between contrast and spatial resolution for the given techniques.

Results

The reproducibility test was conducted to calculate the errors in the parameters of the Inverter Image Quality Figure (IQFInv) and the percentage of detectability of holes, associated with voltage variations and current-time product. The calculation involved multiplying the standard deviation by the Student's coefficient, assuming a Gaussian distribution. This allowed an assessment of the consistency and reliability of the contrast curve measurements.

Conclusions

The obtained results allowed analyzing the relationship between the technical factors employed in digital radiology for pediatric chest radiography protocols. By evaluating the contrast curve measurements, the study aimed to obtain information about how variations in voltage and current-time product affect image quality. This analysis helps to assess the impact of different technical parameters on the visibility of structures and the overall image quality on pediatric chest radiographs.

How Intensities can be calibrated by theory

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Introduction

Dosimetry evaluates the efficiency and accuracy of an image, pattern, detector, X-ray optic, and source. Often it indicates improvement of one fluorescer or image detection system on its own, but preferably compared with another, a standard optic, or a reference standard. This is where high accuracy measurements can be extremely insightful, where reference standards can be extremely insightful, and where theoretical predictions can be extremely insightful. In principle, these can make a naïve theory computation using e.g. FFAST into a cutting edge and major contribution to the literature. Current status and prospects will be discussed.

Methods

Key theoretical databases, currently used widely, include FFAST, especially away from an edge, and other similar and older databases. The challenge of information content near edges, or in definition resolution and efficiency, through arbitrary samples or phantoms, requires: well-prepared reference samples including metal foils to compare with phantoms or unknowns; careful reference measurements; and theoretical predictions perhaps using GRASP2K, TD-DFT, FDMX and FEFF theoretical approaches.

Results

FFAST continues to generate a reliable baseline with reliable uncertainties for all materials thus far investigated. However, the challenges look to and require something more, depending upon the theoretical and experimental question and calibration, including accurate measurement, definition and propagation of uncertainties, packages including GRASP2K, FEFF and FDMX. A range of these issues are being published in the new encyclopaedia, Handbuch: X-ray Absorption Spectroscopy and related techniques: The international Tables for Crystallography Volume I.

Conclusions

The Future is developing rapidly. Standards of publications in associated Journals including Radiation Physics and Chemistry is increasing, in parallel with the increasing Impact Factor. Guidelines for strengthening good work for publication are important across all fields. Theoretical and experimental challenges continue and there is much excitement for the progress to be reported in the future.

Biodosimetry, **R**adiobiology and **R**etrospective **D**osimetry

Irradiation of NK-92-CD-16 cells using a clinical linear electron accelerator as a method to reduce their proliferative potential keeping their cytotoxic capacity against multiple myeloma

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Introduction

NK-92-CD16 cells exhibit high basal cytotoxicity against other tumour cells, specially in combination with therapeutic antibodies, but their tumourigenic nature prevents them from being administered directly to patients due to the danger of their unlimited proliferation. This work investigates the exposure of NK-92-CD16 cells to ionising radiation from clinac as a method of reducing their proliferative potential, as well as the variation of their cytotoxic capacity against multiple myeloma (MM) cells.

Methods

Every cell sample was set inside a water phantom. Simulation was performed on a GE High Speed CT, and dose plan (2 opposed 10FFF beams from a Varian TB HD120) was calculated with AccurosXB in Eclipse. Five assays varing initial cell density and dose were addressed:

Assay	Cells by T25 flask	Absorbed Dose (Gy)
1	810^6 (no resuspension)	10
2	810^6	10
3	210^6	10
4	410^6	10
5	810^6	15

After exposure, cells were put back into culture. In parallel, a no exposed control sample was also cultured, all at the same initial cell density. Using microscopy and flow cytometry, the following parameters were analysed over the following days: cell density, cell viability and CD16 protein expression level. The NK-92-CD16 cells were also incubated with MM cells to assess their cytotoxic capacity after irradiation.

Results

Assay 1 showed a density decrease in the next 48h, and then cell density started to grow. Assays 2, 3, 4 were resuspended, did not show repopulation, and viability results were similar to each other (100% dead cells in 300h). In addition, their cytotoxic capacity decreased less than 20% from the control cells. In assay 5, a faster density drop than the former assays was observed as well as a loss of cytotoxicity over 50% compared to the control sample.

