CHERNE 2018 - 14th Workshop on European Collaboration in Higher Education on Radiological and Nuclear Engineering and Radiation Protection

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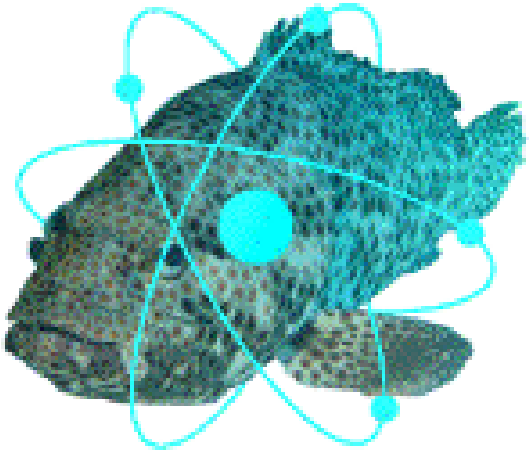

Book of Abstracts

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Global Training In NORM management

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The aim of this one year project is to work towards a sustainable collaboration in education and science between European partners from the Educational CHERNE network, Research oriented European NORM Association (ENA) and developing countries participating in the IAEA NORM Environet. The international activities planned in this project will be embedded in an electronic learning environment that can be expanded and optimised based on the experience in the Erasmus + Partnerschip 'Blended learning in radiation protection and radioecology'in collaboration with CHERNE network and IAEA Environet.
A good practices training school (26-30 November 2018) is organised to educate bachelor, master and PhD students, regarding the management of NORM related sites, exchanging know-how between partners and promoting the interaction of European students and students from developing countries. The training school aims at demonstrating good practices and mapping and discussing problematic NORM sites all over the world and dealing with cases from Angola, Belgium, Brazil, Egypt, Indonesia⋯The illustrated cases will be integrated in the electronic learning platform. In addition, teleconference presentations before and during the training school are set up for two reasons: (1) firstly to prepare the participants for the training activities and stimulate the interaction and efficiency of the real mobility and (2) secondly to give also students and teachers from countries that we cannot support the opportunity to attend and interact in a part of the program (primarily the presentations but also in the round tables).
In April 2018, a workshop was organised for the preparation and testing of the electronic learning environment and in May and October 2018 we will invite guest lectures/explore sites that will provide demonstration cases for the electronic learning environment & training school. The results of the organised workshop and lectures are presented on the Cherne workshop together with a preliminary program of the actual training organised in the fall of 2018. For this training, we allow 20 participants where we aim to have a balance between students UHasselt –students from other CHERNE members and students from outside of Europe (IAEA-Environet).

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English for Nuclear Science Studies as a New Interdisciplinary Hybrid Course

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For all of us non-native speakers to learn English has been a challenge at a certain point in our lives. It is said that chemists, physicists, engineers, lawyers, philologists speak in a different language from the rest of society. The discovery of radioactivity a century ago opened up a new field "nuclear science". Nowadays Nuclear English is the most demanding English not only for specialists but also for society since there is a large, growing, and vital community of people who use the applications of nuclear science to tackle a wide-ranging set of problems in medicine, engineering and other fields of our life.

Probably that was the reason why we wrote a textbook "Nuclear Chemistry: improving professional skills in English"in 2011.
As a branch of chemistry, the activities of nuclear chemists frequently span several traditional areas of chemistry such as organic, analytical, inorganic, and physical chemistry. One term that is frequently associated with nuclear chemistry is that of radiochemistry. The term radiochemistry refers to the chemistry of radioactive substances. All radiochemists are, by definition, nuclear chemists, but not all nuclear chemists are radiochemists. Many nuclear chemists use nonchemical (physical) techniques to study nuclear phenomena, and it is not radiochemistry.
In this book we have tried to be as comprehensive as possible. We have attempted to present nuclear chemistry and the associated applications at a level suitable for an undergraduate student. Our aim was to convey the essence of the ideas and the blend of theory and experiment that characterizes nuclear chemistry. Our hope is that the reader can use this book for an introductory treatment of the subject and can use the end-of-unit references as a guide to more advanced and detailed presentations. A book like this one is in the curious position of being simultaneously "advanced"and "introductory". It is advanced in the sense of building on grammatical, lexical rules and collocations important for non-native speakers of English. At the same time, students are being introduced into the field of Nuclear Chemistry.
We wrote in the preface "We really hope this book as a quick refresher course will be also helpful to professionals working within the realm of nuclear science who are non-native English speakers. This would include not only nuclear chemists, either trained or in training but also technologists, engineers, physicists, basic scientists". Seven years have passed after the publishing of this book and today we have the strong opinion to enhance the content of the book towards "Nuclear Science" . In view of the fact that present-day students are digital by nature we are going to create blending online and onsite a hybrid course instead of printed book only.
The main thing is that we are looking for the enthusiasts among the representatives of nuclear engineering for cooperation on the creation of such a course.

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Radiological Technology and Radiological Physics Programmes at the FNSPE CTU Prague

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Degree Programmes Radiological Technology and Radiological Physics, taught at the Department of Dosimetry and Application of Ionizing Radiation at the Faculty of Nuclear Sciences and Physical Engineering of the CTU in Prague, are within the boundaries of both physics and medicine. As such, they must be accredited by the National Accreditation Bureau for Higher Education, but they are also approved by the Ministry of Health. They are therefore recognized as health care professions. All three levels of education in these fields, bachelor, master and doctoral, cover three subject areas: radiodiagnostics, nuclear medicine, and radiotherapy.
The radiological technologist's (the bachelor level) main concern is radiation protection in performing routine programme procedures (including dosimetric measurements) and especially in assisting the medical physicists. In practice. This means performing operation and long-term stability tests of medical instruments using ionizing radiation, preparing local radiological standards, determining local diagnostic reference levels, participation in introducing new diagnostic methods, calculations of doses received by patients, etc.
The master´s degree course in Radiological Physics gives to the graduate´s more complex competences, especially to perform the profession of radiological physicist. The curriculum includes several medical subjects and on-the-job experience and training in medical centres. The students familiarise themselves in detail with the use of ionizing radiation for diagnostic and therapeutic in health care, the physical and technological principles of modern imaging techniques in medicine and advanced radiotherapy using radionuclides, accelerators and other specific equipment, and medical disciplines such as anatomy, physiology, human body biology, biochemistry and pharmacology.
The graduates are ready to apply for positions of medical physicists in departments of radiology, nuclear medicine, and radiotherapy or in the departments of medical physics and/or radiation protection in hospitals. They closely collaborate with the medical staff in administering diagnostic and

