INTERNATIONAL ATOMIC ENERGY AGENCY

Report of the TM on

"Enhancing Education Programmes on Radiation Sciences in Cooperation with IAEA Collaborating Centres"

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FOREWORD

Radiation technologies have long been recognized as a valuable energy efficient and environmental friendly technology, which form the base for multibillion dollar industry. This technology is equally important both for developed and developing countries. However, the full potential of the technology is still remain to be realized, and one of the critical requirements to achieve this is the continued availability of adequately qualified personnel both in research&development, as well as at the irradiation facilities. Additionally, the decision makers as well as the end-users need to get reliable information about the potentials of this technology.

The Technical Meeting on "Enhancing Education Programmes on Radiation Sciences in Cooperation with IAEA Collaborating Centres" was held from 6 to 10 July 2015 at the IAEA, and was aimed at reviewing the present status of education on radiation sciences relevant to radiation processing in Member States, and the assistance the IAEA is giving to Member States Institutions. The participants identified the needs and gaps, suggested appropriate methodologies, especially taking into account the role of the IAEA and its network of Collaborating Centres, in meeting the objective of providing adequately trained professionals in radiation sciences and technology.

This report of the meeting is divided into two main parts: the first part gives a summary of the talks by the participants, as well as the identified educational needs and gaps for various target audience, followed by a projected roadmap of possible actions. The second part of the report contains a more detailed contribution by the meeting participants.

The IAEA acknowledges the immense contributions of all the participants of this Technical Meeting. The IAEA officer responsible for this publication was A. Safrany of the Division and Physical and Chemical Sciences.
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EXECUTIVE SUMMARY

1. BACKGROUND

Radiation processing technologies are one of the available green production processes, which are being successfully applied in both developed and developing countries, and substantial industries are in place based on several mature radiation processing applications.

The IAEA has been supporting Member States in their effort to utilize radiation based technologies for many different applications ranging from sterilization of single-use medical products to development of advanced materials for applications in medicine, agriculture and environmental remediation. The IAEA Technical Cooperation and Regional Cooperation Projects enable Member States in building necessary infrastructure as well as human capacity building to meet the challenges of development and deployment of processes and products based on radiation technologies. IAEA Coordinated Research Projects provide fertile ground for bringing together scientists from developing and developed countries to jointly focus on well-defined areas of research and exchange of knowledge, experience and ideas for their mutual benefits in the areas of emerging technologies. IAEA publications, guidelines and training modules complement these efforts. These programmes have played a key role in successful adoption of radiation technologies by the Member States and have brought significant socio-economic benefits to their respective societies. The potential of the technology however still remains to be fully realized. It is now well recognized that the continued availability of a reservoir of adequately qualified personnel in the areas of radiation technology is among the critical requirements to ensure sustained and enhanced growth of this technology in future.

The purpose of this meeting was to provide a forum to review and discuss the status of education on radiation sciences in IAEA Member States, and the role IAEA can proactively play in meeting the objective of providing adequately trained professionals in radiation sciences and technology. The meeting assessed the adequacy of training courses currently being organized and suggested appropriate cost effective methodologies such as e-learning modules for online training materials, and identified focus areas of research to address the emerging avenues for radiation technology applications.

2. MAIN OBJECTIVES AND COUNTRIES INVOLVED

The Technical meeting is aimed at reviewing the present status of education on radiation sciences in Member States and the assistance the IAEA is giving to Member States Institutions.

2.1. Main Objectives:

- Review of regular courses at the University in the Member State in the field of radiation sciences and technology, at what level, with what regularity;
• Review of initiatives at the University in the Member State to introduce radiation science/technology courses;
• Review of the IAEA assistance to the Member States relevant to education;
• Review of needs for IAEA assistance, definition of problems and gaps;
• Discuss Solutions, future actions and implementation plan, with special emphasis on the role of IAEA Collaborating Centres.

2.2. Expected Outputs:

• The principal output of the meeting will be a meeting report summarizing the status of the education on radiation sciences in IAEA Member States, and a strategy for effective solution to meet the present needs and future expectations through identified actions and plans for their implementation.

2.3. Countries Involved:

The following Member States were represented at the meeting:

- Argentina
- Brazil
- Canada
- Cuba
- Egypt
- France
- Ghana
- Hungary
- India
- Italy
- Japan
- Korea
- Malaysia
- Poland
- Thailand
- Turkey
- USA

2.4. Work done at the Meeting:

Each participant reviewed the educational activities in their own country relevant to radiation processing applications, and discussed in depth the needs for education both for students, professionals as well as general public. It was concluded, that every facet of the society needs an educational or information outreach regarding radiation sciences and application. The form of the outreach should be adequately tailord to give the maximum benefit.

The summaries of the participants contribution is given as follows:
3. SUMMARY OF PARTICIPANTS REPORTS

3.1. Argentina

3.1.1. Summary

Educational activities and Human Resources development programs, related to radiation sciences and technology, are performed mainly by three academic institutes which belong to the CNEA (the National Commission of Atomic Energy) and national universities: Instituto Balseiro (IB), Instituto Sabato (IS) and Instituto Dan Beninson (IDB).

Many regular courses in the area of Nuclear Science and Engineering, which belong to the three Institutes, are taught by professors from universities and researchers from the CNEA and the CONICET (National Scientific and Technical Research Council – Argentina). There are courses of different duration, which can be classified in: technical studies; degree studies (> 2,600 hrs.); specialization studies (>360 hrs.); Master studies (>540 h + 160 hrs, experimental work) and Doctorate studies. More than 60 foreign students have graduated from CNEA Institutes and hundreds have attended topical courses, seminars and training internships.

In the specific subject of Radiation Science and Technology there are only one technical degree, one degree and one specialization degree, just started this year in the IDB in the field of radiation applications. However there are many topics included and the radiation technology applications is a minor one.

3.1.2. Problems and Recommendations

Argentina has low development in the area of radiation processing and their applications to the industrial process. Also the number of researchers in the field is not enough to have a critical mass to be sustainable in the coming years and support the education of future generations of researchers, experts and teachers.

Therefore, an international cooperation in the field of education with other Members States, especially with regional members, is a great opportunity to change the present situation. For example, Incentives to increment the regional cooperation in the field could be another important action to strengthen the educational activities.

The production of a digital information repository, to be loaded on the e-learning platform, is a critical issue of an e-learning platform and the use of Spanish/Portuguese language is mandatory for a high penetration of the platform in the country and in the Latin America region.

The use of e-learning platforms will enhance the Human Resources development in the field of radiation technology. However, the experimental activities are highly motivating actions during the learning process to adopt this technology. Therefore, a ‘mix-mode’ teaching (e-learning plus experimental activities) looks like the most promising system. The lack of (educational) facilities is an important subject to be overcome. The country has only one multipurpose Co-60 gamma facility, a gammacell with very low activity and no e-beam machine.
In order to support educational and research activities in this field with an appropriate experimental training, it is suggested the following possible actions:

- Support the cooperation in educational aspect with the Member States, with the especial focus in Latin America Member States;
- Impulse the mobility of student and teachers to partner institutions in other countries, especially regional ones, to create human resources in the field;
- Support to the country to obtain educational equipment for performing a sustainable development.

3.2. Brazil

3.2.1. Summary

1. The Radiation Technology Centre (CTR) – Institute of Energetic and Nuclear Research (IPEN), in São Paulo, SP.

MSc and PhD Courses

Concentration Areas:

- Nuclear Technology - Applications
- Nuclear Technology - Reactors
- Nuclear Technology - Materials

2. CDTN / CNEN (Belo Horizonte-MG-Brazil)

MSc and PhD Courses

Concentration areas: Science and Technology of Materials, Science and Technology Radiation, Science and Technology of Minerals and Environment and Science and Technology of Nuclear Reactors

3. IEN/CNEN (Rio de Janeiro-Brazil)

MSc Course

Concentration Areas: Technology and Reactor Safety, Applied Computational Methods,

4. IRD/CNEN (Rio de Janeiro-RJ-Brazil):

- Radiation Biophysics
- Medical Physics
- Metrology
- Radioecology.
5. CRCN-NE/CNEN (Recife – Brazil)

The Post Graduate Program in Nuclear and Energy Technologies (PROTEN) is linked to the Technology and Geosciences Center (CTG / UFPE) and the Northeast Regional Nuclear Sciences Center (CRCN-NE / CNEN). Areas of Concentration:

- Radioisotopes Applications in Agriculture and Environment, Radioisotopes Applications in Industry and Medicine, Dosimetry and Nuclear Instrumentation, Reactors Engineering
- Renewable Energy Sources

3.3. Canada

3.3.1. Summary

Canada has been always in the forefront of world developments in nuclear science. Canada is strongly involved in the area of power production, cancer therapy and diagnostics, on the production of medical and industrial radio-isotope and gamma processing (Kunstadt, 1990). With the foundation of the Canadian Irradiation Centre in 1987, where the Atomic Energy Canada (now Nordion Int.) and the Institute Armand-Frappier (now INRS – Institut Armand-Frappier) joint their effort to assure the formation and training in irradiation of new scientists, to deliver training to industry and regulators in the safe and efficient operation of industrial irradiator, to demonstrate the Canadian technology, to assure technology transfer and to develop by the scientists new technologies in irradiation. Since the opening of the Canadian Irradiation Centre in 1987, collaborations with IAEA were assured for 35 fellowships training, to deliver short training (i.e. Food Irradiation Process Control School (FIPCOS) course) and for research collaboration via several research coordination meetings (RCM). The Canadian Irradiation Center via INRS – Institute Armand-Frappier, has assured the formation of 12 Ph.D., 25 M. Sc. and 25 professional masters in food irradiation, on development of polymers using irradiation and on the mechanism of action of irradiation on bacteria. Nordion also offers training on radiation safety for irradiation operator and officer, facility management and irradiation technology for inspectors.

Several other institutions in Canada provide also formation in irradiation (University of British Colombia, Dalhousie University, University of Ontario and the Radiation safety Institute of Canada) on Food Irradiation, Radiation Safety, Health Physics and Radiation Sciences and Prevention of cancer development.

The presentation described the status of education on radiation sciences in Canada and proposes some avenue to assure international training via e-learning, online modules and identify focus area of research to address emerging avenues for irradiation technology applications.

REFERENCE

3.4. Cuba

3.4.1. Summary

The Nuclear Program in Cuba includes practices with radiation in medicine, industry and research. Organizations deals with radiations science in Cuba are divided into two main categories: those which promote and develop nuclear applications and those which regulate them. Applications are mainly under the subordination of Ministry of Science, Technology and Environment and the Ministry of Public Health.

Radiotherapy, Nuclear Medicine and Radiology are among the medicine practices. A project in course is devoted to introduce new medical technologies for the production of positronic radionuclides. The first cyclotron and associated equipment for medical uses will be installed in the near future. Among the industrial practices we can mention: Industrial irradiation, industrial radiography, nuclear gauges, use of radiotracers, oil logging and others. Two industrial irradiators are installed in Cuba, one of Category 1 and other of Category IV, according to the usual classification. A project in course is set to get the Category IV irradiator to be operative again.

Human resources (university degree) to be employed in those institutions are been formed during the last 30 years basically in the Higher Institute for Technologies and Applied Sciences (InSTEC by its Spanish acronym), subordinated to the Higher Education Ministry. Other institutions, mainly subordinated to the Ministry on Public Health also contribute to the competence building. The formation of professionals at InSTEC includes basic sciences, mainly in nuclear technologies. Three university degrees in Nuclear Physics, Nuclear and Energetic Technology Engineering and Radiochemistry are developed in five years duration courses. A Master Degree program includes the same three degrees and also Medical Physics. A PhD program (in different modes) also includes the three specialities.

Another institutions have been implemented another initiatives in order to prepare the human resources. Here we can mention Diplomas in Medical Physics, Radiotherapy Physics, Radiation Protection and Physical Aspects of Nuclear Medicine.

E-learning has not a broadly presence in the building of competence in Cuba. Two initiatives of a professional institution (Center for Radiation Protection and Hygiene) and one of InSTEC have been implemented.

For more than 20 years IAEA have been supported the Cuban efforts in building competence in radiation sciences, mainly through the assign of budget and lecturers for different specialized courses and events and accepting Cuban scholarship holders in regional and interregional courses.

3.4.2. Problems and Recommendations

The main problems of education of radiation sciences in Cuba deal with lack of technological infrastructure. Here it can be included the lack of proper installations for research and laboratory practices, poor Internet connectivity and band width. Another important problem in the near future will be the replacement of professionals.
The IAEA can assist Cuba through promotion of access to new equipment using TC Projects, joint research, university exchange, donations, etc.

3.5. Egypt

3.5.1. Summary

The Egyptian Atomic Energy Authority (EAEA) was established in 1955 and became a member state of the IAEA in 1958. EAEA is the focal point of contact for agency technical assistance. In Egyptian universities, there are at least a regular course of nuclear and radiation chemistry and physics at faculties of sciences. There is a department for Nuclear Engineering and Radiation Chemistry in the Faculty of Engineering, Alexandria University. During the summer vacation of Universities, training programmers are organized for the undergraduate students of engineering and sciences faculties to provide good knowledge on radiation processing in various fields. The Undergraduate research project programmer in the final year of engineering and science faculties can coordinate with EAEA under a supervision of EAEA staffs. Many master's and Ph.D. thesis are accomplished with the collaboration of all Universities of Egypt. This is not only for the staffs of EAEA but also for the staffs working at Universities under the supervision of EAEA professors. The thesis should be related to the field of radiation processing and its applications in various fields and the experimental work is done at the Atomic Energy Authority. Regular Conferences and workshops related to radiation processing and peaceful nuclear applications are organized by the societies of EAEA and Universities staffs and the postgraduate students are participating.

3.5.2. Problems

Needs and problems recognised are the need for the practical application for the undergraduate student. Also, there are no enough facilities for the students in nuclear area and the need for radiation and nuclear institute for the undergraduate student wishes to engage in nuclear area.