Conclusions

Irradiation of resuspended NK-92-CD-16 with 10 Gy in a clinac is effective in removing its proliferative potential while keeping at least 80% of the cytotoxic capacity on MM cells compared to the control sample.

Development of multi-wavelength optically stimulated luminescence reader

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Introduction

The new multi-wavelength optically stimulated luminescence(OSL) reader is developed for research on retrospective dosimetry. IR (850 nm), green (520 nm), blue (445 nm), and UVA (405 nm) are used as stimulating light sources, and they are designed to be replaceable.

Methods

To verify OSL reader performance, background dose measurements and performance tests of each light source are performed. The OSL signals are measured for standard quartz and chip resistance and the SAR(Single Aliquot Regeneration) method is used to obtain the absorbed dose.

Results

Significant OSL signal is found in GSL, BSL, and UV-OSL, and background level signal is measured in IRSL. In the case of standard quartz, the absorbed dose of GSL and UV-OSL is relatively accurate, but the absorbed dose of BSL is smaller than the original irradiated radiation. In the case of chip resistance, a very small value of the UV-OSL was detected, making it difficult to obtain the absorbed dose from the dose response curve.

Conclusions

A new OSL reader that can measure OSL signal using various stimulating light sources is developed. UV-OSL is also able to obtain absorbed dose through SAR method like GSL and BSL. Unlike the fading characteristics of other light sources, UVA is expected to be suitable for retrospective dosimetry because it takes a relatively long time to decrease. In order to use UV-OSL for retrospective dosimetry practically, detailed characteristic evaluation is required through additional experiments.

Luminescence Characteristics of Fortified Nutrient Salts for Application in Retrospective Dosimetry

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Introduction

Extensive research was conducted on various emergency dosimetry techniques for triage, prompted by the potential risks of radiological and nuclear incidents that may expose the general public to radiation. The objective of this study was to examine the feasibility of utilizing fortified nutrient salts for retrospective dosimetry within the dose range associated with triage scenarios. Our investigation focused on the optically stimulated luminescence (OSL) signal present in the samples, including the limit of detection, dose response, reproducibility and fading. The optimal temperature and light intensity for conducting OSL measurements were explored.

Methods

Four distinct types of sea salts produced by Solana Pag Croatia, were subjected of examination. The sample set encompassed fine sea salt and three distinct fortified sea salts: one with a 50% reduction in sodium compared to regular salt, one fortified with potassium and one fortified with calcium and magnesium. The measurements were carried out utilizing a Riso TL/OSL DA-20 reader. OSL was performed using blue LED with continuous-wave stimulation.

Results

Significant radiation-induced thermoluminescence(TL) and OSL signals were observed. The dose response analysis demonstrated a linear relationship, indicating consistent and predictable behavior in response to varying radiation doses. The ratios of the measured doses to the given doses were comperable.

Conclusions

Examination revealed that the samples did not exhibit significant natural TL and OSL signals. However, upon exposure to radiation, the investigated samples displayed robust TL and OSL signals, indicating their responsiveness to radiation-induced stimulation. A fading test was conducted over 14 days, revealing negligible fading effects. While the results of the SAR OSL dose recovery test displayed minor deviations within the acceptable range of error. Consequently, the examined salt samples hold potential for utilization as emergency dosimeters.

Genotoxic Effects of ablative treatment with I131 determined through the analysis of dicentrics in peripheral blood lymphocytes. Can it influence the clinical management of patients with differentiated thyroid carcinoma?

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Introduction

Internal radiotherapy with I131 in patients with differentiated thyroid carcinoma is used after thyroidectomy to achieve ablation of residual thyroid tissue and to treat recurrences or metastases. The total dose to the tumor depends on the administered therapeutic activity and the retention of I131. This study aims to identify the variables that can best predict the whole-body absorbed dose by estimating, through biological dosimetry, the exposure dose in the bone marrow (BM) using the dicentric chromosome determination method in peripheral blood lymphocytes.