therapeutic procedures, namely in the physical and technical aspects. The course programme trains students also for positions focusing on nuclear safety and radiation protection.
The Doctoral programme and topics of doctoral theses are closely related to the master programme in Radiological Physics, giving a more in-depth insight into special areas of radiological physics. The coursework part of the programme comprises new methods in radiodiagnostics, radiotherapy and nuclear medicine, microdosimetry, radiobiology and the use of Monte Carlo method in radiological physics.
The implementation of these educational programmes requires close co-operation with medical institutions, both in teaching and in providing practical training. It is not in the faculty's capabilities to own and operate costly medical instrumentation such as medical accelerators, CT scanners, etc. However, the basic equipment of the faculty has recently been expanded by a unique simulator, the only one in the Czech Republic. It is a virtual environment of a radiotherapy treatment room. Through captivating 3D views and life size visualizations, it offers an excellent platform for supplying radiation therapy training to students.
The programmes are designed in accordance with and comply with the standards and recommendations of the European Federation of Organisations for Medical Physics.

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Information and analytical support of the chemical component for nuclear knowledge portal BelNET

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This study deals with the initiative undertaken at the Belarusian State University (BSU) related to nuclear knowledge portal.
The International Atomic Energy Agency (IAEA) pays close attention to the problems of nuclear knowledge management. Every developed country with its own nuclear industry has to create and maintain a national portal of nuclear knowledge integrated into the global system of nuclear knowledge management. Nowadays under the auspices of the IAEA numerous national and international portals of nuclear knowledge are created in Europe, Asia, Africa and America. BSU is currently developing an educational and research web portal nuclear knowledge BelNET (Belarusian Nuclear Education and Training Portal). In the future we believe that this specialized electronic portal will be a national portal of nuclear knowledge.
Currently the concept of the portal BelNET, its structure and taxonomy according to IAEA requirements have been developed. Software of portal BelNET is free and based on electronic system eLab of client-server architecture. The mission of the portal is the formation of favorable information, sociocultural, business and educational environments for sustainable development of nuclear energy in Belarus. The main basic principles of the Portal are transparency and continuous improvement. The content of portal is an absolutely unique product including information in nuclear physics, radiochemistry, radiation protection, water chemical regime (WCR) but it constantly requires updates and maintenance. The motto of portal is "Easy to use –easy to update".
The bilingual content for the Portal on the basis of the analysis of the water treatment process organization and WCR of the primary and second circuits at VVER NPPs including the Belarusian NPP has been developed. The water treatment schemes for NPPs are considered, various WCR of the primary and second circuits are analyzed. The original articles, books, IAEA materials, etc. in two languages (Russian and English) have been selected to be uploaded to the Portal. The glossary of the portal is supplemented with terms of nuclear energy. The prepared materials will be useful for students and teachers in the educational process as well as for employees of the nuclear industry. Now we have no doubt that the Portal is a necessary component in the present-day educational environment. The implementation of specified web technologies will serve to improve the quality of education, the motivation of learners, and economy of academic hours along with deeper mastering a subject.

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Radon exposure and exhalation awareness on Civil Engineering teaching

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Radon is a natural radioactive gas derived from geologic materials and abundant in granitic areas. Indoor environment radon contamination can be induced by either outdoor air entering dwellings and radon contamination of water but the ionizing radiation from naturally occurring radioactive materials (NORM) present in building materials, should not be underestimated. Civil engineering students were challenged to understand the complexity of dealing with radon either from the material chosen not only for new dwelling construction but also when rehabilitation is concerned. Accurate understanding where radon is generated and how to avoid its dissemination on indoor environment is very important in the classification of the radon source strength in building materials. To obtain these goals students were trained on the basics of nuclear physics and radon specific problems and tested various building materials, coatings and finishing materials. From the experience gathered trough several master dissertations awareness was gained as how to avoid materials that are more prone to exhalate radon but also those that are more efficient in sealing radon exaltation which is most significant on building rehabilitation. The subject is particularly pertinent in geographic regions where natural radioactivity and radon levels are higher than normal, as it is the case of the geological setting of the broader region where the University of Beira Interior is settled. Besides, being able to raise awareness of future professionals on the building industry we were able to start an index of building materials characterized by either the typical radon exhalation levels or permeability, that presented some surprises in between the already expected results. In the same time, we were able to determine that some silicone-based sealants, usually recommended for sealing out radon from entering premises by fractures, were, in fact, quite permeable to radon. We discuss on the origin of such differentiated behavior.

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MEET-CINCH: A Project for the European Cooperation in Education in Nuclear and Radio Chemistry

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Expertise in nuclear and radiochemistry (NRC) is of strategic relevance in order to maintain European nuclear operations. There are many applications that need NRC skills other than the more obvious context of nuclear power and assessment of disposal options for nuclear waste. This includes medical applications, such as radiologic diagnostics and therapy, but also dating in geology and archaeology, nuclear forensics and safeguard operations, radiation protection, and also basic research e.g. on super heavy elements.
To maintain the fading expertise and skills in NRC, a sequence of Euratom-supported projects was initiated 7 years ago aiming at the Europe-wide collaboration in education and training in nuclear chemistry and radiochemistry. The MEET-CINCH project is the third CINCH-based project. In

the first two projects, CINCH and CINCH-II, status quo in NRC education at European universities was assessed, minimum requirements for bachelor, master and postgraduate programs to achieve approved NRC curricula were defined, and a number of theoretical and practical courses were developed using hands-on and e-learning approaches and platforms.
The MEET-CINCH project consists of three actions. A teaching package for high schools and a MOOC on NRC for bachelor students are built in order to attract young persons to the NRC field and to spread its relevance. Specific material for general public will be produced to enhance people general awareness to the beneficial use of nuclear and radiochemistry techniques and methods. Two additional actions focus on vocational training and university education. This will highlight the value of a career in the nuclear chemistry field and what learning tools are available. MEET-CINCH is developing completely new education and training approaches based on remote teaching and the flipped classroom concept, including and further developing material generated in the previous projects, such as the NucWik platform and the remote controlled RoboLab experiments. MEET-CINCH is going to provide ECVET course modules in an e-Shop adapted to the needs of end-users which have been surveyed in the previous projects.
The consortium includes POLIMI and other 11 partners from nine European member states; both academia and nuclear laboratories are represented. All partners are experienced in conducting training and education. Networking on national and European level will be an important part of the project, facilitated by having ENEN as one of the partners and by having structural links with other Euratom projects.