3.6. France

3.6.1. Summary

France has a long tradition and has provided a strong background to radiation science and technology since the major discoveries by H. Becquerel, P. Curie and M. Sklodowska-Curie. Since then, the interdependence between science and technology has continued to develop with a need for researchers and qualified technologists specialized in the fields of nuclear science, radiochemistry, radiation chemistry and their applications for health and for industry.

Being the leading institution for research, development and innovation in his field of responsibility, the CEA is active in four main areas: low-carbon energies, defense and security, information technologies and health technologies. In each of these fields, CEA maintains a cross-disciplinary culture of engineers and researchers, building on the synergies between fundamental and technological research. CEA exerts another responsibility by managing the “Institut national des sciences et
techniques nucléaires “(INSTN), a higher education institute founded in 1956 for training engineers, researchers and technical staff involved in the French civilian nuclear programme initiated in the years 1950.

About 40 curricula are proposed by INSTN based on the expertise of CEA and of his research (CNRS, INSERM) and academic partners (several universities and Higher Schools. In particular, 5 MSc degrees are granted by INSTN: Atomic engineering, Nuclear reactor engineering, Nuclear science and technology, Nuclear medicine, Qualification in radiological and medical physics.

Besides this training activities centred on the energy applications, the French academic education also includes the medical utilization of various types of radiation included in the basic and specialization courses taught in the Faculties of Medicine (47), Pharmacy (24) and Odontology.

The education of students in the broad field of applications of radiation science and technology is by far less visible and organized though the discipline is present as a compulsory or elective courses of training programmes or diploma in Astrophysics, Physical chemistry, Materials or Polymer science, Nanoscience and nanotechnology, etc. The tight link between research and education is evident after the analysis of the educational offer in Universities and departments of institutions as CEA and CNRS, where a large number of international level groups develop original activities. A list of representative topics and support laboratories (not exhaustive) is presented in the report. A number of courses, mainly at MSc level, are proposed by the universities and higher schools, with an orientation towards the domain of research of the involved pedagogical teams.

3.6.2. Recommendations

1 - List the main domains application and evaluate the type and number of associated job positions which drive the need for specific training programmes, try to define a limited number of domains sharing the same (or somehow related) specificities:

- Food and drug processing
- Sterilization
- Polymer materials (plastics, composites, biomaterials, coatings, lithographic materials)
- Treatment of industrial / municipal effluents and municipal wastes

2 - Discuss the different options for proposing educational initiatives:

(i) One (or more) specialization training programme(s),

- Adapted to the level and objective of the trainees,
- Focused on “radiation processing” to be included (earned credits taken into account) or added to conventional curricula (BSc, MSc, PhD) existing in the different member states.

and/or
A global curriculum,

- Self-consistent, and dedicated to the formation of students in the perspective of well-defined positions in industry or academia.

For both options, the architecture, the content of the courses, the prerequisites, should be defined around:

- basic core of scientific knowledge (radiation sources, radiochemistry, particle physics, chemical kinetics, free radical chemistry, molecular biology, solid state chemistry, spectroscopic and physical methods of characterization, environmental chemistry);

- a set of concepts and methods for implementing radiation processing (radiation sources and accelerators, dosimetry, radioprotection, simulation, quality control / quality assurance, basic maintenance, principles of Life cycle assessment);

- specialized courses should be proposed to address the needs in terms of knowledge and practical skills of each of the application domain, e.g. domain A “Sterilization/food preservation” (main relation with biology), domain B “Polymers and materials processing” (main relation with materials science), domain C “Environmental applications”

An on-going Erasmus + Key Action 2 “Joint innovative training and teaching/learning program in enhancing development and transfer knowledge of application of ionizing radiation in materials processing” coordinated by ICNT (Warsaw, Poland) has been selected in 2014. This initiative will provide a training programme with the associated educational tools to be analysed and evaluated in the perspective of a broader international educational project in the domain.

At the doctoral level, the Marie Curie Sklodowska Actions, a tool of European Union programme Horizon 2020 can offer the frame of such an initiative since students of non-EU states can apply and benefit from the mobility supports.

3.7. Ghana

3.7.1. Summary

The Ghana Atomic Energy Commission (GAEC) was established in 1963 and its currently made up of 5 Institutes: National Nuclear Research Institute; Radiation Protection Institute Biotechnology and Nuclear Agriculture Research Institute; Radiological and Medical Sciences Research Institute; Ghana Space Science and Technology Institute
Regular courses in radiation sciences and technology are mainly taught at the School of Nuclear and Allied Sciences (SNAS) which was established in 2006 by GAEC and the University of Ghana. It has been recognised by the IAEA as a Regional Designated Centre for Post Graduate Education Certificate in Radiation Protection and Safety of Radiation Sources (PGEC); Nuclear Science Technology Programme and Medical Physics Education Programme. The School is made up of the Departments of Nuclear Sciences and Applications; Nuclear Safety and Security; Nuclear Engineering; Medical Physics; Nuclear Agriculture and Radiation Processing. Specific courses related to radiation processing are taught at the Dept. of Nuclear Agriculture and Radiation Processing. These courses are: M. Phil. (Radiation Processing); PhD (Food Security and Radiation Processing) (to commence in 2015).

Initiatives of academic and professional institutions in education of radiation sciences are mainly those of GAEC and SNAS. These are Human Resource Development Programme (Sandwich programmes); Post Graduate Education Course (PGEC) in Radiation Protection and Safety of Radiation Sources; Nuclear Science Technology Programme (NTSP); Medical Physics Education Programme; establishment of AFRANEST Platform for e-learning; AFRA and National TC projects.

3.7.2. Problems and Recommendations

The problems and gaps that exist in education in radiation sciences and technology in Ghana include limited training courses and fellowships; absence of ICT-based modules for training and teaching as well as lack of fully developed e-learning platforms at the regional and national levels. Currently the IAEA supports education in radiation science and technology through the assistance given to SNAS and GAEC in the areas of Human Resource Development Programme (Sandwich programmes); Post Graduate Education Course (PGEC) in Radiation Protection and Safety of Radiation Sources; Nuclear Science Technology Programme (NTSP); Medical Physics Education Programme; Establishment of AFRANEST Platform for e-learning; AFRA Regional programmes and National TC projects.

So, in order to solve the problems and gaps that exist in education in radiation sciences and technology in Ghana:

1. IAEA should create an international focal point or centre of excellence in the field of radiation science and technology to support the work of collaborating centres.

2. IAEA should strengthened collaborating centres to enable them deliver educational programmes to meet future needs through the development of ICT-based modules for online use in teaching and training; provision of laboratory scale irradiators for teaching and research and development of undergraduate training programmes to provide human resource for industry, institutions or products for further training for higher degrees (Masters, PhD).

3. IAEA should assist member states in accelerating the pace of technology adoption by using innovative outreach approach targeting policy makers and industry executives in education programmes.

4. Inter-regional participation of courses by member states should be promoted.
3.8. Hungary

3.8.1. Summary

Education programmes on radiation sciences is carried out in Hungary mainly in universities, but selected programmes are given in certain research centres too, in most cases also in cooperation with universities. The education on these subjects is based on the requirements of the existing radiation and nuclear infrastructure, i.e. to fulfill the needs of the safe operation of Paks Nuclear Power Plant, as well as the tasks of the Public Limited Company for Radioactive Waste Management on one side, while to ensure the safe operation of gamma irradiation facilities, as well as to satisfy the needs on the use of radioisotopes in medicine and industry including the existing basic and applied radiation research requirements on the other side. There are more than twenty universities in Hungary, but only a few of them have courses on radiation sciences both in the frame of undergraduate and postgraduate education mainly for chemists, physicists and chemical-, material- and environmental engineers. These universities are the Éötvös Lóránd University, the University of Technology and Economics and the Óbuda University in Budapest, the Pannon University in Veszprém and the University of Debrecen. 

The education programmes aim at the introduction into the basics of nuclear science (radiochemistry, radioanalytical chemistry, radiopharmacy, radioecology, nuclear engineering) required to understand technical applications of nuclear methods. Danger and biological consequences of radiation is also discussed because it is becoming a real demand of modern society. 

These courses involve the topics of interaction between radiation and matter, basics of nuclear chemistry and physics, radiation chemistry and protection, physical, chemical and biological effects of radiation, nuclear methods in chemical analysis, application of radioisotopes in industry, medicine, biochemistry, biology, principles of dosimetry and types of dosimeters, environmental control, etc. Education is also carried out at research institutions, mainly at the Hungarian Academy of Sciences, Centre for Energy Research partly in the frame of individual courses and partly in cooperation with the universities discussed above. These educations, which involve both theoretical and practical parts, are given both for Hungarian as well as for foreign students in the frame of bilateral (HUNEN program) or multilateral (IAEA, EU JRC institutions) programs for shorter (1-2 weeks) or longer (3 months) periods. The IAEA plays a significant role in these programs both by utilizing its regional technical cooperation programs and by the fellowship programs.

3.8.2. Problems and Recommendations

Severe problems to ensure the necessary well educated manpower to run all these programs involve the substitution of the present older generation due to resignation foreseen in the near future, the lack of the financial sources for infrastructure and the declining position of radiation research. 

Therefore the efforts of the IAEA to strenghten the education in these fields is of basic importance.
3.9. India

3.9.1 Summary

Dr K. Indira Priyadarsini, from Bhabha Atomic Research Centre (BARC), Department of Atomic Energy (DAE), India, gave an overview of current status of education and research on radiation sciences in India. BARC, as a premier multi-disciplinary national research centre, has full-fledged programmes on all the areas of radiation sciences and technology. New centres have also been established by the government of India in different parts of the country on related research areas. Institutes like Advanced Centre for Training, Research, Education in Cancer (ACTREC; under Tata Memorial Centre, an autonomous Institution under the Dept of Atomic Energy), and National Centre for Free Radical Research (NCFRR), Pune and Inter-University Accelerator Centre (IUAC), Delhi have dedicated research programmes on different aspects of radiation sciences. A few other universities like Pune University, teach radiation chemistry and biology as a part of the post-graduation curriculum. Additionally, some independent professional bodies like Indian Society for Radiation and Photochemical Sciences (ISRAPS), Indian Nuclear Society (INS) and Indian Association of Nuclear Chemists and Allied Scientists (IANCAS) help in promoting education and research in radiation sciences in academic institutions and universities.

BARC has a state-of-art infrastructure for pursuing R & D, covering the entire spectrum of nuclear science & engineering programme. It has an excellent orientation course (previously known as training school), initiated by the founder of Indian atomic energy programme, Dr Homi Bhabha, to educate and train newly recruited bright young post-graduates and engineers, nearly 150 to 200 in number, on all the aspects of nuclear energy programme. This training programme spanning over a year has been very successful and brought out world class researchers in the last 58 years. As a part of this one-year orientation course, topics related to radiation sciences, like charge particle interactions, radiation chemistry, radiolysis of water, radiation biology, radiation protection, dosimetry, radiation polymerization, isotope applications, accelerators, radiation sources etc, are taught in detail along with relevant experimental work. The programme has a high teacher to student ratio, taught by active researchers in the respective areas. With the inception of Homi Bhabha National Institute (HBNI), an autonomous institute under DAE, many of these training courses are now conducted by HBNI and it also awards PhD degrees, postgraduate degrees and post-graduate diplomas in these specialized areas of radiation sciences. In the last 25 years, BARC has produced more than 500 research articles and 50 PhDs exclusively in the fields of radiation chemistry and radiation technology.

The researchers are regularly invited in several international meetings on radiation chemistry and technology either as experts or as mentors. The young investigators received awards and travel support to attend these meetings. With the continuous inputs from R & D on radiation chemistry and technology, the researchers from this center have been able to demonstrate many new technologies in the areas of polymers, nanomaterials, food irradiation, radiation sterilization and new health care products and some of these have been transferred to industries successfully. The researchers from DAE have regular collaboration with the industries in the country & developed many new technologies like hydrogels for wound dressings, irradiated cables, coloured gem stones, biodegradable natural polymers, new radiation processed polymers with improved properties, urban sewage sludge hygienisation plants etc.
3.9.2 India - IAEA cooperation

India is an active member of all IAEA programmes in general and RCA activities in particular, and has been participating as experts/consultants in technical meetings, workshops and training courses organized by IAEA. In some of the regional training programmes conducted at the collaborating centers in the Asian region on radiation technology, several members from DAE gave lectures as experts or attended the training courses like for example, e-beam applications in polymer processing, food irradiation and environmental pollutants, etc. India is one of the first few countries in the region to have initiated research in these areas. BARC-DAE has excellent trained manpower and expertise on various areas of radiation sciences and will continue to make available its expertise, as required for IAEA activities and events.

3.9.3 Suggestions for enhancing education in radiation sciences

In order to explore the full potential of radiation technology for societal up-lift, she opined that there is a need for developing trained manpower on radiation technology all over the world. This will not only expand the radiation technology to more industries, but would also act as a public outreach programme. Other than BARC, there is no full-fledged programme on radiation chemistry & technology as a special course in any institute or university in India. Therefore it may be useful to conduct IAEA approved workshops in universities and other institutions in India in co-ordination with BARC experts. It would also be useful to create an International Radiation Learning Centre in India for users from nearby member countries. The researchers from BARC/DAE can help in teaching and conducting these courses. Their expertise can be used to bring out monographs and course materials.

3.10. Italy

3.10.1. Summary

Higher scientific education in Italy is mainly covered by universities and superior graduate schools (Schools of Excellence). State-funded public universities are by large the most represented in Italy, particularly among the largest institutions. Since 1999, the Universities issue the following qualifications, corresponding to the “Bologna Process” structure (three cycles): Laurea (L), corresponding to a first-cycle qualification, Laurea magistrale (LM), corresponding to a second-cycle qualification, Dottorato di ricerca (PhD) or scuola di specializzazione (specialisation courses), corresponding to a third-cycle qualification.

In addition, universities may organise courses (higher continuing education studies) open to the holders of a 1st cycle (L) and 2nd cycle (LM) degree, respectively. They are finalised to the education and training of professionals, often with a strong involvement of industry and/or public bodies.