Methods

Prospective study includes 47 patients who received ablative doses of I131treated after hormonal suppression or TSHrh administration. Biological dosimetry was performed by dicentric chromosomes analysis pre and post-treatment, determining the exposure dose to the BM. These data were compared with the administered I131 activity, renal function and glomerular filtration rate, body mass index and TSH. Currently, the dose is estimated in parallel, measuring the patient's exposure rate in reproducible geometric conditions in the first days after taking the treatment.

Results

Statistically significant appearance of dicentrics after treatment was demonstrated. With an average administered activity of 126mCi, the absorbed dose in BM was 0.27Gy, with no significant correlation between both parameters. Variables with the strongest correlation were BMI (inverse) and creatinine detected in patients with renal failure.

Conclusions

The radiation related genotoxic effects on BM due to high dose regimens of I131, intended for ablative purposes, does not imply a significant risk of myelotoxicity in "de novo" treated patients, with no significant differences between the ranges of activities used in clinical practice, but it would be advisable to adjust the administered activities according to them to avoid significant medullar damage, especially in patients who may require repeated treatments.

New radiobiology detector using scintillating arrays

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The radiobiological experiments show that in order to make an adequate correspondance between the biological effects and the dosimetric measurements it is necessary to have a high resolution dose map (~ microns). Having this in mind a project is being developed at Laboratório de Instrumentação e Física Experimental de Partículas (LIP), in Portugal, that aims at the development of a detector to allow for the performance of radiobiology studies with high spatial resolution, real time dose measurements and tissue equivalence using scintillating optical fibres.

To ensure the minimum of dead space in the detector and offset in the measurements in each fibre, it is necessary that the optical fibres are juxtaposed and parallel to each other. In order to have a well built array a specialized tool was designed. After the assembly of the optical fibre array the assembly quality has to be checked. To this end, confocal microscopy with fluorescence, was used to get a 3D image of the optical fibre array. The results show that the optical fibre relative positions are within the tolerances that were calculated, nevertheless the relative standard deviation also shows there is room for improvement when it comes to have a more consistent optical fibre positioning. The experimental measurements were performed using in a 50 kV X-ray tube and a electrometer used as a charge integrator. The detector went through an equalization process performed to correct the signal read in each of the detector's channels. The results show that the measurements reproducible to within 3%. The detector is still to be tested with protons. These measurements will be performed in the near future at HollandPTC.

Radiation **S**hielding and **D**osimetry at **A**ccelerators

Evaluating the Performance of a New Plastic Scintillator Detector for Small Field Dosimetry of Photon Beams in Conventional Linear Accelerators

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Introduction

The presented study aimed to evaluate the performance of a new plastic scintillator detector developed by BluePhysics (BluePhysics model 10, BP10) for small field dosimetry of photon beams in conventional linacs, following the recommendations of IAEA TRS-483 code of practice.

Methods

The scintillator sensor consists of a core material of fluorescent doped polystyrene and a cladding material of acrylic. This sensor is coupled to a plastic optical fiber that transports the radiation signal to the acquisition unit. Cerenkov effect is taken into account by placing an identical second fiber next to the transport plastic optical fiber. To evaluate the performance of the scintillator detector, the Cerenkov calibration coefficients were obtained and the monitor unit linearity and dose rate constancy tests were performed at energies 6MV and 6FFF in two linacs of two Iberian institutions, one in Coimbra (Portugal) and the other in Seville (Spain). Output factors (OF), beam profiles, and percent depth doses (PDD) of square fields (down to 0.5x0.5 cm2), as well as OF of elongated fields (one size, X or Y, fixed at 1cm and the other in the range 2-40cm), were also measured using BP10 and other detectors.

Results

Measurements regarding the BP10 characterization confirmed the results presented in a previous study on a MR linac. OF, beam profiles, and PDD measured using BP10 and other detectors agreed for the tested energies in both centers and also comparing to similar published results.

Conclusions

This study shows the suitability of a new plastic scintillator for clinical dosimetry of small square and elongated fields, in conventional linacs. Its exceptional time resolution enables the visualization of a single monitor unit delivered by a linac. Lastly, BP10 detector does not need any small field correction factors for OF determination (down to 0.5x0x5cm^2 fields). This allows for very versatile use within a wide range of clinical photon field sizes.