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Determination of the activity meter calibration factor for Re-188

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Aim
An innovative brachytherapy treatment based on Re-188 has been recently developed for squamous cell carcinomas of the skin. The planning and delivering of the treatment requires an accurate knowledge of the source activity and thus proper calibration of activity meters. However, reference sources for calibration purposes are not always available, as in the case of short-lived radionuclides. The aim of this work was to determine the calibration factors for Re-188 by comparing the results of measurements conducted with the calibration meters with those obtained using an HPGe spectrometer.

Materials and methods
Calibration factors were experimentally determined for two different activity meters, a Capintec CRC15 and a MecMurphil MP-DC. This study was conducted on a Rhenium-188 compound produced by OncoBeta® GmbH for Rhenium-SCT® therapy. In the compound, Re-188 is bound to a fluid matrix that can be applied over the tumor with a dedicated applicator. We considered two different geometries, point source and 5 ml vial, and we prepared three different samples for each, in order to reduce the uncertainties. All samples were measured using the activity meters and the results were recorded in terms of ionization current. The activity of each sample was accurately quantified, within an uncertainty of 5%, with a multichannel analyzer equipped with an HPGe detector (relative efficiency of 30% and resolution of 1.8 keV at 1332 keV). The spectrometer was previously calibrated using a multi-radionuclide certified reference solution (Areva CERCA LEA, Pierrelatte Cedex, France). The calibration process was conducted according to the IEC 61452 standard. The measurements were performed after a partial decay of Re-188, to achieve a dead time always below 4%. The spectrometry results were elaborated with Genie 2000 software (Canberra). We calculated the two calibration factors for each sample by comparing the activities and the recorded ionization currents. The final results were determined as averages of those factors.

Results
The final calibration factors (relative to Cs-137) for the MecMurphil MP-DC are:
• 4,44 ± 0,23 for point-like sources
• 4,44 ± 0,23 for 5ml solutions
The final calibration factors (relative to Tc-99m) for the Capintec CRC15 are:
• 2,21 ± 0,09 for point-like sources
• 2,46 ± 0,10 for 5ml solutions

Conclusion
With the presented method we managed to determine calibration factors with an uncertainty below 6%. This procedure can be reproduced in every laboratory and shows that accurate calibration factors for Re-188 may be obtained, preserving metrological traceability to standards and allowing the use of activity meters for the related radiopharmaceutical procedures. The same methodology can be applied for other radionuclides.

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Assessment of Radon in air and in water in the Portuguese-speaking African countries (PALOP)

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Scientific and technological knowledge are fundamental in social and economic development and contribute to the improvement not only to populations social well-being, but as well as to the quality of life.
Although, in recent decades, the Portuguese-speaking African countries (PALOP) have developed their system of higher education, still there is a clear insufficiency in the number of MSc and PhD graduates, particularly in areas with a great potential for economic and social development, such as life related sciences. This reality shows there is room for progress and improvement in those areas. One of the goals of the present project is to help young African students to develop skills and knowledge, in the fields of life and environment sciences. In this way, this research should contribute to provide highly trained human resources, essential to assure the enhanced role and revitalization of African universities and to create conditions for scientific research in the field of health, life and environment sciences.
Radon is a radioactive noble gas ubiquitous in the natural environment including
air, soils and water. Its importance arises from two different aspects: on one hand it is an environmental hazard with recognized effects in the human health; on the other hand, it is a useful geophysical tool for tracing dynamic properties of the environment. So, our objective is to develop a system for detection and monitoring of radon in the air and in water for human consumption seeking to improve life quality. Population exposure to radon occurs primarily through inhalation, resulting in radiation to the lung and to a lesser degree other organ. Yet, in conditions of very high radon concentrations in drinking water, ingestion can be the primary source of exposure of organs other than the lungs. The radiological evaluation of water is therefore important to assess concentration

and doses, particularly of long half-life isotopes that can circulate on the public water distribution systems and reach the user, being responsible in some circumstances for exposures above recommended levels.
The aim of this project is to develop and fully test low-cost alpha detectors for radon. In a first stage, our priority is to assess the radon concentration, in air and water, in a previously selected area. The radon concentration indoor is measured using CR-39 detectors and for the drinking water the RAD7 radon equipment from the American manufactures Durridge is used. The radon concentration in studied dwellings ranged between 30 to 415 Bq/m3 and for the collected water samples values between 39 to 207 Bq/L were obtained.

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ANALYSIS OF THE VERTICAL DISTRIBUTION AND THE SIZE FRACTIONATION OF NATURAL AND ARTIFICIAL RADIONUCLIDES IN THE SOIL IN THE VICINITY OF HOT SPRINGS