Universities autonomously determine educational contents of individual degree courses. Individual institutions, however, when establishing a I or II cycle degree programme they have to adopt a few general requirements fixed at national level in relation to groups (“classi”) of similar degree courses that bind up to 2/3 of each curriculum, thus allowing some flexibility especially for elective courses.
In this contest, a number of regular courses or course modules on topics that pertain to broad field of “Radiation Science and Technology” are taught in Italian Universities, mainly as part of LM Programmes in the area of Physics, Chemistry and Chemical Technology, Biology and Biotechnology, Chemical Engineering, Nuclear Engineering and Ionising Radiation applications, Medicine (e.g. LM in Medical Radiology Techniques, Medical Imaging and Radiotherapy) and Pharmacy and in the Specialisation Course in Radiology and Imaging Diagnostics. The most relevant courses for education in the field of Radiation Science and Technology related to radiation processing applications are represented by two groups: 1) Radiation Physics, Radiation Biophysics, Radiobiology, Dosimetry, and to some extent Medical Physics; 2) Radiation Chemistry and Radiation Processing and Applications. The first group of courses is taught to LM students of specific programmes or curricula in Physics, Nuclear Engineering and Medicine; in the second group fall only two elective courses that are offered to the students of LM in “Photochemistry and Molecular Materials” (course title: Radiation Chemistry) and LM in “Biologia della Salute” (course title: Ionizing Radiations and Living Matter) of the University of Bologna. A course module on “Radiation engineering of organic and/or inorganic nanoparticles” is included in the elective course on “Functional Nanostructured Materials” offered to Chemical Engineering MS students of the University of Palermo.

The most remarkable initiative of a higher education programme devoted to the Nuclear and Radiation Science and Technology in Italy was represented by European School of Advanced Studies on Nuclear and Ionising Radiations Technologies, organized by the University Institute for Advanced Studies (IUSS), in cooperation with IAEA. It was lunched as a pioneering initiative in 1998 and run every year until the 2009/10 and for two more years in 2012/2013 and 2013/14. It was characterised by a strong link with industries, academic institutions and research centres and by the participation in the educational activities of specialists from different Countries. It was offered to both Italian and foreign students; and about 50% of the students every year were awarded with a tuition waiver, also through IAEA fellowships.

Other, non-regular educational activities in radiation science and technology-related fields are being organised by many Academic institutions, e.g. within the framework of Erasmus International Mobility programmes, with the support of the Ministry of Instruction, University and Research (MIUR) or sponsored by the International Cooperation for Research and Education Programmes of the Universities (e.g. Progetto CORI at the University of Palermo).

Another ongoing activity is the Erasmus+, KA2 project titled “Joint innovative training and teaching/learning program in enhancing, developing and transfer knowledge of application of ionizing radiation in materials processing”, which involves the University of Palermo together with Universities and Research Institution in Lithuania, France, Poland, Romania and Turkey. The expected outputs are two intensive 9 ETCS courses on “Radiation processing of materials” to be delivered in fall 2015 and in fall 2016; the write-up of a book on the course content and the organisation of a number of dissemination events.
3.11. Japan

3.11.1. Summary

Status of the lectures on radiation sciences in Japanese universities are investigated from the viewpoint of radiation chemistry involved in our institute. The resulting investigation showed the lecture contents of radiation science corresponded to radiology in medical departments although the radiation science is considered to be a general scientific area covers radiation chemistry, radiation physics, radiation biology, radiology, and so on. These lectures on radiation science in medical department contain radiation chemistry as a part of lecture contents in Japan. This is because Japanese “Radiation Science” is a name of organ of national institute of radiological science and this term is usually used in the meaning of medical radiation science or radiology in Japan. In this situation, 74.3 thousands students (2.9 % of university students) in 79 medical departments learn the fundamental radiation chemistry, radiation biology and radiochemistry in the lecture on radiation science such as radiation therapy and nuclear medicine as regular courses. The lecture on radiation chemistry mainly has been given in the department engineering of graduate school. In the department of science, there is not so much difference in the contents of lecture on radiation chemistry and radiation science.

The staff of our institute gave the lecture on radiation chemistry, radiation biology and accelerator physics in regular course in universities to develop human recourse of the next generation in the radiation technology. These lectures contribute to accumulate knowledge for national qualification examination for radiological technologist, extensive knowledge of nuclear energy science, comprehensive knowledge of radiation applications, and topics of radiation applications such as applied biology and ion beam technology. Outcome in dissemination of lecture contents is to publish the 11 series of textbooks prepared from the lecture notes in nuclear professional school of the University of Tokyo. The two subjects related to nuclear technology were translated into English and published as English textbook. Dissemination of radiation chemistry through lectures is profitable for human resource development in Japanese universities since participating students notice the advantages of radiation chemistry after attending the lecture. Students were all attention to the technology transfer of radiation application and patent strategy.

As a contribution to IAEA regional and domestic training courses, Japanese experts in regional and domestic training courses in RAS1014 gave the lecture on grafting technology, its environmental and industrial application, and up-scaling for technology transfer of grafting. Furthermore, they performed demonstration and experiment of grafting to promote the understanding of grafting technology and its technology transfer.

3.11.2. Problems and Recommendations

The expert noted that shortage of number of lecturer and preparation time for the informative documents and slides which are not overlapped with those prepared local lecturers.

Discussion among the participants should be added in training course program to promote the management of grafting technology to overcome the domestic obstacles in political and economical problems.
3.12. Korea

3.12.1. Summary

To educate and train the students for nuclear science and Technology and relative applications, 8 universities manage related department for under graduated and graduated students. University of Science and Technology (UST) is supported by Ministry of Science, ICT and Future Planning in Korea since 2004. UST is the unique graduate university based on National Research Institutes in Korea. 17 Ph.D course and 12 Master course students are educated for Responsibility for R&D on nuclear technology and nuclear activities in applied areas such as medicine, agriculture, food and life sciences. There are graduate-level regular programs (Ms course, Ph.D. course) for domestic and international students in KAERI (Korea Atomic Energy Research Institute).

In cooperation with collaborating center, we have provided training for experts from the developing countries, participate in the research program for developing radiation application technology such as collaborative research projects led by IAEA, dispatch IAEA experts in radiation application technology, hold international technology conventions, workshops and seminars in Korea organized by IAEA and have IAEA trainees and scientists visit as part of technical cooperation with the IAEA, and played our role as a radiation technology donor country.

3.12.2. Recommendations

To enhance education programme on radiation science and human resources development, Active knowledge transfer through training courses, workshops, scientific meetings, conferences to related institutes is recommended. To gain knowledge and establish networking with collaborating centre for enhancing educational programme on radiation science is recommended. We hope to expande our cooperation on radiation processing technology with collaborating centre.

3.13. Malaysia

3.13.1. Summary

Radiation science is a basic knowledge prerequisite for pursuing the application of radiation in various fields such as agriculture, medicine, industry and environment. Therefore it is a very important basic knowledge for all personnel that involve directly or indirectly in R & D, production, manufacturing and services in relation to radiation processing. In Malaysia, education on radiation sciences have been accepted and incorporated in the University curriculum for undergraduate studies in all 5 main public Universities (UKM, UM, UPM, USM and UTM). Currently, the subject of radiation is introduced either as part of nuclear sciences program or in relation to health and safety. Therefore, there is still area for further improvement and enhancement to cover a wide range of radiation sciences in relation to chemistry, physics, biology and environment including its broad and diverse applications.

Currently, there are 1205 Atomic Energy License Holders in Malaysia with the major users are in the area of nuclear gauging, NDT and irradiation services plants. In view of this, radiation protection and radiation safety are strictly enforced and the education program on this subject is well established in
Malaysia. It is also supported strongly by IAEA through the establishment of PGEC since 2000, as the Regional Training Centre on radiation protection and safety for Asia and Pacific Region.

Beside formal education on radiation sciences at the University, research institute such as the Malaysian Nuclear Agency has played the leading role in the promotion and education of radiation chemistry and radiation processing. This task is entrusted to the Division of Radiation Processing Technology of the Malaysian Nuclear Agency. In relation to this, the Division was designated as the IAEA Collaborating Centre (IAEA CC) on Radiation Processing of Natural Polymer in 2006 for a period of 3 years, until 2009. The IAEA CC was extended for another 4 years from 2010 to 2014 with the expansion of scope of activity to Radiation Processing of Natural Polymer and Nano-materials. This was to take advantages of the newly established nano-materials laboratory and facilities at the Radiation Processing Division of the Nuclear Malaysia in 2010.

In the past 8 years, 2006-2014, IAEA CC was very active in providing laboratory and facilities for the research students pursuing their MSc/PhD and under graduate industrial training, receiving IAEA fellows and scientific visitors including organizing training course and the regional and national level.

3.13.2. Problems and Recommendations

Many of these research students have no background on radiation chemistry and radiation processing. They are totally depends on the advice and supervision of the personnel of the IAEA CC.

Therefore, it is recommendable that such research students should enroll formally in the training course on radiation chemistry as part of their MSc/PhD program. In this regards, IAEA CC, being an established center on Radiation processing of Natural Polymer and Nanomaterial can play a significant role in providing the venue for such formal training course, even at the regional level. The content of such training course should be designed, harmonize and coordinated by the IAEA. IAEA as the specialized UN Agency in nuclear science and technology can also play a role as an independent body for such task and for issuing the certificate for the course.

3.14. Poland

3.14.1. Summary

Poland has developed and implemented some original radiation technologies (e.g. flue gas purification, hydrogel wound dressings) and utilizes some of the generally known radiation techniques (sterilization, decontamination of food, polymer cross-linking), albeit at a limited scale. There are two industrial-scale EB installations for sterilization and food irradiation, a few in-house EB installations in polymer industry and in flue gas treatment, as well as one semi-industrial-scale gamma installation. Two research institutions, Institute of Nuclear Chemistry and Technology (INCT) in Warsaw and the Institute of Applied Radiation Chemistry (IARC) in Lodz (a specialized unit of the Lodz University of Technology) conduct studies on radiation technology development. Therefore there is some demand for specialists in radiation technology, but limited in number. So far, no Polish university runs a full-fledged, regular B.Sc. or M.Sc. program specifically on radiation chemistry and/or technology.
Currently most activities in the atomic field in Poland are focused on the recently (re)started program of nuclear power generation. The decision to build at least two nuclear power plants caused many important changes. According to the new Atomic Law, the National Atomic Energy Agency should focus solely on regulatory oversight of activities related to nuclear and radiation technologies. It means that it does not any longer play the role of a governmental organization coordinating or supporting education activities in the nuclear and radiation areas. Therefore, such activities are expected to be conducted by universities (based on their own decision and judgement), non-university research institutions (formally lacking the right to run studies and grant diplomas), NGOs and the nuclear & radiation industry itself. Educating Polish society in these matters is a huge task, due to strong historical prejudices and phobias (cold war – atomic bombs, Chernobyl, general lack of trust in authorities in these issues), general lack of knowledge in these matters, often far-from-professional level of journalism, and also due to tendencies to diminish the importance of teaching science at Polish schools. It also becomes more and more difficult to run advanced studies in any branch of science or technology, due to the decreasing level of knowledge of candidates and inadequate selection procedures (no entrance examinations).

Basic information on radioactivity, isotopes and their application is included in curricula of most B.Sc. and M.Sc. programs in physics, chemistry and chemical technology. However, there are only few programs of studies focused on nuclear engineering or radiation technology. The former topic is taught, as a separate program of studies, at the AGH University of Technology in Cracow. Postgraduate studies on nuclear energy engineering are offered at the Gdansk University of Technology and by a consortium of Warsaw University of Technology, Wroclaw University of Technology, and National Centre for Nuclear Research (the site of the only research nuclear reactor in Poland) and INCT, which is the IAEA Collaborating Centre. Extensive course on radiation chemistry and technology is taught both at B.Sc. and M.Sc. levels at the Faculty of Chemistry, Lodz University of Technology, basing on the facilities of IARC. So far these courses are a part of curriculum at the specialization “Biomaterials- and Radiation Engineering” within the Chemical Technology course. However, there are plans to re-organize these curricula and provide a separate program or a specialization on “Nuclear and radiation engineering”. An ideal situation would be to have a separate M.Sc. program on radiation engineering, but the current demand in Poland is estimated as insufficient. Both INCT and IARC run Ph.D. studies in radiation chemistry and radiation technology.

3.15. Thailand

3.15.1. Summary

There are 3 eras of education on radiation processing in Thailand. The 1st era started in 1979, the course in radiation chemistry and processing was established in the Department of Nuclear Engineering, Faculty of Engineering, Chulalongkorn (CU). This course was inactive in 2010. In the 2nd era, the radiation and chemistry and processing field was then established from 2008-2010 in Department of Applied Radiation and Isotopes, Faculty of Science, Kasetsart University (KU). In 2010, Faculty of Science operated the interdisciplinary program on M.Sc. and Ph.D. on Nanomaterials Science operated in the Department of Materials Science. The course related to radiation chemistry and processing was improved and newly established and rearranged to be organized only in the Department of Materials.
Science, Faculty of Science in the 3rd era in 2012. It is important to note that 20% of the core course on “Synthesis and Fabrication of Nanomaterials”, is irradiation technology part. In 2013, the elective course for M.Sc. on “Modification of Polymer and Nanomaterial using Radiation” was provided and the course includes Introduction to radiation science; Radiation sources used in polymers and nanomaterials modification; Interactions of electromagnetic radiation and charged particles in polymers; Basic radiation chemistry of polymers in aqueous system; Effects of radiation on polymers; Polymerization, grafted copolymerization, polymeric degradation and cross-linking by radiation induction; Radiation fabrication of polymer-based nanomaterials and applications. In 2015, an elective course on “Advanced Fabrication of Polymeric Nanomaterial using Radiation” was provided for Ph.D. composing of Advanced radiation chemistry for polymeric nanomaterial fabrication by bottom-up and top-down processes; Advanced radiation methods for nanoscale size control of polymeric nanomaterials; Radiation-induced ion track, surface grafting, coating, blend and composite; Properties and characterizations of radiation-fabricated polymeric nanomaterials. In 2014, a center of radiation processing for polymer modification and nanotechnology (CRPN) was taken an effort to to establish for making radiation processing technology for materials more visible. CRPN is expected to be a center for providing education, research development and technology transfer not only students but also other scientists and researchers in the country.