Radiation shielding for NanoTerasu – a compact 3 GeV next generation synchrotron radiation facility in Japan

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Introduction

A compact 3 GeV next-generation synchrotron radiation facility, NanoTerasu, is currently constructed at Aobayama New campus of Tohoku University in Miyagi prefecture, Japan. NanoTerasu provides both high-brilliance soft and hard X-rays, generated by insertion devices in the storage ring of 3 GeV electrons. 10 of the 28 planned beamlines have been installed and will be operational from 2024. NanoTerasu is the first facility in Japan, designed to exclude most of the experimental hall from radiation-controlled area under the policy that "users can use this facility as much as possible without the license of radiation workers".

Methods

The Monte-Carlo simulation code PHITS[1] was employed in the shielding analysis using a precise 3D geometry based on 2D CAD. The dose behind shields should be calculated for the primary beam and secondary particles following loss of the primary beam. Especially, a gas bremsstrahlung radiation (GB) was simulated based on the interaction between 3 GeV electrons and a gas whose composition was assumed from the measured data for the recent synchrotron facilities. Leakage radiations were also estimated by PHITS that transports X-rays in the beam pipe and experimental hutch from a synchrotron radiation (SR) source calculated by the SPECTRA code. Residual activities were also evaluated by using DCHAIN-SP code.

Results

Radiation leakage originating from primary beam loss, GB and SR was estimated to be minor compared to the regulatory limitation for the radiation-controlled area in NanoTerasu. Residual activities, such as N-13, O-15, and Ar-41 in air, was quite under regulatory limits.

Conclusions

Radiation shielding analysis by using PHITS is effective for the design of NanoTerasu in which most of the experimental area should be under regulatory limits of radiation-controlled area.

References

1. Sato, T. et al. Features of Particle and Heavy Ion Transport code System (PHITS) version 3.02. J Nucl Sci Technol 3131, 1–7 (2018).

Adding a cyclotron-based 5th treatment room to the MedAustron ion therapy center

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Introduction

The MedAustron Radiation Therapy Center plans to expand the existing facility (synchrotron with max 800 MeV protons, as well as max 400 MeV/u carbon ions) with a commercially available cyclotron (230 MeV protons) including a gantry beamline. This will allow optimal use of the accelerator facility - patient capacity for carbon ion therapy will be increased, large volume tumors and pediatric patients can be treated more efficiently in the cyclotron facility due to the higher beam current. In addition, one accelerator can serve as a backup for the other. For the environmental impact assessment, detailed calculations are required for dimensioning the structural radiation protection.

Methods

The calculations for the shielding effect of the concrete surround were made using Monte Carlo simulations. Since the transport calculations of the secondary particles through concrete up to 3.5 m thick are very computationally intensive, variance reduction methods were applied.

Results

It follows from the operating principle of a therapy cyclotron that only protons with the maximum energy of 230 MeV are extracted from the machine, which are then reduced to the requested energies by means of a “degrader system”. For the shielding calculations, it follows that the entire energy spectrum must be considered based on the planned patient mix. High energies produce more dose from secondary radiation around the patient, lower energies near the cyclotron.

Conclusions

The calculated ambient dose maps show that at the locations accessible to the general population the dose is in any case below 0.1 mSv/a, and in monitored areas 0.6 mSv/a. A safety factor of 10 was applied to the legal limits of 1 mSv/a and 6 mSv/a, respectively, to account for possible uncertainties or unknown quantities in the simulations.

Shielding and activation studies for a concrete-iron-concrete sandwich structure wall in the CMUH proton therapy facility

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Introduction

The proton therapy facility at China Medical University Hospital (CMUH) is equipped with a Varian 250-MeV cyclotron and two rotating gantry treatment rooms, which is currently under construction and is expected to start beam tests soon. In various parts of the facility, ordinary concrete with a thickness of 1.7-4.7 m was employed for bulk shielding. At some locations, additional iron or lead plates were used to shield local hotspots. Among them, a concrete-iron-concrete (0.9-0.2-0.9 m) sandwich structure wall of 2-m thickness is of the most interest because it is the partition wall between two adjoining treatment rooms, aiming to reduce the radiation level in the other room while a treatment room is operating. In a proton therapy facility, neutrons generally dominate the radiation field outside the shielding. High atomic number materials are effective in the attenuation of photons; however, their interactions with neutrons are complex, which largely depends on the neutron energies. In addition to the induced radioactivity in concrete, the embedded iron layer could be another source of neutron-induced radioactive nuclei, as mentioned in some literature that the reinforcement bars in structural concrete could contribute considerably to the overall activation. These issues motivated us to perform a detailed analysis on the shielding performance and activation susceptibility of the concrete-iron-concrete sandwich structure wall.