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Lead-210 is a naturally occurring radionuclide of great importance for environmental studies. Its vertical distribution in the soil, combined with that of ²²⁶Ra, may provide useful information on the radon released to the atmosphere in the region, due to soil radon exhalation, or radon carried by ground water. Previous research has shown that natural radioactivity levels –in particular ²¹⁰Pb and ²²⁶Ra activity in the ground –may be higher near hot springs^[1].
In this work, two different locations near hot springs were selected for soil sampling: Kamena Vourla and Thermopylae in Greece. Depending on the special soil characteristics of each sampling location, it was decided to collect soil cores up to a depth of 22 cm from Kamena Vourla, and surface soil from Thermopylae. The soil cores were separated by 1 cm pitch, while the surface soil samples were separated into seven particle size fractions by dry sieving, using a sieving machine and sieves in the range of 0.045-2 mm. All samples were analyzed at the Nuclear Engineering Department of the National Technical University of Athens, by high resolution gamma-ray spectrometry, using an XtRa germanium detector and a Low Energy germanium detector, to determine: (a) the terrestrial natural radionuclides ²³⁴Th, ²²⁶Ra, ²¹⁰Pb, ²²⁸Ra, ²²⁸Th, ⁴⁰K, (b) the cosmogenic radionuclide ⁷Be, and (c) the artificial radionuclides ¹³⁷Cs and ¹⁰⁶Ru. It is worth mentioning that the ¹⁰⁶Ru that was detected in samples collected from both locations is the result of an accidental release over Europe, a few days before the sampling took place.
The vertical profile of the radionuclides obtained from the core sample analysis indicated a disturbance in the first 7 cm of the soil, while at greater depth the concentrations for all radionuclides were as expected. Lead-210 activity was higher than that of ²²⁶Ra, showing a disruption in the radioactive equilibrium, as expected. The analysis of the size-fractionated samples showed –as expected –a higher activity concentration for ²¹⁰Pb and ¹³⁷Cs in the finer fractions. The radioactive equilibrium between ²³⁴Th, ²²⁶Ra, ²¹⁰Pb was found to be significantly disturbed in all size fractions, suggesting that the cause was mainly hot spring water periodically flooding the sampling terrain.

[1] Beitollahi M, Ghiassi-Nejad M, Esmaeli A, Dunker R. 2007. Radiological studies in the hot spring region of Mahallat, Central Iran. Radiat Prot Dosim 123(4), 505–508

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Radiochemistry and Monte Carlo integrated approach to radio-

logical characterization for nuclear facilities decommissioning

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In the last decades, hundreds of nuclear reactors have been shut-down and have experienced decommissioning operations. This is also the case of L-54M Politecnico di Milano nuclear research reactor. Since shut-down in 1979, the plant has been managed according to deferred dismantling strategy. Following National and International well-established guidelines, several activities, such as spent nuclear fuel removal and primary circuit decontamination, have already been performed to guarantee facility safe storage as well as safety of workers and public. Recently, preliminary radiological characterizations have been launched, even though a more extended campaign would be necessary to implement facility decommissioning and restore unrestricted reuse status.
In the framework of the IAEA irradiated GRAphite Processing Approaches (GRAPA) collaborative research project, a general radiochemistry and Monte Carlo integrated approach has been developed to study materials activation and support radiological characterization campaign. First of all, the system physical model has to be created in the Monte Carlo code, by including all geometrical and material composition structural features as well as the complete neutronic history of the plant. Some input script limitations need to be overlooked by a careful simplification process that guarantees the best model accuracy and point-to-point mass conservation. In case of uncertainties, a sensitivity analysis should be carried out. Afterwards, in order to verify the model accuracy, several system properties described by the code are selected and compared with the available experimental values. For sake of example, criticality data and neutron fluxes could be used to verify the Monte Carlo model of a nuclear reactor. Thereafter, the main radionuclides of interest for decommissioning purposes have to be selected, along with their production reactions and impurity activation precursors in virgin materials. Finally, the Monte Carlo output can be properly processed to produce a 3D activation map for each simulated radionuclide. In order to obtain the ultimate model validation, the simulated activity concentrations are point-to-point compared with the available radiometric measurements. A sufficient number of irradiated samples should be collected and analyzed to determine γ-emitting and pure β-emitting radionuclides, so as to complete the model validation and strengthen its trustworthiness.
This integrated method, thanks to its general principles, could be applied to any nuclear reactor or facility undergoing decommissioning, thus helping reducing the characterization efforts and, possibly, the associated costs.

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Ionizing radiation effects on polymer biodegradation

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The great properties of conventional synthetic plastics have allowed a wide range of applications. Packaging constitutes the larger market segment and, due to its specific function, it rapidly becomes waste that increasingly accumulates in the environment. Most of the conventional petrochemical-based plastics are not biodegradable and the production of biodegradable and bio-based plastics is still limited by the high production costs and the poorer properties. Nowadays efforts have been

devoted to enhancing conventional plastic degradability and to tailor biodegradable polymer properties.
Finding a cost-effective and environmental-friendly solution for the treatment of plastic waste is extremely important. It is well known that ionizing radiation can modify polymers, affording many practical applications. In particular, gamma radiation can facilitate the material degradation by inducing oxidative fragmentations of polymer backbone. Experimental activities have been addressed to investigate if a radiation treatment of bio-based plastics could represent an effective pre-treatment to improve their biodegradation.
Commercial and synthesized polymers with different rate of biodegradability have been selected, such as polyethylene (PE) and the biodegradable polybutylene succinate (PBS). Polymer films have been irradiated by Co-60 sources in an industrial plant for sterilization and the impact on the rate of biodegradation in compost has been evaluated. Polymers have been irradiated at absorbed doses up to hundreds of kGy taking into account also the effect of different irradiation environments. Radiation-induced changes of the chemical properties have been evaluated as a function of the absorbed dose by means of different techniques in order to correlate their changes to the biodegradability in compost. In general, the degradability of the considered systems is increased in opportune irradiation conditions: by optimizing the irradiation process, a common environment of irradiation could be adopted for all the systems. The research performed confirmed that the radiation-induced degradation could be considered as an effective pre-treatment to enhance the biodegradation rate of some polymeric systems.