SWOT analysis of radiation science related to radiation processing in Thailand. **Strength** are radiation processing compost of 5E, Efficient, Enable, Economic, Energy saved, Environmentally friendly, the country continuously develops radiation processing technology through education and research operation over 35 years; the country has productivity indicated from graduated students, publications and patents; and this technology has been strongly supported by IAEA. **Weaknesses** are unacceptable technology for people who lack of knowledge and lack of facilities. **Opportunity** of radiation processing is an emerging and competitive technology and a green technology for sustainability. **Threats** are other acceptable used processes and competitive technologies. The recommendations to IAEA are to provide (i) visiting professorships to fulfill the course for each country; (ii) good education materials, e.g., e-learning and (iii) supports for new-wave students/researchers in terms of graduate scholarships/fellowships and supports for industrial-shaing for research and researcher.

### 3.16. Turkey

#### 3.16.1. Summary

The infrastructure, and research activities performed in recent years in the Laboratories for Radiation & Polymer Science (LRPS) under the Hacettepe University, Department of Chemistry, Polymer Chemistry Division were summarized in the first part of the presentation. The brief history of nuclear science and radiation science and technology in Turkey and overview research centres, institutes and universities related with Nuclear and Radiation Science and Technology was given in details in the second part of the presentation. The undergraduate and graduate education programs related with nuclear sciences and radiation science and technology in Turkey was introduced and the courses given by institute of Nuclear Sciences of Ege University, Energy Institute of Istanbul Technical University Department of Nuclear Engineering, Chemistry Department and Polymer Science and Technology Division of Hacettepe University were presented by using European Credit Transfer and
Accumulation System (ECTS) forms in the thirst part of the presentation. The course objectives, learning outcomes and course contents of some of selected courses presented in details also in this section. In the final part of the presentation the IAEA assistance to Turkey relevant to education, Problems and gaps and future actions and implementation plans were reviewed.

3.17. USA

3.17.1. Summary

The US Department of Energy manages a number of national laboratories such as the Argonne National Laboratory and the Fermi National Laboratory. All of these laboratories are focused on a variety of research projects focused on high energy physics, accelerator technology, and specialized training programs. To develop an inventory of university-based academic programs related to radiation sciences and radiation technology applications, the American Nuclear Society’s online resources were screened for university programs in nuclear engineering. Based on this list, the top 25 university programs were identified and their undergraduate and graduate educational programs were analyzed. A total of 1153 courses were analyzed using a variety of search terms. Based on this analysis, 93 courses (29 at undergraduate level and 64 at the graduate level) were found to be dealing with radiation technology and sciences. This summation of courses may have to be revised based on using newer search terms and screening approaches.

3.17.2. Problems and Recommendations

Very often radiation technology related courses may be offered in departments other than Nuclear Engineering. For example, at Texas A&M University a relevant radiation technology-related course (Microbiology fo Food Irradiation) is offered by the Nutrition and Food Sciences department rather than the Nuclear Engineering Department. It is always a challenge to develop and offer new courses in university departments because successful course offering are always dependent on student enrollment and non-compete provisions with pre-existing courses. A major challenge in developing radiation-technology related courses is the lack of radiation technology on many campuses. Unless the institution is well equipped, these courses tend to become primarily theoretical courses. Another challenge facing the offering of such courses is the limited number of faculty members who have active programs in nuclear technology applications such as in radiation processing, etc.

Given the growing applications of radiation technology in society, there is ample opportunity to develop new graduate and undergraduate courses related to the varied applications of this technology in society. The IAEA can play a key role in the advancement of educational programming related to radiation technology applications and processing. Specifically, there are opportunities to develop new educational modules targeting the K-12 school audience, specialized technical certification programs as well as outreach programs targeting the potential technology end-users. The IAEA Collaborating Centres can serve as an excellent platform for the delivery of these courses. However, the technology that is used to deliver these programs have to be state of the art and very immersive and cutting edge. Failure to employ immersive technologies could lead to diminished impact. Specialized IAEA Technical Certification/Training programs in dosimetry, operating and managing irradiation facilities,
food processing, wastewater treatment, environmental remediation, medical waste treatment, radiation technology related business development could be developed and delivered via one or more IAEA Collaborating Centers. Another IAEA-stimulated research/educational opportunity is the fostering of Collaborating Centre-Industry Consortia. These consortia could be made financially sustainable by adopting a subscription based membership that is customized to regional and national abilities and needs.

4. SUMMARY OF IAEA CONTRIBUTIONS

**Reviewing the current status of education on Radiation Sciences assisted by the IAEA**

For the past 10 years, the International Atomic Energy Agency has been assisting many programs to enhance the education on radiation technology. In total, the Agency has assisted 8 Coordinated Research Projects, 13 Regional Technical Cooperation projects and hundreds of national scale Technical Cooperation projects, 44 Regional Training Courses, 1 E-learning Training Module, 7 publications with many Technical Documents and working materials, 4 Technical Meetings in the past with 1 Technical Meeting and 1 Conference planned for the future.

For the Coordinated Research Projects (CRP), there were 8 Research projects that were either completed or active. In which, 3 projects were completed in the last 5 years and 5 projects are currently active.

In the area of Technical Cooperation (TC), there were 13 Regional Technical Cooperation Projects that were assisted by the agency. Out of 13 Regional Technical Cooperation projects, 4 were related to Materials, 3 were related to Cultural Heritage, 3 were related to Environment, 2 were related to Processing, and 2 were related to Technology. Besides the Regional Technical Cooperation projects, there were hundreds of National scale Technical Cooperation projects to enhance the education on radiation technology.

Under the Regional Technical Cooperation, there was the Regional Training Courses (RTC). In total, there were 44 Regional Training Courses in the last 10 years across 5 regions such as Africa, Asia, Middle East, Europe, and South America. To summarize the trainings for each region, there were 2 RTCs in Africa, 13 RTCs in Asia, 8 RTCs in Middle East, 19 RTCs in Europe, 2 RTCs in South America and a total of 762 people from these regions have participated in these trainings.

Besides the Coordinated Research Projects and the Technical Cooperation, the IAEA has also made E-learning Training Modules and Publications to enhance the education on radiation sciences. The Agency has made 1 E-learning Training Module, 7 publications, and many Technical Documents and working Materials to encourage the education on radiation sciences.

As for the Meetings and Conferences, there were 4 Technical Meetings(TM) in the past with 1 upcoming Technical Meeting and 1 upcoming Conference planned for the future in regards to education on radiation sciences.
5. RECOGNIZED PROBLEMS AND GAPS/NEEDS IN EDUCATION PROGRAMMES IN MEMBER STATES ON RADIATION SCIENCES

The meeting participants identified a number of “needs” in educational programs. The participants categorized these needs based on the intended target groups such as K-12, undergraduate, graduate and professional programs.

K to 12th grade

K-12 students need to be exposed to how radiation technologies are improving the world around them.

K-12 students need to be exposed to possible careers in radiation sciences and technologies.

Undergraduate Program Needs

Degree Programs (universities): Bachelor’s degree in Radiation Sciences and Technology.

There is a need for certificate programs, electronic course modules and electives in Radiation Chemistry/Radiation Biology/Radiation biochemistry/Dosimetry/Radiation Safety/Machine sources/Isotope technology/etc.

There is a need to partner with private industry and develop internship programs relevant to radiation technology applications.

Graduate Program Needs

There is a need for new degrees such as Professional Science Masters/Professional Masters and DES (Diplome Etudes Superior) related to Radiation Sciences and Technology.

There is a need to expand graduate level course modules, courses, and Certificate Programs.

There is a need to effectively communicate radiation technology with other disciplines to encourage transdisciplinary collaborations, graduate student research, and education.

There is a need for more uniform content in courses related to radiation science and technology that are currently included in curricula dedicated to other disciplinary degrees.

There is a need to expand student laboratory based training at Collaborating centers, research institutes/centers, and universities specifically related to radiation sciences and applications.

There is a need to develop and expand graduate student internships in radiation technology related private enterprises.

There is a need to expand Visiting professorships at the IAEA, Collaborating Center, research institutes/centers, universities related to radiation sciences and applications.

There is a need to develop and expand professional seminar series at the collaborating centers, research institutes/centers, universities, and industry.

There is a need to develop and expand graduate student study tours and field visits at the IAEA, Collaborating Centers and private industry.
There is a need to develop and expand digital resources (e-learning) in the form of textbooks, reference material at the IAEA, Collaborating Centers, research institutes/centers, universities, industry.

There is a need to develop and expand master and doctorate student fellowships at the IAEA, Collaborating Centers, research institutes/centers, universities, and industry.

**Industry/Policy Maker/Government Needs**

There is a need for short courses, seminar series, and Certificate programs that are developed and delivered by the IAEA, universities, private industries, research centers, and collaborating centers). These short courses could focus on:

- Radiation sources
- Industrial applications of radiation technology
- Equipment repair and service
- Dosimetry (affordable and accessible, language sensitive, eg., in Russia)
- Entrepreneurship programs (business model development, ROI, etc etc)

There is a need to develop 1-day/2-days workshops aimed for Executives and decision makers in government and private industry as it relates to radiation technology applications. These workshops should emphasize value propositions such as green technology, reduced carbon footprint, value-added products, expanded export markets, small business development, knowledge creation in population, and ability to transfer knowledge from academia to industry.

**Research Base Needs**

There is a need to train personnel for expanding R&D in radiation sciences and technology using one year post-graduate course, pre- and post doctoral fellowships that are administed through collaborating centers, universities, research centers and institutes.

**Regional Technology Centers (IAEA, local government, industry, collaborating center)**

There is a need for the establishment of regional radiation technology centers either through existing collaborating centers or research centers/institutes.

**General public**

There is a continuous need for materials (both printed and digital) for public service announcements, social media platforms, open days, speakers to local schools, technology introduction to other professional/public societies, high schools and university clubs.
6. CONCLUSION

While the previous and current education-oriented IAEA activities are addressing some of the needs of the radiation technology community worldwide, representatives of the Member States present at the TM believe that there is a definite need and opportunity for expanding IAEA actions in the field of education, including actions reaching beyond the well-established system of tools used in the regional and national Technical Co-operation Projects.

Analysis of country reports and extensive discussions have led to a set of recommendations for short-term and long-term actions. They include stronger involvement of IAEA Collaborating Centers in educational activities, but also emphasize the need of coordinating their actions with universities, professional organizations and societies, as well with radiation industry and potential end-users of radiation technologies.

As the most desired long-term action the participants identified the need of establishing, in a coordinated action, an international academy for Radiation Science and Technology, with the main goal of organizing one-year postgraduate studies fully devoted to radiation sciences and its industrial applications. The participants stressed that this can be only achieved by common efforts of partners from academia, research and industry, with efficient support of IAEA and its Collaborating Centers.

It was concluded that establishing of graduate level International Academy for Radiation Science and Technology under the framework of IAEA will provide synergetic effects for the recruiting the best graduate students worldwide and enhance the interest to the radiation science and technology and its application.

It is essential to design and develop peer-reviewed curricula and course material for the education and training of the future world-class scientists and technologists in the field of Radiation Science and Technology.

It was concluded that the lack of access to radiation facilities (for education and research) in some regions of the world is currently hampering wider exploitation of these technologies. Therefore, the availability of IAEA Collaborating Centers and the development of regional technology centers can go a long way in addressing these educational needs.

The meeting participants concluded that these improvements in educational activities and outreach efforts will have significant impacts on the future generations, industry, and society at large.

Meeting participants concluded that for effective implementation of these collaborative efforts to enhance educational activities, there will be a need for IAEA to facilitate the official documentation of collaborative arrangements.
7. RECOMMENDATIONS

7.1. "Near Term” recommendations:

- IAEA is recommended to include radiation technology related education and training with current activities related to knowledge management such as AFRANEST, LANENT, ANET.

- IAEA is recommended to establish a technical expert panel to elaborate and implement a strategy for the development of techno-scientific curricula, higher education courses, and peer-reviewed supporting material to be adopted as a gold standard in the field of radiation science and technology for non-power applications. These materials should be maintained on a website as a repository.

- IAEA is recommended to expand regional training programs to emphasize the education of the fundamental principles of the underlying radiation science and technology.

- IAEA is recommended to support the development of appropriate e-learning modules related to radiation sciences and technology and applications.

- IAEA is recommended to expand regional training programs into interregional training programs such as summer schools or winter schools utilizing the Collaborating Centers, research centers, and universities to the maximum extent possible.

- IAEA is recommended to initiate a new concept of interregional technical cooperation projects focusing on the education of radiation technology applications.

- IAEA is recommended to sponsor Visiting Professorships, study visits, workshops, and conferences (that promote student and early-career scientists’ participation) focusing on radiation science and technology.

- IAEA is recommended to continually improve the delivery of educational programs by adopting new technology platforms to enable remote access, e-learning, and evaluation. Appropriate Collaborating Center involvement in these activities is required.

- The IAEA is recommended to develop Technical certification programs in specific topic areas to meet the needs of the radiation technology industry.

- The IAEA is recommended to promote the participation of private industry in the development of entrepreneurship programs to commercialize radiation technologies.

- The IAEA is recommended to promote linkages with other international programs such as EU H2020.

- The IAEA is recommended to partner with transdisciplinary professional societies and enable the development and delivery of radiation technology educational programs to these societies.

- The IAEA is recommended to provide challenge funds to stimulate IAEA Collaborating Centre- Private Industry consortia to support fellowships, R&D and educational activities.
• The IAEA is recommended to expand the Collaborating Centre program by identifying new focus areas in radiation technology applications given the evolving diversity of applications and technology needs.