Methods

The FLUKA Monte Carlo code was employed to simulate the radiation field induced by the assumed beam loss scenarios in the CMUH proton therapy facility. Accordingly, the radiation attenuation and induced radioactivity in the three-layer (concrete-iron-concrete) shielding wall were evaluated by comparing with a reference case in which no iron layer is in the 2-m concrete wall.

Results

Compared with a 2-m thick concrete wall, the benefit of the concrete-iron-concrete sandwich structure wall in shielding performance is only marginal, further reducing the transmitted dose rates by roughly a factor of two for radiation produced during proton bombardment of a water phantom. By contrast, the same three-layer shielding wall can further reduce the transmitted dose rates by roughly a factor of 20 for 18-MV photon irradiation in a medical LINAC facility. Regarding the induced radioactivity, this study focused on long-lived radionuclides induced in concrete and iron by neutrons, primarily seven radionuclides of ^{22}Na, ^{54}Mn, ^{55}Fe, ^{60}Co, ^{134}Cs, ^{152}Eu, and ^{154}Eu in concrete and three radionuclides of ^{54}Mn, ^{55}Fe and ^{60}Co in iron. The results showed that the specific activities of ^{54}Mn, ^{55}Fe and ^{60}Co in the iron layer were indeed higher than those in the neighboring concrete by a factor of 250, 80, and 5, respectively. More results and detailed discussion will be presented at the conference.

Conclusions

The shielding performance and activation susceptibility of the concrete-iron-concrete sandwich structure wall in the CMUH proton therapy facility was investigated in an integrated manner through FLUKA Monte Carlo simulations. The results of this study may provide supplemental and useful information for those interested in related topics.

Novel pulsed high-energy photon reference field for dosemeter testing

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Introduction

Radiation protection at modern accelerator facilities used in science, technology and medicine shall meet the legal and normative requirements. However, dosimetric measurements at such facilities are performed using area dosemeters whose suitability for these high-energy and pulsed radiation fields cannot be tested according to the state of the art in science and technology due to the lack of suitable reference fields. Currently, type testing is usually performed up to energies of 7 MeV and in continuous radiation fields. The performance of radiation protection dosemeters, however, can be compromised by pulsed and high-energy radiation fields.

Methods

As part of a nationally funded project, one such pulsed high-energy photon reference field was established constituting increased ambient dose rate levels such as those occurring behind (insufficient) shielding of medical and research accelerator facilities. A commercial medical linear accelerator at PTB was chosen as radiation source. The shielding comprises a 2 m-thick wall of a concrete composition not especially made for radiation shielding.

Results

The ambient dose rates behind the shielding (with respect to the beam direction) were measured using a secondary standard ionization chamber to achieve traceability to the corresponding national standards. Energy spectra behind the wall were obtained for photons by measurements and unfolding techniques. Additionally, Monte Carlo simulations of the energy spectra and dose distributions behind the wall were performed at various distances along and besides the beam axis.

Conclusions

The reference field can be used for the characterization of radiation protection dosemeters. First results show over-responses as well as severe under-responses. The project was funded by the BfS (project no. 3619S22364).

Calibration of the Online Dose Monitoring System at the Free-Electron Laser SwissFEL

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Introduction

The latest large scale research facility of the Paul Scherrer Institute, the free-electron laser SwissFEL, installed in a 740 m long building, consists of four main parts: Injector and electron source, linear accelerator, undulator line and several experimental areas. The facility accelerates electrons to a maximal energy of 5.8 GeV with repetition rates up to 100 Hz. The building is integrated in a regional recreation area with shielding of the accelerator vault dimensioned to tolerate temporary beam losses. An online dose monitoring system capable of shutting down SwissFEL ensures compliance with the legal requirements. Since areas adjacent to the accelerator vault are partially accessible to the public, the system measures the neutron dose inside the accelerator vault and calibrates it to the positions outside.