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Advanced separation strategies for spent nuclear fuel reprocessing studied at Politecnico di Milano Radiochemistry Lab within European Projects

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Actinide recycling by the so-called Partitioning & Transmutation (P&T) strategy is considered worldwide, and particularly in several European countries, as one of the most promising strategies to reduce the inventory of radioactive waste and optimise the use of natural resources. In Europe, the research programs dedicated to hydrometallurgical separation of MA have been supported mostly by the European Commission (EC).
Most of the partitioning strategies rely on a three step approach: i) separation of U (and sometimes also Pu) from spent fuel dissolution liquors; ii) An(III) + Ln(III) co-extraction; iii) An(III)/Ln(III) separation. In fact, Ln are characterised by high neutron-capture cross-section and they must be removed in order to achieve an efficient MA transmutation. Unfortunately, the similar chemical behaviour of 4f and 5f elements together with the unfavourable mass ratio are major difficulties to be dealt with. The processes developed around the world differ from the extracting systems involved in these different steps and the possibility to merge them into a single one. Initially, a two steps approach based on two extraction cycles was proposed. A first step, called DIAMEX (DIAMide EXtraction), was dedicated to the separation of trivalent MA and Ln from other fission products contained in the PUREX raffinate. A second step, named SANEX (Selective ActiNide EXtraction), was aimed at separating trivalent MA from Ln. In the following joint research projects, the improvement of the DIAMEX process and of the MA separation by selective extraction in a SANEX-type process were the main goals.
Within the last projects, special attention has been devoted to process safety issues. Furthermore, the researchers' efforts have been focused on developing more compact and simplified separation strategies for the An recycling by reducing the number of cycles. With this aim, three novel heterogeneous approaches have been outlined: innovative-SANEX, 1cycle-SANEX and EXAm (EXtraction of Americium). Moreover, an innovative homogeneous concept has been introduced with the

GANEX (Grouped ActiNide EXtraction) process, with the aim of recovering all TRU in a single solution thus enhancing the proliferation resistance.
At Politecnico di Milano, the Radiochemistry Group has been involved in the study and characterization of different organic extractants suitable for application in the abovementioned processes. Examples of such studies are presented and discussed.

Scientific / **18**

Studies on fuel-coolant chemical interaction in Lead-cooled Fast Reactors at Politecnico di Milano

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Within the development of Lead-cooled Fast Reactors, the chemical compatibility of lead with oxide fuels is still a little explored matter. The possibility to predict the effects of the chemical interaction among lead, steel and irradiated nuclear fuel as a consequence of a cladding failure event or a severe nuclear accident is of paramount importance to assess the safety of such nuclear systems.
To this purpose, experimental research activities with oxide fuels are technically complicated, hazardous, and expensive. On the contrary, thanks to the recent progresses achieved in the field, theoretical and computational chemistry combined with semi-empirical methods can enable us to acquire missing thermodynamic parameters and to perform thermodynamic analysis or phase diagram calculations for multi-phase and multi-component systems.
The Radiochemistry Group at Politecnico di Milano is working on such topic within the framework of a national project promoted by MiSE and ENEA. An approach based on theoretical calculations combined with experimental activities by inactive elements or compounds mimicking the fuel composition and behaviour could strongly contribute to make important breakthroughs in the understanding of the chemical behaviour of the fuel-coolant system in Lead-cooled Fast Reactors.

Scientific / **2**

MEFISIG : Modelling irradiated electronic components used in space industry

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The SEE (Single Event Effect) problematic in electronic components used in space industry is assessed using a Monte Carlo method. This work is focused on modelling two different structures of 18nm-transistors to simulate the transport of ionising particles through the components using C++'s toolkit Geant4. Single Event Transients (SET) are particular cases of SEE that can cause voltage spikes at a node in a circuit and that can be produced by an incident ionising particle. Several hardening methods (i.e. physical shielding) already exist to reduce the effects of these incidents but there is a need to predict SET in order to know their probability of occurrence and estimate the global lifetime of the devices. SET have been studied using Spice simulations by introducing arbitrary

voltage sources (time constants and charge) to emulate the voltage spikes occurring at a node. Time constants can be approximated but the problem lies with the amount of free charges created by ionisation linked to an incident particle. Using Geant4 as simulation tool to evaluate the electron production in the components it can be possible to get good approximation values for the extra charge input. In this paper, we introduce preliminary results concerning electron production in the depletion zone of a transistor depending on the physics table used in Geant4 and depending on the strike angle as a first step in the reliability study of the model created. Once the model reliability is completely assessed, it will be possible to couple Geant4's output with TCAD softwares in order to perform fully-physical simulations of the devices including its electronic response following a single particle strike.

Scientific / 22

Fluorapatite as immobilization matrix for nuclear waste

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The safe confinement of the nuclear waste coming from fuel reprocessing operations is one of the key points in the sustainable development of the nuclear fuel cycle and, in general, of nuclear energy.
Fluoride-containing radioactive wastes are generated during the pyrochemical reprocessing of spent nuclear fuels. They differ significantly from the wastes arising from hydrochemical processing, due to the high halides content. The vitrification of these wastes in alkali borosilicate glass is not viable due to the low solubility of fluoride ions in such host matrices. For this reason, alternative wasteform candidates were investigated, including apatite. Apatites, M5(XO4)3Y, are known to accommodate a large variety of cations (mono-, bi- and trivalent) and anions in non-stoichiometric compositions, thanks to the high flexibility of their structure. Moreover, these host systems exhibit a good resistance towards leaching and radiation-induced damage, which mitigates against release of radioactive isotopes from the matrices into the environment. Of particular interest in environmental and materials sciences is the use of apatite to sequester radionuclides such as 90Sr.
In the present work, a new approach for the preparation of the Sr-substituted fluorapatites by solid state reaction was investigated. The obtained apatitic phases were characterized by powder X-ray diffraction, Raman spectroscopy, Scanning Electron Microscopy (SEM) and Energy Dispersive Spectroscopy (EDS). The influence of some synthetic parameters, such as the temperature, the SrF2 amount and the homogeneization, was evaluated. The results suggest that the considered synthetic procedure could be reasonably applied to the confinement of the radionuclides contained in some types of nuclear waste.