• The IAEA is recommended to adopt successful internet-based K-12 outreach activities. Effective internet-based K-12 activities specific for other subject matters that already exist can be used as examples.

7.2. “Long-Term” recommendations:

• The IAEA is recommended to support the development of regional radiation-technology centers to support technology demonstration, educational programs, and technology applications.

• The IAEA is recommended to promote the integration of radiation science courses into academic degrees related to areas such as polymer chemistry, biology and environmental engineering.

• The IAEA is recommended to promote and support the institution of a MSc/Ph.D.-level *International Academy for Radiation Science and Technology* involving experts as faculty and recruiting the best graduate students worldwide. The course delivery should be based on the most effective modality and should involve different IAEA Collaborating Centers.

• IAEA is recommended to support member states to acquire irradiation and related equipment to support educational activities in radiation processing.

• The IAEA is recommended to suggest a particular year as the Year of Radiation Science & Applications.
REPORTS BY PARTICIPANTS IN THE TECHNICAL MEETING
PRESENT STATUS OF EDUCATION PROGRAMMES ON RADIATION SCIENCES IN ARGENTINA

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1. INTRODUCTION

Educational activities and Human Resources development programs, related to Radiation Sciences and Technology, are performed mainly by three academic institutes which belong to the CNEA (the National Commission of Atomic Energy) and national universities:

- Instituto Balseiro (IB) belongs to the CNEA and Universidad Nacional de Cuyo (UNCU), created in 1955. Since 1977 it has a regular course of Nuclear Engineering (the oldest course in Latin America). The Institute shares the campus with the CAB (Bariloche Atomic Center)- (in Bariloche city).

- Instituto Sabato (IS) belongs to the CNEA and Universidad National de San Martin (UNSAM), created in 1993. The main focus is the Metallurgic Engineering. The Institute shares the campus with the CAC (Constituyentes Atomic Center) in San Martin city.

- Instituto Dan Beninson (IDB) belongs to the CNEA and UNSAM, created in 2006. The Institute shares the campus with the CAE (Ezeiza Atomic Center) in Ezeiza city.
2. REVIEW OF REGULAR COURSES IN THE FIELD OF RADIATION SCIENCES AND TECHNOLOGY

The following regular courses, which belong to the three Institutes mentioned before (in brackets), are taught by Professors from universities and researchers from the CNEA and the CONICET (National Scientific and Technical Research Council – Argentina). There are courses of different duration, which can be classified in: technical studies; degree studies (> 2,600 hrs.); specialization studies (>360 hrs.); Master studies (>540 h + 160 hrs. experimental work) and Doctorate studies.

Technical studies

- Nuclear Applications (IDB)

Degree studies

- Physics (IB); since 1955.
- Nuclear Engineering (IB)
- Mechanical Engineering (IB); since 2003.
- Materials Engineering (IS); since 1993.
- Telecommunications Engineering (IB); since 2012.
- Nuclear Engineering. Application oriented (IDB); since 2015

Specialization studies

- Technological Applications of Nuclear Energy. CEATEN (IB - UBA); since 1995.
- Radiochemistry and Nuclear Applications (IDB)
- Non-destructive Testing (IS)
- Nuclear Reactors and Fuel Cycle (IDB)

Master studies

- Master in Physics Science (IB); since 2003.
- Master in Medical Physics (IB-FUESMEN); since 2003.
- Master in Nuclear Engineering (IB)
- Master in Engineering (IB)
- Master in Material Science and Technology (IS)
Doctorate studies

- Physics PhD (IB); since 1965.
- Engineering Sciences PhD (IB); since 1998.
- Nuclear Engineering PhD (IB); since 1975.
- Science and Technology - Physics PhD (IS); since 1998.
- Science and Technology - Materials PhD (IS); since 1998.
- Nuclear Technology PhD (IDB); since 2010.

It is important to remark some features of these courses to improve the quality of learning: (i) hands-on learning; (ii) few students/course; (iii) high professor/student ratio; (iv) teachers are active engineers, technologists and scientists; (v) all students have a full fellowship (CNEA fellowship); (vi) admission process is free of charge; (vii) low desertion rate (<10%) and (viii) well-defined course duration and (ix) an academic council. Other interesting features are: (i) it is not required the Argentine nationality; (ii) students should have passed four semesters of Physics, Engineering or similar courses/studies for the admittance and (iii) they should pass an admission exam (once a year in six Argentinean cities and other cities abroad according to the student nationality).

More than 60 foreign students have graduated from CNEA Institutes and hundreds have attended topical courses, seminars and training internships.

In the specific subject of Radiation Science and Technology there are only one technical degree, one degree and one specialization degree, just started this year in the IDB (see above, highlighted) in the field of applications. However there are many topics included and the radiation processing applications is a minor one.

3. REVIEW OF INITIATIVES AT UNIVERSITIES TO INTRODUCE RADIATION SCIENCE/TECHNOLOGY COURSES

Other institutions, in collaboration with CNEA, enhance the Human Resources formation in radiation sciences:

- The CUTEN (University Center of Nuclear Technology), since 2013 created by the CNEA in collaboration with Universidad Nacional de Cordoba (UNC). This centre has the reactor RA-0 for experimental and teaching activities (since 1969) corresponding to practices of Biomedical Engineering and Electronic engineering courses. See the courses in the previous item.
- The Universidad Nacional de Rosario (UNR) has had a nuclear reactor (RA-4) for research and teaching purposes since 1972. Experimental and teaching activities correspond to experimental practices of Physics degree.
The FUESMEN (School of Nuclear Medicine Foundation), since 1991. See the courses in the previous item.

In addition, other Universities teach courses related to Nuclear Technology and Medicine:

- Technical studies in Nuclear Medicine (Universidad de Buenos Aires) since 2013.
- Medical Physics (UNSAM)
- Medical Physics (Universidad Nacional de La Plata)
- Medical Physics Engineering (Universidad Favaloro)
- Specialization in Nuclear Medical Physics (UNSAM)
- Master in Medical Physics (UBA)

4. REVIEW OF THE IAEA ASSISTANCE TO EDUCATION

The most important IAEA assistance to Argentina and Latin America was through the ARCAL program (Regional Agreement for promotions of Nuclear Science and Technology in Latin America and the Caribbean) which has been running since 1984 (http://www.arcal-lac.org/index.php/en/que-es-arcal/como-nacion-arcal). Since the launch of the program, the member countries -together with the IAEA- have made different contributions of funds for the implementation of the workshops, courses, meetings, seminars, training and equipment necessary for the development of the project activities. 20 member States have joint this strategic program until now. In the last two years (2013-2014) the revision of the previous ARCAL program (2007-2013) was finished and the new Regional Strategic Profile (PER 2016-2021) has been prepared, according to the new socio-economic context of the member States.

The RLA0039 project corresponding to ARCAL CXX had the main objective to create the Latin America Network for Collaboration and Education in Nuclear Medicine (2009). In addition, the CNEA and their Academic Institutes are founding members of the Latin American Network for Education and Training in Nuclear Technology (LANENT) during 2009.

On the basis of a practical arrangement signed in 2012, the IAEA Cyber Learning (CLP4NET) Platform has been installed and is operated by the CNEA as the hub for Latin America.

In 2008 IB was designated as an IAEA Collaborating Centre for Human Resources Development for Nuclear Technologies and their Applications. Period 2008-2012.

In 2013 it was signed a common action plan among different regional nuclear educational networks such as AFRA-NEST(Africa), ANENT (Asia), ENEN (Europe) and LANENT(Latin America) in order to perform a collaborative work.
5. REVIEW OF NEEDS FOR IAEA ASSISTANCE, DEFINITION OF PROBLEMS AND GAPS

Argentina has low development in the area of Radiation Processing and their applications to the industrial process. Also the number of researchers in the field is not enough to have a critical mass to be sustainable in the coming years and support the education of future generations of researchers, experts and teachers. Therefore, an international cooperation in the field of education with other Members States, especially with regional members, is a great opportunity to change the present situation.

Incentives to increment the regional cooperation in the field could be another important action to strengthen the educational activities.

The production of a digital information repository, to be loaded on the e-learning platform, is a critical issue of an e-learning platform. Also the use of Spanish/Portuguese language is mandatory for a high penetration of the platform in the country and in the Latin America region.

6. SOLUTIONS, FUTURE ACTIONS AND IMPLEMENTATION PLAN.

The use of e-learning platforms will enhance the Human Resources development in the field of radiation technology. However, the experimental activities are highly motivating actions during the learning process to adopt this technology. Therefore, a ‘mix-mode’ teaching (e-learning plus experimental activities) looks like the most promising system. The lack of (educational) facilities is an important subject to be overcome. The country has only one multipurpose Co-60 gamma facility, a gammacell with very low activity and no e-beam machine.

In order to support educational and research activities in this field with an appropriated experimental training, it is suggested the following possible actions:

(i) Support the cooperation in educational aspect with the Member States, with the especial focus in Latin America Member States;

(ii) Impulse the mobility of student and teachers to partner institutions in other countries, especially regional ones, to create Human Resources in the field;

(iii) Support to the country to obtain educational equipment for performing a sustainable development.
RADIATION SOURCES EDUCATION IN BRAZIL

A.A. Da Silva

Brazilian National Energy Commission – CNEN

There are 05 nuclear research centers supported by CNEN that provide graduate program in the nuclear field in Brazil. Some of them have several research activities related to Radiation Sources Technology:

1. The Radiation Technology Centre (CTR) – Institute of Energetic and Nuclear Research (IPEN), in São Paulo, SP;

MSc and PhD Courses

The Radiation Technology Centre (CTR) was founded in 1972 at IPEN, to disseminate and consolidate the techniques that lead to radiation technology and radioisotope applications in industry, in Human Health, Agriculture and Environmental Protection in Brazil. The development of scientific knowledge, human resources, technology transfer and generation of products and services are aimed at different segments of Brazilian society.

1.1. Nuclear Techniques Application Areas

Research and development, innovation, products and services are performed in this center, supporting local industries and scientific communities regarding the use of radiation technology. The Ionizing Radiation Applications program is in line with the Director Plan of the IPEN/CNEN. This program has four sub-programs:

- Food and Agricultural Products Irradiation;
- Radiation and Radioisotopes Applications in Industry and Environmental Protection;
- Applications of Radioisotopes and radiation on human health, and
- Radiation Infrastructure and Facilities and Nuclear Instrumentation for Technical Applications.

Concentration Areas

The Graduate Program at IPEN/CNEN has Master (02 years) and PhD (04 years) degrees concentrate in the following areas:

- Nuclear Technology - Applications
- Nuclear Technology - Materials
- Nuclear Technology - Reactors

2. CDTN / CNEN (Belo Horizonte-MG-Brazil)

Msc and PhD Courses

Concentration areas: Science and Technology of Materials, Science and Technology Radiation, Science and Technology of Minerals and Environment and Science and Technology of Nuclear Reactors

Research areas:

NANOTECHNOLOGY - Study of the synthesis of nanomaterials and correlation between its structures and physical, chemical and biological properties.

NEW MATERIALS - Study of new materials related to nuclear engineering.

METROLOGIA RADIATION - Study of techniques and methods of metrology of ionizing radiation for applications in diagnostic radiology, radiotherapy and nuclear medicine.

IONIZING RADIATION IN HEALTH AND BIOLOGY - Study of the use of ionizing radiation for the development of vaccines bio-remediators, probiotics, and radioactive molecules for diagnosis and therapy and food biosafety.

GEOCHEMISTRY AND GEOLOGY IN MINERAL RESOURCES AND ENVIRONMENT - Study mineral crystal chemistry, geochemistry and fluid in strategic mineral deposits and rocks suitable for implantation of radioactive waste repositories.

METALURGIA EXTRACTION AND ENVIRONMENT - Study of industrial processes for their improvement and obtaining high purity products, in compliance with environmental requirements.

TECHNICAL NUCLEAR INDUSTRY AND ENVIRONMENT - Study of nuclear techniques in industrial and environmental processes.

NUCLEAR REACTORS TECHNOLOGY - Studies in technology of nuclear reactors involving theoretical methods for neutron analysis and Thermal Fluid Dynamics systems and components of nuclear and radioactive facilities, thermo-hydraulic and experimental use of the research reactor TRIGA IPR-R1.

STRUCTURAL INTEGRITY - Study of experimental or numerical techniques for the characterization of defects and description of the mechanical behavior and structural components of nuclear, to establish the damage stage and the prediction or life extension.
3. IEN/CNEN (Rio de Janeiro-Brazil)

MSc Course

3.1 Research Activities:

Concentration Areas: Technology and Reactor Safety, Applied Computational Methods, Environmental Impact of Nuclear Facilities and Nuclear Technical Applications

Research areas:

- Reactor Physics
- Thermohydraulics
- Structural Mechanics
- Accident Analysis and System Reliability
- Technical Ultrasonic Non-conventional and Measures
- Experimental assemblies, Similarity Systems and Reduced Scale
- Interest Nuclear Materials
- Nuclear Fuel Cycle
- New Concepts of Nuclear Reactor
- Safety and Licensing Reactors
- Computational Mechanics
- Artificial Intelligence
- Human Factors
- Virtual Reality
- High Performance Computing
- Robotics and Control
- Control Room engineering
- Risk analysis
- Radiological Impact
- Selection of Sites
- Waste management
• Environmental Modeling
• Radioecology
• Biokinetics Radioisotopes;
• Radiotracers for application in the oil and gas industry;
• Application of nuclear techniques in multiphase systems (water / oil / gas);
• Evaluation and optimization of wastewater treatment plants, industrial and urban, using radioactive tracers;
• Measurements in mineral transport systems employing gamma radiation sources;
• Radionuclides technology application in mechanical wear of materials analysis

4. IRD/CNEN (Rio de Janeiro-RJ-Brazil)

MSc and PhD Programs

The IRD is a National Reference Center in the areas of radiation protection and metrology of ionizing radiation relating to applications of ionizing radiation in medicine, industry, power plants and other fields of human activity, aimed at worker protection, patient and the public in general.