Methods

For the calibration of the system, the shielding configuration of the accelerator vault was divided in ‘recurring areas‘ and ‘special areas’, referred to as shielding classes. For each shielding class, the effectiveness of the shielding was determined using Monte Carlo-methods and a generic beam loss scenario. The results were used to assign adequate alarm thresholds to the approximately 50 survey instruments installed within the accelerator vault. Exceeding an alarm threshold leads to an immediate shutdown of SwissFEL.

Results

The method and its compliance with legal requirements were verified by dedicated measurement campaigns. For this purpose, the primary electron beam was intentionally misdirected to produce losses near the shielding class under investigation and subsequently the dose rates were monitored at positions of interest inside and outside the accelerator vault.

Conclusions

The measurements have shown that the method used and the alarm thresholds are adequate to ensure that the dose levels in accessible areas near the accelerator vault comply with the legal requirements.

Investigation of the neutron radiation field inside the accelerator tunnel during operation of the Swiss Light Source (SLS)

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Introduction

The Swiss Light Source (SLS) is a 2.4 GeV third generation electron accelerator used for the production of synchrotron radiation. It consists of a linear accelerator, a booster and a storage ring providing light for various applications. An upgrade of part of the accelerator complex is foreseen in October 2023 to improve the quality of the light. The upgrade will also include the replacement of the storage ring. The clearance of this material from regulatory control requires information on the beam loss behavior and the radiation fields inside the accelerator tunnel. This work describes the measurements of the neutron radiation fields inside the tunnel and results of this study.

Methods

The measurements inside the accelerator tunnel were performed with commercial neutron dose rate meters suitable for detecting neutrons with high-energy and a pulsed time structure. The measurements were performed at dedicated beam loss points determined by measuring the residual gamma dose rate along the storage ring.

Results

The behavior of the measured dose rates in time implies that they can be divided into three types. These are continuous dose rate, medium intensity spikes and high intensity spikes. Each type of dose rate is related to the specific type of beam loss.

Conclusions

The behavior of the neutron dose rate in different operating modes of the accelerator was investigated. The overall contribution of the different types of beam loss to the integral dose was evaluated.

The analysis of the results shows that most of the material activation (around 95%) is caused by the continuous beam loss.

Dosimetry at low and ultra-high dose rates at FLASHlab@PITZ

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Introduction

The Photon Injector Test facility at DESY in Zeuthen (PITZ) is an electron research accelerator (22 MeV) and provides unique beam parameters regarding delivered dose and dose rate. With a demonstrated average dose rate up to 10^6 Gy/s and peak dose rates up to 10^{11} Gy/s, PITZ is already fully capable of ultra-high dose rate irradiation. Further upgrades are possible. Using reduced beam intensity, also dose rates down to 0.05 Gy/s have been demonstrated. Apart from biological experiments where exact dosimetry is crucial, different detectors have been and are being tested for their limits.

Methods

Proper dosimetry is a challenge for such high dose rate beams available at PITZ. Gafchromic films were characterized to be used as reference dosimetry. Different properties of the Gafchromic films were investigated e.g., dose rate dependency. Cross checks using Alanine and luminescent crystals are planned. A PPC05 ionization chamber is being tested at low and high dose rates.

In air measurements as well as in water measurements in a 30x30x30 cm^3 water phantom were done. Depth dose curves for four different beam optics were measured. All measurements are compared with Monte Carlo simulations using FLUKA.

Results

No dose rate dependency of Gafchromic films up to a maximum dose rate of $7x10^{10}$ Gy/s was shown. Correction factors of the PPC05 ionization chamber for high dose rates are calculated. Monte Carlo simulations and measurements show good agreement for in air as well as in water measurements.

Conclusions

The PITZ accelerator is fully capable of ultra-high dose rate irradiation. Different detectors and their capabilities were tested up to $7x10^{10}$ Gy/s and they can be used as dosimetric tools to build a reference base for future FLASH-RT measurements and detector characterization at PITZ.

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