Scientific / 9

Heavy metals and radioactive nuclide concentrations in mosses in Greece

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During the 2015/2016 moss survey, ninety-five (95) samples of Hypnum cupressiforme Hedw., were collected in the region of Northern Greece during the end of summer 2016, covering a regular grid of 30 km x 30 km. The samples collected from different altitudes, from 30 m to 1450 m above the mean sea level. The regions from where samples were collected were open regions in most of the sampling sites, avoiding possible contact of mosses with surface water.
All samples were analyzed to the content of heavy metals (using INAA) and of natural and artificial radionuclides (using low energy gamma ray measurements). Studying the concentrations of heavy metals in mosses in the region of Northern Greece, provide information about the air quality, the identification of possible local pollution sources and transboundary transport of heavy metals, and finally assessing possible health risks in the region of investigation.
The concentrations of 33 elements were determined in all moss samples by using INAA performed in Frank Laboratory of Neutron Physics, Joint Institute for Nuclear Research, Dubna, Russia (Frontasyeva 2011; Pavlov et al., 2014). The concentration of Zn is higher in the region close to the Bulgarian boarders, indicating the transboundary transfer of Zn from the zinc-lead smelter in the region of Kardzhali in Bulgaria. Higher concentrations of Al and V are observed in regions where there are metal industries and in regions close to coal fired power plants and lignite mining. Areas with manufacturing industries, as well as electricity and heat production activities, present also a rise in concentrations of As, Cr and Ni elements.
Mosses can be used as a sampling medium for monitoring of radionuclide deposition. All 95 moss samples were analyzed for activity concentration of 137Cs, 7Be, 210Pb and 40K. 7Be concentrations ranged from 69 to 1280 Bq kg-1, and the concentrations of 137Cs ranged from 0 to 425 Bq kg-1. The concentrations of 210Pb were between 147 and 1920 Bq kg-1 and for 40K were between 120 and 750 Bq kg-1. Differences have been observed in the activity concentrations between the mosses collected from ground surface, rocks, branches and near roots (Figure 2). 7Be and 210Pb activity concentrations are higher in moss samples from the ground surface and rocks than those near roots. 137Cs and 40K concentrations are higher in mosses collected near roots.
This study has shown that the relatively cheap moss method can be used to determine regional differences and temporal changes in the atmospheric deposition of several elements. This enables the effectiveness of emission-reduction measures to be assessed.

Scientific / Education / 3

Analysis of the bias induced by the voxel and unstructured mesh Monte Carlo models with the MCNP6 code

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The use of Monte Carlo methods for the set up of treatment planning systems (TPS) in radiotherapy applications is a current standard. The most advanced modeling techniques aim to directly link the output of CT scans to the patient specific model build up instead of standard phantoms and look up tables. This phase represents a critical step since even the most accurate segmentation and organ volume definition must be translated into a suitable input for the Monte Carlo code. During that step usually the segmented volume is mapped on a regular geometrical lattice (cubic voxels). A more sophisticated option appears to be a volume description based on unstructured mesh (UM) typical of current finite element codes. In this paper we compared the two approaches analyzing the bias induced by the different choices.
Starting from anonymous patient DICOM files coming from the CT scans, suitable segmentation and volume definition have been carried out and voxelized and UM based equivalent models for the Monte Carlo code MCNP6 have been built. The various computational phantoms, covering some significant portion of the human body (head, lower limb) have been used as a benchmark of the dose

distribution obtained from X-Ray sources commonly used in radiotherapy applications. Experimental measurements on phantom slabs irradiated by an X-Ray tube were carried out preliminarily as validation of the simulated radiation source. As shown in the results, the UM computational phantoms (built through the Simpleware SCAN-IPTM tool) can reduce the bias induced by the regularity of the classical cubic voxel geometry, gives a more accurate description of the volume and complex surfaces and, thanks to an optimized discretization of the volumes, are also able to reduce the computational work.
For the same UM models, various comparisons with different voxel sizes have been produced to investigate the dose distributions and evaluate the relation between voxel effects and voxel edge lengths. The comparison shows a convergence pattern of the voxel model to the UM one. It is possible to see that the most significant bias occurs where the dose gradient is higher, along the beam borders and at tissue interfaces. These simulations showed that the UM can be used reliably to compute the dose distributions within computational anthropomorphous phantoms obtained from CT scans.
The comparison between voxel and UM models for the MCNP6 code has been performed with particular reference to the bias induced by the two approaches when building the patient's computational phantom. The results have shown how the voxel model highlights the border field effects with respect to the UM that can handle in a more refined way complex radiation fields and geometries. In conclusion the application of UM in Monte Carlo methods can provide models which represent accurately the complex surfaces of human structures, with significant benefits over voxel models.

Scientific / Education / 6

HCAL-J: Hadron calorimeter for the study of nucleon Form Factors at Jefferson Lab

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This talk reports on the HCAL-J hadron calorimeter, that we assemble at Jefferson Laboratory in Newport News, VA-US.
The main interest of JLAB [1] physics is the study of fundamental interactions and constituents of hadronic matter by a longitudinally polarized electron beam; in particular, the electromagnetic Form Factors of nucleons are studied using a continuous electron beam as a probe, accelerated up to 12GeV by CEBAF (Continuous Electron Beam Accelerator Facility). The upgrade to higher energies allows carrying out measurements at high values of transferred momentum and, therefore,
a more in-depth study of the internal structure of the nucleon.
To this purpose, we build the SBS (Super Big Bite Spectrometer) [2], which consists of a series of elements including a dipole magnet to curve the track of the recoil particles, to be able to determine their momentum, and a series of GEM (Gas Electron Multiplier) trackers, which have the task of measuring the direction of the recoils. Moreover two analyzers for the measurement of the polarization components and a hadron calorimeter called HCAL-J [3] for the measurement of particle energy, are used in order to apply the so called "recoil polarization method"which consists of the measurement of the longitudinal and transverse polarization of the scattered recoil [4].
The study, through SBS, of the electromagnetic form factors of nucleons allows for deriving the ratio between these two components, which results to be proportional to the ratio between the electric and magnetic Form Factors of the studied nucleon. [5]
We will use the HCAL-J hadron calorimeter in several experiments for the study of the internal structure of nucleons, i.e. for the study of proton and neutron Form Factors.
HCAL-J is a sampling calorimeter useful for measuring the energy of a particle, after that it is absorbed; the peculiarity of this detector is that the output signal is proportional to particle energy.