The Doctoral and Master Programs are concentrating in the following areas:

• Radiation Biophysics
• Medical Physics
• Metrology
• Radioecology.

5. CRCN-NE/CNEN (Recife – Brazil)

The Post Graduate Program in Nuclear and Energy Technologies (PROTEN) is linked to the Technology and Geosciences Center (CTG / UFPE) and the Northeast Regional Nuclear Sciences Center (CRCN-NE / CNEN). It is the responsibility of the Department of Nuclear Energy (DEN) of UFPE (Federal University of Pernambuco), the only institution of the North and Northeast with experience and proper qualifications to train human resources in nuclear technology.

Areas of Concentration:

• Radioisotopes Applications in Agriculture and Environment
• Radioisotopes Applications in Industry and Medicine
• Dosimetry and Nuclear Instrumentation
• Reactors Engineering
• Renewable Energy Sources
ENHANCING EDUCATION PROGRAMMES ON RADIATION SCIENCES IN COOPERATION WITH IAEA COLLABORATING CENTRES (CANADA)

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INTRODUCTION

Canada has been always in the forefront of world developments in nuclear science. Canada is strongly involved in the area of power production, cancer therapy and diagnostics, on the production of medical and industrial radio-isotope and gamma processing (Kunstadt, 1990). With the foundation of the Canadian Irradiation Centre in 1987, where the Atomic Energy Canada (now Nordion Int.) and the Institute Armand-Frappier (now INRS – Institut Armand-Frappier) joint their effort to assure the formation and training in irradiation of new scientists, to deliver training to industry and regulators in the safe and efficient operation of industrial irradiator, to demonstrate the Canadian technology, to assure technology transfer and to develop by the scientists new technologies in irradiation. Since the opening of the Canadian Irradiation Centre in 1987, collaborations with IAEA were assured for fellowship training, to deliver short training (i.e. Food Irradiation Process Control School (FIPCOS) course) and for research collaboration (research coordination meeting (RCM)).

Several other institutions in Canada provide formation in irradiation (University of British Colombia, Dalhousie University, University of Ontario and the Radiation safety Institute of Canada. This paper will describe the status of education on radiation sciences in Canada and propose some avenue to assure international training via e-learning, online modules and identify focus area of research to address emerging avenues for irradiation technology applications.

EDUCATION PROGRAM IN CANADA

1. Nordion Int.

Nordion Int. delivers relevant and insightful training courses to a wide range of industry professionals. They provide effective, hands-on instruction—basic, advanced and specialized—that takes full advantage of their comprehensive facilities. Their training courses are related to:

- Radiation Safety in Industrial Irradiation Operations
- Radiation Safety Review for Irradiator Operators
- Radiation Safety Officer
• Facility and Process Management (Includes course components on basic, advanced and specialized industrial irradiation operations)

• Industrial Irradiator Operator

• Irradiator Technology for Inspectors

The objective of the Radiation Safety in Industrial Irradiation Operations course is to provide participants with a basic understanding of radiation safety principles, procedures, and practices relevant to industrial irradiation operations. The course is designed to meet the United States Nuclear Regulatory Commission (U.S.N.R.C.) requirements as part of the training of irradiator operators.

The course of the Radiation Safety Review for Irradiator Operators can ensure continued safe operation of an irradiation facility, proper training of operating personnel, and to meet training regulations. The course is also recommended as a procedural review for a radiation facility.

The Radiation Safety Officer course is a comprehensive program for organizations with either an industrial or research irradiator. The objective of the course is to prepare participants to qualify as Radiation Safety Officers (RSO) for full-scale, gamma irradiation facilities.

The Facility and Process Management course is to help prepare new or potential facility managers perform their job. Content of the courses covers basic, advanced, and specialized industrial irradiation operations. The Industrial Irradiator Operator course is to prepare participants to become licensed irradiator operators. Finally, the Irradiator Technology for Inspectors course is to provide participants with a comprehensive overview of the technology so that they can perform thorough inspections.

2. Radiation Safety Institute of Canada

The mission of the Radiation Safety Institute of Canada is the prevention of cancer, occupational illness and injury from unacceptable exposure to radiation. This institute assures training courses related on:

2.1-x-Ray Safety

• Understanding of atomic properties

• Comprehension of radiation types and properties

• Detailed knowledge of x-ray production and types of x-ray machines

• How x-rays interact with matter and shields

• Knowledge of types and sources of x-ray exposure and effects of x-rays on human health and genetics

• Knowledge of select Ontario Ministry of Labour Occupational Health and Safety Act X-Ray Safety regulations
2.2- X-Ray Safety Officer (XSO)

- Understanding radiation
- X-rays: radiation made by machine
- Radiation quantities and units
- Biological and health effects of exposure to X-rays
- X-ray systems, X-ray imaging and safety survey
- Scattering and attenuation of X-rays
- Radiation detection, instrumentation and dosimetry
- Radiation protection principles and practices

This formation permits a comprehension of radiation types and properties. Gives information to how radiation doses can be calculated and measured. The effects of radiation exposure on human health and genetics are covered as well as the control of external and internal radiation exposure. The contamination risks and procedures related to radioactive sources and the operating and emergency procedures related to radioactive substances and devices are covered. Finally, the program will permit the familiarization with select Canadian Nuclear Safety Commission regulations.

3. Dalhousie University

The Dalhousie University offers a training course on radiation safety. The training cover the properties of irradiation; the biological effects of irradiation; the basic irradiation protection; give some keys to contamination control; procedure information on radioactive decontamination procedures; provide policies on radiation safety and on Sealed sources and Gamma cell irradiator.

4. University of Ontario

The University of Toronto offers a four-year Bachelor of Science in Health Physics and Radiation Science program. The program provides an advanced science curriculum with a strong emphasis on the safety aspects of ionizing radiations.

The program included formation in:

- Mathematics
- Physical and biological sciences and Technology.
- Radiation detection and measurement
- Imaging
- Radiation biophysics
- How radiation is produced and used in a wide range of applications
- Specialization and includes two thesis projects
- Included in the program are courses such as
  - Industrial Applications of Radiation Techniques
  - Introduction to Nuclear Reactor Technology
  - Medical Imaging
  - Radiation Biophysics and Dosimetry
  - Radiation Detection and Measurement
  - Radiological and Health Physics
  - Therapeutic Applications of Radiation Techniques

5. University of British Colombia

The University of British Colombia in Canada provides a course on Preservation of Food with ionizing Energy. The content of the course cover:

- Types of source of ionizing energy and irradiator layout
- Regulations in Canada and in other countries
- Wholesomeness and safety of food irradiation
- Preservation principle about food irradiation
- Concerns about food irradiation
- Factor affecting food irradiation
- (safety, resistance of microorganisms and enzyme, cost)
- Potential applications
- Consumer acceptance
6. INRS-Institute Armand-Frappier and the Canadian Irradiation Centre (CIC)

6.1 Formation

6.1.1 Formation in collaboration with IAEA

INRS-Institute Armand-Frappier and the CIC were involved for several years on the Food Irradiation Process Control School (FIPCOS) Training course. The program included:

- Biological effect of irradiation
- Radiation Chemistry basics
- Radiation chemistry on food biochemistry
- General effect of radiation on food components
- Effect of irradiation on nutritional value of foods
- Application of irradiation for fruits, vegetables, meat, cereals,
- General effect of irradiation on packaging
- Irradiation and insecticides
- Type of irradiators
- Safe operation of an irradiation facility
- Dosimetry

6.1.2 Formation at INRS-Institute Armand-Frappier

A professional master program based on the content of the FIPCOS training course was developed at CIC. However, only 1 student has done his inscription and the program has been post-pone. Then, the program was abandoned, because of the lack of scientists involved. Some years after, CIC has started the preparation with IAEA of an educational program for a superior diploma of study via distant learning modules, with the involvement of all international recognized scientists in irradiation in collaboration with IAEA. Again, the preparation of the program was abandoned.

However, INRS-Institute Armand-Frappier offers a Master in Applied Microbiology and a Ph.D. in Biology. The master degree is a formation of 2 years of research including 4 months of lectures. The Ph.D. in Biology is a 4 years of research. The research and graduated studies formation in irradiation is offered through the Research Laboratories in Sciences Applied to Food and through the Canadian Irradiation Centre.

Research in the bio-food sector ensures innovation through the development of new technologies, new processes, new ingredients and concrete solutions to industrial problems. The Research Laboratories in Sciences Applied to Food and the Canadian Irradiation Centre offer research activities on the:
• Development of different combined treatments with gamma irradiation (mild heat, ozonation) in food systems to assure food innocuity.

• Development of different combined sanitation treatments using novel technologies in order to increase the bacterial and insect sensitivity and to improve the food quality.

• Development of different reinforced and biodegradable active films and coatings using nanopolymers and natural polymers for their biodegradability

• Use spices, fruit or plant extracts, and probiotic bacteria metabolites for their antimicrobial, insecticide, antioxidant for the development of combined treatments with irradiation.

• Development of intelligent reinforced films for pathogens detection

6.2 Training

The Canadian Irradiation Centre (CIC) and INRS-Institute Armand-Frappier is also well involved in international research collaborations and training in collaboration with IAEA. Since the opening of the CIC, this Institute has assured the formation of more than 34 trainees who came from over 15 countries through IAEA fellowship. This institution has also collaborations with other universities in France, USA, Antilles, South America, China and Central America.

6.3 Feasibility studies and transfer of the technologies

The CIC has done in collaboration with the Thai Irradiation Centre (TIC) and Nordion Int., feasibility studies in order to submit to Health and Welfare in both countries petitions to accept in Canada and in Thailand the irradiation of mangoes, papayas and Tiger Shrimps. More than 6 trainees came at CIC via Training Fellowship from IAEA between 1987 and 1992.

6.4 Transfer of knowledge

With the presence of the Museum Armand-Frappier in the campus of INRS-Institut Armand-Frappier, transfer of knowledge in food irradiation and food innocuity is assured. The museum organizes also summer camp of 1-2 weeks for children and teenager to encourage them to pursue in the future career in sciences. The young students can participate to scientific experiments with graduate students and present at the end of the camp a seminar on what was done with the presentation and the explanation of the results. Also, the Museum Armand Frappier is planning to found the Center of Science Interpretation for the general public. Finally, a one day formations are also organized with the participation of the parents in order to transfer the knowledge and the novelty in sciences including irradiation technology.

6.5 Scientific productivity following collaboration with IAEA and other universities

The CIC had until now an important productivity in irradiation following collaboration with IAEA members and other universities.
Since the last 28 years, 25 Master degrees, 12 Ph.D. have been awarded at INRS-Institut Armand-Frappier and since the last 5 years, 25 professional master degrees have been awarded at INRS-Institut Armand-Frappier on the development of irradiation technology. The number of publications on each research program can be enumerated that way:

- Films: grafting, reinforcing, crosslinking: 38
- Food Coating and irradiation: 15
- Insect and molds radiosensitization: 2
- Bacterial Radioresistance and Mechanism of action: 21
- Bacterial radiosensitization: 56

Total: 132

Following collaboration with IAEA, 6 Book Chapters and tecDoc documents were produced. The CIC was also invited to publish an article on the recommendations following the nuclear accident in Japan. The publication reference is:


7. Suggestions of appropriate e-learning modules for online training materials and focus area research to address the emerging avenues for radiation technology applications.

7.1 Online training

Food irradiation is a safe technology who can assure food safety. However, the adoption of this technology is very slow. The lack of knowledge of the population is one of the reasons for the present situation. The education of consumers, consumer-marketing, technician, industrials and inspectors about current developments in food irradiation is essential to avoid situations perceived high risk (Thompson et al., 2004). Until now, some individuals believe that irradiation can make the food radioactive, can cause cancer, can decrease the nutritional value of foods and can even make spoiled foods marketable (Lumpe et al., 2000). The development of computer simulation for a visit of a food irradiation research and industrial irradiation facilities, presentation of scientists and industrials involved in food irradiation to describe the opportunities and challenges, and the research in this field will help to the adoption of the technology (Thompson et al., 2004). According to Thompson and Knight (2015), professional training can significantly change beliefs and change behaviors toward food irradiation.

The development of an international e-learning programs in collaboration with the IAEA, adapted for students, scientists, inspectors, industrials, consumer-marketing and consumers will permit the development of the technology and assure a good and affordable formation in irradiation throughout the world.
7.2 Recommendations

The recommendation is to reactivate the program of Master or a Superior diploma of study already under preparation by the CIC via distant learning modules in collaboration with IAEA and all members. It is suggest to develop e-learning in Irradiation Technology for students, technicians, inspectors, industrials and professional in health science and to give basic formation for the general public. The formation could include basic information on:

- Biological effect of irradiation
- Radiation Chemistry basics
- Radiation chemistry on food biochemistry
- General effect of radiation on food components
- Effect of irradiation on nutritional value of foods
- Application of irradiation on food
- Type of irradiators
- Safe operation of an irradiation facility
- Dosimetry

It is also suggested to give e-learning formation in new technologies for scientists or as superior studies. This formation could include:

- Irradiation and biological radioresistance and radiosensitization
  (Bacteria, Insects, Parasites and Viruses resistance: mechanism studies)
- Irradiation on chemistry and biochemistry
- Combined technologies with irradiation to assure bacterial, insects, parasites and viruses radiosensitization.
- Irradiation and polymer science including biodegradable packaging, active packaging and coating, using crosslinking and grafting
- Irradiation and polymers for medical applications or other industrial applications
- Irradiation and insecticides degradation
- Irradiation of Food for immunocompromised people

7.3 Emerging area research

Bacterial, Insect, Parasites and Viruses resistance and their mechanism studies as well as the development of technologies to assure bacterial, insects, parasites and viruses radiosensitization using
combined treatments with irradiation still has to be developed to assure food safety. In this regard, development of stable active coatings, encapsulations and new packaging materials is also needed and has been proposed as novel alternative treatments to assure food safety.

Research on irradiation for diverse polymers, improvement of plant resistance or for the development of new plant varieties represent also emerging technologies. The effect of irradiation on residual insecticides by-products on food has also to be known. Very few studies have been done in these aspects.

Finally, the development of irradiation of Food for immunocompromised people represent a need and the education of professional in health science will be probably have a benefit effect on the development and on the adoption of the technology for immunocompromised people.

7.4 Needs for IAEA assistance

Creation of IAEA Collaborating Center in order to facilitate collaboration and create synergy between participants of member countries to offer these following services in irradiation:

1- Creation of a research network with researchers from member countries
2- Applied research and Transfer of technologies to industries via post-graduate studies via the research network
3- M. Sc. and Ph.D.
4- Training fellowship in specific area
5- Professional master
6- Technical certification
7- Continuing formation certificate

REFERENCES


PRESENT STATUS OF EDUCATION ON RADIATION SCIENCES IN CUBA

Alejandro Hernández Saiz, MSc.


Cuba is a member of IAEA since its creation in 1957 and began to receive the benefits of the Technical Cooperation since 1977. The Ministry of Science, Technology and Environment (CITMA) is the liaison organization between the Cuban Government and IAEA. On behalf of CITMA, the Agency for Nuclear Energy and Advance Technologies (AENTA), acts as the National Liaison Office for the Technical Cooperation with IAEA to coordinate, promote and manage projects and programs with nuclear profile.

The Nuclear Program in Cuba includes practices with radiation in medicine, industry and research. Organizations deals with radiations science in Cuba are divided into two main categories: those which promote and develop nuclear applications and those which regulate them. Applications are mainly developed by institutions grouped in the AENTA, the Ministry of Public Health (MINSAP), the Ministry of Agriculture and the Ministry of Industries and regulated by the National Center for Nuclear Security (CNSN/CITMA), the State Center for the Control of Drugs and Medical Equipment (CECMED/MINSAP) and the National Group for Environmental Health (DNSA/MINSAP), which acts as the Regulatory Board for Radiodiagnostic.

Radiotherapy, Nuclear Medicine and Radiology are among the more widely used medical practices in Cuba. A project in course is devoted to introduce new medical technologies for the production of positronic radionuclides. The first cyclotron and associated equipment for medical uses will be installed in the near future.

Among the industrial practices it can be mentioned: Industrial irradiation, industrial radiography, nuclear gauges, and use of radiotracers, oil well logging and others. Concerning industrial irradiation, three industrial irradiators (60Co) are installed in Cuba, two of Category I and other of Category IV, according to the usual classification. Due to the low activity of radioactive sources, the existent facilities can’t respond to the demand of irradiation services and research projects in radiation processing. Nevertheless there has the regulatory base and standards that guarantee the correct application of this technology. In the frame of the Technical Cooperation with Sharing Investments, Cuban government has the willingness to evaluate the feasibility to finance a part of the necessary funds to acquire new irradiation facilities. Nowadays a project in course is set to get the Category IV irradiator to be operative again.

AENTA employs more than 700 persons (708), more than 400 (404) are scientists and engineers. They are assisted by more than 200 (214) technicians with bachelor degree and about 90 in the support staff. Among the 404 university degree, 30 % (about 120) are graduated with nuclear profiles.
Human resources with nuclear profiles (university degree) to be employed in medical, industrial and research institutions are being formed during the last 30 years basically in the Higher Institute for Technologies and Applied Sciences (InSTEC), subordinated to the Higher Education Ministry. Other institutions, mainly subordinated to the Ministry on Public Health also contribute to building competence. The formation of professionals at InSTEC includes basic sciences, mainly in nuclear technologies. Three university degrees in Nuclear Physics, Nuclear and Energetic Technology Engineering and Radiochemistry are developed in five years duration courses. A Master Degree program includes the same three degrees and also Medical Physics. A PhD program (in different modes) also includes the three specialities. InSTEC keeps strong relationships with Universities and research centers in Latin America and Europe.

Another institutions have been implemented another initiatives in order to prepare the human resources. Here it can be mentioned Diplomas in Medical Physics, Radiotherapy Physics, Radiation Protection and Physical Aspects of Nuclear Medicine.

For almost 20 years the Center for Radiation Protection and Hygiene (CPHR) has been organizing the National Course on Fundamentals of Radiation Protection. The course is aimed to bring a general training to Radiation Safety Officers from the whole country and has the formal recognition of the Regulatory Authority. The course is a two weeks long and is organized twice in a year. Since 1996, more than 500 professionals from medical, industrial and research institutions have participated in the course. Other actions related to building competence in Radiation Protection are:

- Conception of a Postgraduate Specialty in Radiation Protection, based on the IAEA Syllabus (similar to that implemented in Argentina).
- Accept an IAEA Peer per View Mission (EduTA) for 2016.
- To establish an IAEA Regional Training Center.
- Formal recognition for courses providers.
- Implementation of a National Strategy for Education and Training on Radiation Protection, through the application of an IAEA approach published in RS-G-1.4 “Building Competence in Radiation Protection and the Safe Use of Radiation Sources”.

E-learning in programs on radiation sciences has not a broadly presence in the building competence in Cuba. Two initiatives of CPHR and one of InSTEC have been implemented. The initiatives of CPHR are Virtual courses on Fundamentals of Radiation Protection and Radiation Protection in Radiodiagnostic. Both courses have been located in an Internet Services Provider server, to facilitate a broad access from the whole country and overseas. Five and one editions respectively have been finished. A total of 86 professionals have taken the courses. InSTEC has conceived and organized e-learning courses to support the presence courses. The main advantages are: Improve the efficiency of the teaching process, less time to acquire knowledge, save time in presence mode activities and allow the self-diagnostic of students.

For almost 40 years IAEA has been supported the Cuban efforts, not only in nuclear activities, but also in other matters of vital importance for the socio-economic life. The main results have been obtained.
in the assimilation of new technologies and personnel training in important topics, such as: human health, agriculture, radiation safety and isotopic hydrology. For the period 2014 – 2017 (short term) Cuba has identified the following specific areas to enhance the cooperation with IAEA:

- Diagnostic and treatment of cancer and heart and neurologic diseases.
- Availability and quality assurance of therapeutic radiopharmaceuticals.
- Sterilization of medical supplies and medicine, blood, packing and modification of materials through irradiation.
- Strengthening of regulatory and radiation safety capacities.
- Irradiation of food to improve the harmlessness and reduction of crops spoiling.
- Integral management of soils and aquatic resources.
- Integral management of coastlines.

IAEA has also supported Cuba in building competence in radiation sciences, mainly through the assign of budget and lecturers for different specialized courses and events and accepting Cuban scholarship holders in regional and interregional courses.

The main problems of education of radiation sciences in Cuba deal with lack of technological infrastructure. Here it can be included the lack of proper installations for research and laboratory practices, poor Internet connectivity and band width. Another important problem in the near future will be the replacement of professionals.

The IAEA can continue assisting Cuba through promotion of access to new equipment by means of TC Projects, joint research, university exchange, donations, etc.

References

ENHANCING EDUCATION PROGRAMMES ON RADIATION SCIENCES IN COOPERATION WITH IAEA COLLABORATING CENTRES (EGYPT)

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Introduction

The Egyptian Atomic Energy Authority (EAEA) was established in 1955, its mandate is to enable the "efficient utilization of the peaceful applications of nuclear energy. The Radiation Protection Activities in Egypt were and still remain among the duties and responsibilities of the Atomic Energy Authority according to Act 288. Egypt became a member state of the IAEA in 1958, and the EAEA is the focal point of contact for agency technical assistance. The EAEA employs more than 1,400 nuclear scientists and engineers, assisted by 3,600 technical and 1,300 support staff. The EAEA is organized into three research centres.

- The Nuclear Research Centre (NRC)
- The Hot Laboratories and Waste Management Centre (HLWMC)
- National Centre for Radiation Research and Technology (NCRRT)

The EAEA has scientists educated in the topmost universities and research institutes.

The undergraduate and postgraduate program in Egypt:

1. The chemistry program (4 years)
2. The physics program (4 years)
3. The engineering program (5 years)
4. The master thesis (1-5 years)
5. The PhD thesis (2-5 years)

There are many activities related to radiation science in education that are spotted in the following:

A. The regular courses at the Egyptian universities related to radiation and nuclear science

Most faculties of sciences, chemistry department, are teaching at least a course of Radiation and Nuclear Science usually at the fourth level. Others are teaching two courses of Radiation and Nuclear science at the third and the fourth levels. In Physics department a course of Atomic and Nuclear Physics is teaching at the third level. Others are teaching two courses the first is Radiation Physics and the second is Nuclear Physics through the third and fourth levels. Some faculties of engineering have a
department for Nuclear Engineering and Chemical Engineering. Staffs from EAEA are lecturing for these students and the practical training if required is made at the Atomic Energy Authority, as well as professors from EAEA are teaching at that departments as a part time. A selection of regular courses related to radiation and nuclear science at the most important universities in Egypt are explained in the following:

**Cairo University**

It is the oldest Egyptian university and one of the important university for nuclear related teaching. In the chemistry department, faculty of science, a course of Nuclear and Radiation Chemistry is teaching through the fourth level, it is focused on the structure of nuclei, nuclear models, nuclear forces, nuclear reaction, direct interaction, radioactivity, kinetics of decay and growth, nuclear reactions, reactors, different sources of ionizing radiations, half life time and its energy, and different applications of radiation processing. In physics department, a course of Nuclear Physics is teaching through the third level, the course specifications are the principles of nuclear physics, the nuclear binding energy, the natural radioactivity theory, Rutherford theory of alpha scattering, the classical properties of the nuclear radius, neutrons- quark theory, nuclear fission and fusion reactions. It offers postgraduate courses in Nuclear Reactors and Radiation Physics, and has a strong connection with Egyptian Atomic Energy Authority (EAEA). The Giza and Fayoum branches operate nuclear relevant divisions. The Mechanical Power Engineering Department, Faculty of Engineering, offers related course is Nuclear Power Plant that is teaching the current nuclear power plant concepts and the environmental economics and safety considerations affecting their design, thermodynamics, thermal hydraulics, and mechanical and electrical aspects of nuclear power facilities.

**Alexandria University, Faculty of Engineering**

There is a department for Nuclear Engineering and Radiation Chemistry is studying the areas of nuclear engineering and are concentrated in the physical and thermal design of the reactors, test the properties of materials, and reactor safety and automatic control.

In the post-graduate, the department gives a diploma degree in Nuclear Plants and also in the radiation after four seasons seminars spread over two years. Moreover it gives a master's degree and a doctorate in nuclear engineering and radiation where the student attend within one year, introductory six decisions spread over two semesters to be selected to serve the subject matter requirement for the partial master's and doctoral degrees.

**Ain Shams University, Faculty of science**

In the physics department, there is a Nuclear Physics division that is teaching the nuclear installation using advanced nuclear techniques as well as working in the field of theoretical nuclear physics, and nuclear structure and reactions. The division also studies in the field of nuclear reactors, nuclear plant, reactor safety, the radiation attenuation processes and radiometric dating of archaeology.

**Helwan University , Faculty of science**

In the chemistry department, a course of Nuclear and Radiation Chemistry is teaching at the fourth level, the course is focused on the radioactivity, kinetics of decay and growth, nuclear reactions,
reactors, different sources of ionizing radiations, half life time and its energy, and different applications of radiation processing. In the physics department, a course of Nuclear Physics is teaching at the third level that studying the nuclear fission and fusion reactors, accelerators, interaction of radiation with matter, radiation damage, detectors, radiation pollution and protection.

Assiut University, Faculty of science

There is a course of Nuclear and Radiation Chemistry is teaching in chemistry department at the third level, the course is focused on the radioactivity, kinetics of decay and growth, nuclear reactions, and reactors.

In the physics department, there are three courses are teaching. The first one is Nuclear Physics is teaching at the third level that studying the nuclear fission and fusion reactors, and accelerators. The second one is Radiation Physics that studying the interaction of radiation with matter, radiation damage, different sources of ionizing radiations, half life time and its energy. The third one is Radiation Physics that explains the radiation pollution and protection of radiation is teaching at the fourth level.

Damietta University, Faculty of science

In the chemistry department, there is a course of Nuclear and Radiation Chemistry is teaching at the fourth level. In the physics department, there are two courses at the third level which are Atomic Physics and Reactors, and Nuclear Physics. There is also an advanced course of Nuclear Physics at the fourth level.

Fayoum University, Faculty of science

In the chemistry department, there is a course of Nuclear and Radiation Chemistry is teaching in at the fourth level. It is focused on the radioactivity, kinetics of decay and growth, nuclear reactions, reactors, nuclear fission and fusion. In the physics department, there are two courses at the fourth level which are Atomic Physics and Reactors, and Nuclear Physics.

Suez Canal University, Faculty of science

In the physics department, there are three courses which are Nuclear Physics (I), (II) and (III) at the second, third and fourth levels, respectively. There are special courses for specialized students which will be professional in the field of nuclear and radiation physics these are Radiation Physics and Physics of Nuclear Reactors and Energy.

Banha University, Faculty of Science

There is a special course for specialized students which will be professional in the field of nuclear and radiation chemistry staffs from EAEA are lecturing for these students, and the courses are related to:

Radiation processing; grafting, crosslinking, sterilization, nanogels, hydrogels for medical, agriculture, environmental waste treatment of waste water from heavy metals and organic pollutants. Also the fundamentals of radiation chemistry and the effect of ionizing radiation on polymers are introduced to the students.
In this regard, the following aspects are given in these courses:

1- The difference between Radiation chemistry, photochemistry and nuclear chemistry.

2- Different radiation sources of ionizing radiations, half life time and its energy.

3- The radiation units

4- Electron beam accelerators

5- The factors affecting on the absorbance of radiation and its interaction with matters. Linear Energy Transfer and stopping power, G- Value, Bremsstrahlung effect

6- The factors affects on radiation processing of polymers.

7- Chemical dosimetry and different chemical dosimeters used, its chemical and physical changes during irradiation and method for detection of such changes.

8- The radiolysis mechanism of H₂O during irradiation with accelerated electrons and with gamma irradiation.