HCAL-J will have a modular structure in which each module, with a front surface of 15x15cm2 and a length of 1m, consists of alternating layers of iron in which the hadron shower forms, and plastic scintillators in which its energy is sampled. The active area consists of 288 modules that include a matrix with 24 modules in length and 12 in width; the thickness of the iron plates is 1.5cm, while the sparkling plate one is 1cm. There are optical fibers between each module, connected to a photomultiplier, in order to look at the light from the scintillating material and convert it into an electric signal, related to the energy of the incident particle. The requirements for any SBS experiment are: match acceptance of SBS magnet/polarimeter, high threshold in energy, while high
trigger efficiency is kept, linear energy response, angular resolution about 5mrad and a time resolution TOF < 1.0ns.
The energy resolution of HCAL-J, estimated through preliminary simulations by Geant4 [6], was found to be 42.3% for a hadron momentum of 2.7GeV/c, gradually improving with increasing the hadron momentum.

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CHARACTERIZATION OF THREE GEM CHAMBERS FOR THE SBS FRONT TRACKER AT JLAB HALL A

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A new Large-Acceptance Forward Angle Spectrometer (Super Bigbite Spectrometer-SBS [1]) is under development for the upcoming experiments in Hall A at the Thomas Jefferson National Accelerator Facility (Virginia-USA) [2], where a longitudinally polarized (up to 85%) electron beam up to 12 GeV energy is now available. The excellent beam intensity (up to 100 μA), combined with innovative polarized targets, will provide luminosity up to 1039/(s·cm2), opening interesting opportunities to investigate unexplored aspects of the inner structure of the nucleons [3].
In its full configuration, the new spectrometer will consist of a dipole magnet, three charged particle trackers, two identical proton polarimeters and a segmented hadron calorimeter [1].
The main requirements for the SBS tracking system come from the upcoming experiments devoted to the measurement of the nucleon form factors at high momentum transfer and more generally from the experiments at high luminosity and with high energy beam.
For these reasons, the SBS tracking system is made of three tracking stations (front, second and third tracker). The front tracker, placed just after the dipole magnet, consists of six layers of large area GEM (Gas Electron Multiplier) chambers (40x150 cm2); each chamber is made by three adjacent GEM modules of 40x50 cm2 active rectangular area (18 modules as a total) [3].
The GEM technology has chosen in order to optimize gain (˜105), spatial resolution (˜80 μm), high

hit rate (˜100 MHz/cm2), cost/performance and high radiation hardness [4].
Members of the JLab12 collaboration INFN (from Catania, Roma, Bari and Genova) together with Istituto Superiore di Sanità of Roma (ISS) has taken in charge the construction and characterization of the front tracker of the spectrometer.
We present the main features of the SBS front tracker and its GEM detectors and, finally, we will discuss the first results of the tracker commissioning at JLab.

References
[1] "The Super-Bigbite Spectrometer for Jefferson Lab Hall A", 20 Gennaio 2010, https://userweb.jlab.org/˜mahbub/HallA/SBS/SBS-CDR_New.pdf
[2] Accelerator Science. Website of the Jefferson Lab, http://www.jlab.org/accelerator-science.
[3] E. Cisbani, "The new SBS spectrometer for high luminosity experiments at JLab Hall A", 2015, http://www.ectstar.eu/sites/www.ectstar.eu/files/talks/1506_ectstar_cisbani_sbs_v1.pdf
[4] F. Mammoliti et al, "GEM tracker for high-luminosity experiments at the JLab Hall A", 2016, https://doi.org/10.1080/10420150.2016.1263633

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Specific Absorption Rate for frequency range used in GSM-900, and GSM-1800

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The surging growth of exposure to Electromagnetic Fields (EMF) represents one of the main factors of people concern about negative biological effects generated by environmental stressors. The world-wide use of cellular phones has generated public concern about exposure to the microwave radiation associated with these phones. The probable biological effects due to the use of mobile phones can be regarded as a result of energy absorbed by the head that may damage the brain and nervous tissues. This presentation explain the probable health effects of mobile phones radio emissions, and presents a theoretical method to calculate the specific absorption rate (SAR) to the microwaves of frequency range used in GSM-900, and GSM-1800 mobile phones. A mobile phone with a single direction antenna as an electromagnetic fields source positioned near the head is assumed, to explain the penetration depth in human head, to analyze the SAR and heat distribution in head tissues.

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Nuclear Engineering activities by Radiochemistry group at Politecnico di Milano

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The Radiochemistry group at Politecnico di Milano is active in several cutting-edge research topics in the areas of Radiochemistry and Radiation Chemistry. Thanks to the availability of the New Integrated Nuclear Laboratories at Campus Bovisa in Milano, the research group is able to develop

education & training activities within the Master degree course in Nuclear Engineering and the Doctoral programme in Energy and Nuclear Science and Technology, as well as R&D activities at national and international level.
Since 2002 the Radiochemistry group is involved in European projects focusing on the hydrometallurgical reprocessing of spent nuclear fuel and, in particular, on the partitioning of minor actinides. The collaboration with Italian and European universities and research institutes enabled to reach relevant scientific results providing fruitful opportunities for student exchanges.
Within the research activities dedicated to the development of Lead-cooled Fast Reactors, the Radiochemistry group has started in 2011 a R&D program focused on getting new insights on the chemical compatibility of lead with the different reactor components by both a theoretical and experimental approach.
Recently, the Radiochemistry lab has been involved in preliminary decommissioning activities of Politecnico di Milano nuclear research reactor, located in Leonardo Campus and shut-down in 1979. Several samples have already been collected, both from surrounding topsoil and from facility components, and analysed to assess target radionuclide activity concentration. Moreover, within an IAEA collaborative research project, an integrated Monte Carlo approach has been developed to study materials activation and support forthcoming radiological characterization campaign.
Within the area of the Radiation Chemistry, the research activities aim at studying the radiation-induced modifications in dosimetric systems for therapy in nuclear medicine, as well as in organic and inorganic matrices for industrial applications. Research in the field of dosimetry is focused around the development, characterization and optimization of gel-based systems, for use in clinical oriented applications; the group also employs advanced imaging techniques oriented towards tridimensional dose mapping in tissue equivalent phantoms, such as Magnetic Resonance Imaging and spatial absorbance measurements.
Experimental activities have been addressed to investigate the effects of ionizing radiation on the physical-chemical properties of commercial/newly synthesized polymers. In particular, in order to face the increasing pollution due to the accumulation of plastic waste in the environment, focused studies are ongoing to evaluate if a radiation treatment of plastics could represent an effective pre-treatment to improve their biodegradation.
Concerning innovative education and training approaches, the Radiochemistry Group is working in a Euratom-supported project aiming on cooperation in education in nuclear chemistry and radiochemistry. In particular, the Group is strongly involved in the development of a Massive Online Open Course on Radiochemistry for bachelor students, in order to attract young persons to the NRC field and give them its fascination and relevance.

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What happened to the Italian Radiochemists?

In Italy, that of "Radiochemist"is now an "endangered species"⋯
After the Referendum of 1987, which produced, in fact, the exit of Italy by the programs for the peaceful use of nuclear energy, the number of young people, students and researchers, interested in nuclear disciplines has declined more and more to the current critical situation.
On the other hand, the need to characterize, from the radiometric point of view, solid and liquid materials coming from different origin and destined for different purposes is increasing. Radiometrical analyses must be performed for management of solid and liquid waste coming from different industrial processes (i.e.: Oil & Gas production, fertilizer production, etc.), to support and control different phases of intervention of the decommissioning and remediation of old industrial plant or for the monitoring of environmental and heath parameters (i.e. radioactivity in drinking water, characterization of building materials, ect.).
While the laboratories able to completely satisfy these requirements are very few and, except for some exceptions, with staff not properly prepared.
As well as the knowledge of specific radiometric measurement techniques, the preparation of the samples to be submitted to radiochemical analysis, requires very good analytical chemistry skills similar, as methodological approach, to those adopted for "trace"analyses.
For these reasons, the use of radiochemical techniques for the preparation and for the analysis of samples, applied to the handling of radioactive samples that can be acquired only with appropriate training in qualified laboratories and under the guidance of experienced tutors.
To remedy this complex situation it is necessary that the Universities, the Research Institutions and

the Control Agencies for environmental and health protection take an active part in sensitizing, guiding and supporting young students in scientific disciplines, especially in Chemical Sciences applied to radiometric measurements.

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KNOWLEDGE MANAGEMENT OF WATER TREATMENT IN NUCLEAR AREA: THE BELARUSIAN STATE UNIVERSITY CASE STUDY

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This study reviews the unique experience of research in the water treatment applied in educational process.
The Faculty of Chemistry of the Belarusian State University (BSU) works in close contact with the Research Institute for Physical and Chemical Problems, which originally stemmed from the Faculty itself, but later separated. The experts of the Research Institute and Faculty of Chemistry developed the new solutions of the water treatment problems. The new technology for water treatment to improve drinking water quality has been proposed. It can be implemented on the scale of large cities at the water treatment plants and at small settlements as well. In cases of emergencies an independent mobile autonomous water treatment plant or portable individual water treatment kit can be used.
The course "Water Chemical Regime"is implemented into the curriculum. It gives an overview of issues of the water chemistry support at operating NPP. It attempts to provide basic knowledge on water pollution and treatment to students and give them hand experience of water treatment. During the practical part the participants realize measurements of real samples contaminated as a result of Chernobyl catastrophe, modeling of waste water treatment. The educational strategy of this course is active learning based on the principles of cooperative learning and pear-lead team learning.
As the international course for winter or summer school we proposed "Water issues at NPP". This course plans to give an overview of issues of the water chemistry support at operating NPP. The aim of this course is to introduce participants on water related safety issues at NPP. It attempts to provide basic knowledge on water pollution and treatment to students and give them hand experience of water treatment.
The strategy of knowledge society development is favored by the openness of educational resources, novel methods of education and teaching, including distance learning. Methodical maintenance of labs has been created in video format, which consistently demonstrates the performance of lab by the students themselves. This material is accompanied by a detailed description, theoretical explanation necessary for the successful finishing of the work. For instance, the videolab "Modeling of NPP Laundry Waste Water Treatment"has been created.
Summing the activity we note with satisfaction that the state-of-the-art and multidisciplinary education together with the strong international communications and research will allow our students to be fully qualified specialists in nuclear engineering and water treatment area.

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Dosimetric properties of gel systems upon different irradiation conditions

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Chemical dosimeters represent a promising instrument for treatment plan verification in radiotherapy. To achieve the required dependability in terms of sensitivity, accuracy, precision and temporal stability of measured dose distributions, it necessary to characterize how such parameters might be influenced by varying irradiation characteristics, to mimic the different scenarios that can be encountered in healthcare.
In this study, dependence of typical dosimetric parameters on photon energy and dose rate, as well as post irradiation temporal stability, have been investigated for different dosimeter types, namely Fricke gels and a polymeric gel.
Fricke gel dosimeters, in their most common form, consist of an acidic gelatin-based solution, containing Fe(II) ions and the chelating agent Xylenol Orange (XO). Ionizing radiation promotes the oxidation of ferrous ions to Fe(III), which is then selectively chelated by the XO, forming a complex which exhibits an optical absorbance peak centered at 585 nm and whose intensity correlates quantitatively with absorbed dose.
The family of polymeric gel dosimeters is very broad, but most commonly they are constituted of a combination of monomers and cross-linking agents, typically dissolved in a gelatin matrix. Polymerization of monomers occurs under irradiation, and the growing polymeric chains are then reticulated by the cross-linker. The resulting polymeric network exhibits an increase in optical opacity proportional to the absorbed dose that can be measured in a similar way as is done with Fricke gels.
In this study, the behavior of a Fricke gel with added sucrose was compared to that of PAGAT (Poly-Acrylamide Gel And THPC), a polymeric dosimeter composed of the monomer acrylamide (AA) and the cross-linker N,N′-Methylenebisacrylamide (BIS). Following specific preparation procedures, each dosimetric solution was poured into spectrophotometric cuvettes, in order to perform optical analysis on the irradiated samples.
Irradiations have been carried out with a 60Co irradiator and an X-ray source, employing different dose rates and photon energies. Optical analysis was performed with an UV/Vis spectrophotometer acquiring absorbance curves and then extracting absorbance values at wavelengths specific for each of the two dosimeters. The obtained values were then plotted against absorbed dose to yield a calibration plot. Temporal stability evaluation was carried out analyzing irradiated samples at different post-irradiation times, namely 1 hour and 24 hours, to assess the variation of dosimetric properties.

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