9- Crosslinking and degradation of polymers during irradiation and the role of polymer morphology on such processes and free radicals mobility.

10- Different applications of radiation processing.

From the above review about the regular courses in the Egyptian universities related to radiation and nuclear science, it can be summarized that all courses are covering the structure of nuclei, nuclear models, nuclear stability, nuclear forces, nuclear reaction, reactors, the nuclear fission and fusion reactors, the sources of ionizing radiations, half life time and its energy, different applications of radiation processing, accelerators, interaction of radiation with matter, radiation damage, detectors, radiation pollution and protection.

B- Annual seminar is always held by Alexandria University, Faculty of Engineering. Many EAEA experts are lecturing in such seminars and is presenting the status of radiation and peaceful nuclear applications. This is a kind of contribution from EAEA with the state’s universities in Egypt. This to introduce radiation processing and nuclear applications not only to the students but also to the Universities staffs.

C- During the summer vacation of Universities, training programs are organized for the undergraduate students from faculties of Engineering and sciences to provide good knowledge on radiation processing in different fields. This training is needed and in some cases is compulsory for students. At the end of this training program the students make a presentation and report about the training and mention the benefits. The department staff and EAEA staff are present to discuss the students and invited guests and graduate students. These training programs are generating knowledge and develop
technology through excellence in research, in conjunction with graduate education, that are recognized by peers in the profession, in the interdisciplinary fields of radiation and nuclear science.

**D**- Undergraduate research project course is a full year project in the final year of engineering and science faculties provides the students with a prime opportunity to explore their aptitude and enthusiasm for original work as well as preparing them for the research environment. The course allows undergraduate science students to conduct an independent research project under the supervision of a professor feature a final report worth. These courses are designed to increase undergraduate research opportunities in the first semester the students do a survey of what was published in the direction of search and then drafted a report, and in the second semester an experiment laboratory process is done according to the availability and it can be done outside the campus. The student who wishes to engage in nuclear and radiation research can coordinate with EAEA under a supervision of EAEA staffs. This course offers the first experience and looking closely at the field.

**E**- Many master's and Ph.D. thesis are accomplished with the collaboration of all universities in Egypt. This is not only for the staffs of EAEA but also for the staffs working at Universities under the supervision of EAEA professors and the experimental work is done at the Atomic Energy Authority. The thesis should be related to the field of radiation processing and its applications in various fields such as:-

- Radiation-induced degradation of natural polymers as a promising application of ionizing radiation to develop natural bioactive agents.

- The possibilities for application to the problem of recycling polymer, due to its ability to cause crosslinking or scission of a wide range of materials without dissolving the sample or having some chemical initiator incorporated in the matrix.

- Radiation technology for sterilization, pasteurization, de-infestation, decontamination of microorganisms.

- Application of radiation technologies for synthesis of hydrogels that considered very important for biomedical applications. Wound dressing, contact lenses and drug delivery system are among their applications in the medical field.

- Radiation processing in wastewater treatment for directly treating and degrading of the organic pollutants. As well as indirect by the creation and develops the materials, hydrogels, used in wastewater treatment.

- Ionizing radiation as a very important tool for the technological development of nanoscience and nanotechnology.
F- Regular Conferences and workshops related to radiation processing and peaceful nuclear applications and nuclear safety are organized by the societies of EAEA and Universities staffs and the postgraduate students are participating.

G- The Centre of Nuclear Studies and Peaceful Applications is a research and training facility, located at Cairo University. The NSPA includes projects on advanced sciences (synchrotrons and accelerators and materials) as well as radiation protection, medical physics and dosimetry. The activities began in 2009 in collaboration with the Egyptian academy of science, EAEA, Italian embassy and the French embassy as well as the international center of theoretical physics with the workshop on reform of graduate studies in nuclear sciences. It organizes a regular workshops and seminars in contribution with EAEA.

Needs and Problems Recognised

- The need to qualify the general knowledge of radiation, radiation processing, and the peaceful nuclear applications. It yet remains unfamiliar to large number of human being.
- The need for the facilities of practical application of the undergraduate student That are limited for the postgraduate ones.
- Limited access database that is impeding the students and the early researchers in radiation nuclear area.
- Little jobs facilities of nuclear area in the country.
- The need for radiation and nuclear institute for the undergraduate student wishes to engage in nuclear area.

The future actions and implementation plan

- create outreach programme at all levels to know deeply the peaceful nuclear applications and the radiation processing.
- create a forum for enriching the general radiation background and the peaceful use of nuclear energy.
- create a short media program for the interaction between the human being and the radiation technology. By the way, it will engage the stakeholders towards the importance of radiation processing in various fields.
- A diploma in radiation is important to provide knowledge on radiation for anyone who works in related to the radiation area.
- Clear and free database to permit full the radiation and nuclear searching.
- Online radiation courses facilities

- Regular conferences and workshops supported by IAEA are organized every year in different member States country. It permit the researchers to exchange and share the experiences as well as it provides the premier interdisciplinary and multidisciplinary forum to present and discuss the most recent innovations, trends, and concerns, practical challenges encountered and the solutions adopted in the field of radiation and nuclear science.
France has a long tradition and has provided a strong background to radiation science and technology since the major discoveries by H. Becquerel, P. Curie and M. Sklodowska-Curie at the turn of the 19th century. The advances of basic science in that domain were readily exploited in various applications, particularly for medical diagnostics and therapy. Since then, the interdependence between science and technology has continued to develop with a need for researchers and qualified technologists specialized in the fields of nuclear science, radiochemistry, radiation chemistry and their applications for health and for industry.

The French Alternative Energies and Atomic Energy Commission (CEA) is a public body established in October 1945 by General de Gaulle. Being the leading institution for research, development and innovation in his field of responsibility, the CEA is active in four main areas: low-carbon energies, defense and security, information technologies and health technologies. In each of these fields, CEA maintains a cross-disciplinary culture of engineers and researchers, building on the synergies between fundamental and technological research. CEA exerts another responsibility by managing the “Institut national des sciences et techniques nucléaires” (INSTN), a higher education institute founded in 1956 for training engineers, researchers and technical staff involved in the French civilian nuclear programme initiated in the years 1950.

About 40 curricula are proposed by INSTN based on the expertise of CEA and of his research (CNRS, INSERM) and academic partners (several universities and Higher Schools as Ecole Polytechnique, Ecole des Mines, Ecole Centrale des arts et manufactures, Ecole des Arts et Métiers, École des Applications Militaires de l'Energie Atomique).

The spectrum of domains covers:

- Nuclear energy,
- New technologies for energy,
- Technico-Economical aspects of energy
- Radiation physics, and radiation chemistry,
- Radiochemistry,
- Materials science,
- Modelling and simulation,
- Nuclear research and technology,
- Construction management,
- Nuclear exploitation, maintenance and logistics
- Waste management, decommissioning
- Radioprotection,
- Nuclear security / safety,
- Detection and measurements of ionizing radiation,
- Survey of installations and of environment,
- Nuclear medicine, radio-pharmacy,
- Medical imaging, medical physics,
- Micro- and nanotechnologies,
- Training of teachers,
- Professional insertion of scientists

In particular, 5 MSc degrees are granted by INSTN:

- Atomic engineering
- Nuclear reactor engineering
- Nuclear science and technology
- Nuclear medicine
- Qualification in radiological and medical physics

Besides this training activities centred on the energy applications, the French academic education also includes the medical utilization of various types of radiation included in the basic and specialization courses taught in the Faculties of Medicine (47), Pharmacy (24) and Odontology. Typical

The education of students in the broad field of applications of radiation science and technology is by far less visible and organized though the discipline is present as a compulsory or elective courses of training programmes or diploma in Astrophysics, Physical chemistry, Materials or Polymer science, Nanoscience and nanotechnology, etc.

The tight link between research and education is evident after the analysis of the educational offer in Universities and departments of institutions as CEA and CNRS, where a large number of international level groups develop original activities. The representative topics and support laboratories (not exhaustive) are listed below together with the parent host institution.
Fundamental aspects of radiolysis

LCP at Université Paris 11, Orsay - IRAMIS at CEA Saclay

Metals, ceramics, magnetism and radiation

LSI at Ecole Polytechnique in Palaiseau - LCP at Université Paris 11, Orsay

Radiation-damage, ageing, stabilization, post-irradiation oxidation of polymers

LPMM at Université Blaise Pascal Clermont-Ferrand – PIMM at ENSAM Paris - CIMAP at CEA-Université de Caen – LMS at Université Paris 11, Chatenay-Malabry

Ion track membranes

CIMAP at CEA - Université de Caen – LSI at Ecole Polytechnique, Palaiseau

Nanogels, grafting onto nanoparticles or nanostructured materials

LSI at Ecole Polytechnique, Palaiseau – LCCMO at Université Paris XI - CERMAV CNRS – Université de Grenoble

Polymer membranes (IEM at Université de Montpellier -LEPMI at CNRS – Université Joseph Fourier Grenoble

Radiochemistry and scintillators

IPHC at CNRS – Université de Strasbourg

Radiobiology

LCP at Université Paris 11, Orsay

Radiation-induced polymerization

ICMR at Université de Reims Champagne Ardenne

A number of courses, mainly at MSc level, are proposed by the universities and higher schools, with an orientation towards the domain of research of the involved pedagogical teams.

Finally, it is worth to mention the training, networking and dissemination activities existing in association of the large instruments (ESRF, SOLEIL, GANIL) as well as some other unique facilities (ELYSE in Orsay, SIRIUS in Palaiseau, ARRONAX in Nantes).
Recommendations

1 - List the main domains application and evaluate the type and number of associated job positions which drive the need for specific training programmes, try to define a limited number of domains sharing the same (or somehow related) specificities:

- Food and drug processing
- Sterilization
- Polymer materials (plastics, composites, biomaterials, coatings, lithographic materials)
- Treatment of industrial / municipal effluents and municipal wastes

2 - Discuss the different options for proposing educational initiatives:

(i) One (or more) specialization training programme(s),
   - Adapted to the level and objective of the trainees,
   - Focused on “radiation processing” to be included (earned credits taken into account) or added to conventional curricula (BSc, MSc, PhD) existing in the different member states.

(ii) A global curriculum,
   - Self-consistent, and dedicated to the formation of students in the perspective of well-defined positions in industry or academia.

For both options, the architecture, the content of the courses, the prerequisites, should be defined around:

- a basic core of scientific knowledge (radiation sources, radiochemistry, particle physics, chemical kinetics, free radical chemistry, molecular biology, solid state chemistry, spectroscopic and physical methods of characterization, environmental chemistry);

- a set of concepts and methods for implementing radiation processing (radiation sources and accelerators, dosimetry, radioprotection, simulation, quality control / quality assurance, basic maintenance, principles of Life cycle assessment);

- specialized courses should be proposed to address the needs in terms of knowledge and practical skills of each of the application domain, e.g. domain A “Sterilization/food preservation” (main relation with biology), domain B “Polymers and materials processing” (main relation with materials science), domain C “Environmental applications”

An on-going Erasmus + Key Action 2 “Joint innovative training and teaching/learning program in enhancing development and transfer knowledge of application of ionizing radiation in materials processing” coordinated by ICNT (Warsaw, Poland) has been selected in 2014. This initiative will
provide a training programme with the associated educational tools to be analysed and evaluated in the perspective of a broader international educational project in the domain.

At the doctoral level, the Marie Curie Sklodowska Actions, a tool of European Union programme Horizon 2020 can offer the frame of such an initiative since students of non-EU states can apply and benefit from y-the mobility supports.

EU H2020 instruments Types : Marie Sklodowska Curie Actions:

Research networks (ITN): support for Innovative Training Networks

ITNs support competitively selected joint research training and/or doctoral programmes, implemented by European partnerships of universities, research institutions, and non-academic organisations.

The research training programmes provide experience outside academia, hence developing innovation and employability skills. ITNs include industrial doctorates, in which non-academic organisations have an equal role to universities in respect of the researcher’s time and supervision, and joint doctoral degrees delivered by several universities. Furthermore, non-European organisations can participate as additional partners in ITNs, enabling doctoral-level candidates to gain experience outside Europe during their training.

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Education programmes on radiation sciences is carried out in Hungary mainly in universities, but selected programmes are given in certain research centres too, in most cases also in cooperation with universities. The education on these subjects is based on the requirements of the existing radiation and nuclear infrastructure, i.e. to fulfill the needs of the safe operation of Paks Nuclear Power Plant, as well as the tasks of the Public Limited Company for Radioactive Waste Management on one side, while to ensure the safe operation of gamma irradiation facilities, as well as to satisfy the needs on the use of radioisotopes in medicine and industry including the existing basic and applied radiation research requirements on the other side. There are close to thirty universities in Hungary, but only a few of them have courses on radiation sciences both in the frame of undergraduate and postgraduate education mainly for chemists, physicists and chemical-, material- and environmental engineers. These universities are the Eötvös Lóránd Science University, the University of Technology and Economics and the Óbuda University in Budapest, the University of Pannonia in Veszprém and the University of Debrecen.

Beside these universities education programmes on radiation sciences are carried out at the Hungarian Academy of Sciences, Centre for Energy Research both for Hungarian and foreign students.

1. Education courses on radiation sciences at Hungarian universities

1.1. Eötvös Lóránd Science University (ELTE, Budapest)

1.1.1. A one semester long BSc course on nuclear chemistry is given at the Chemistry Department. The objective of the course is the introduction into the basics of nuclear science required to understand technical applications of nuclear methods. Danger and biological consequences of radiation is also discussed because it is becoming a real demand of modern society. The course outline involves the basic knowledge of subatomic particles, nuclear structure, stability and instability, decay modes, kinetics of radioactive decay, radioactive decay series, radioactive equilibrium, radiometric dating, interaction of nuclear radiations with matter, detection of nuclear radiations, dosimetry, basics of radiation protection, radiation chemistry, and hot atom chemistry, as well as radioisotopes in nature.

1.1.2. MSc courses are given in the following topics:

**Applications in Nuclear Chemistry** including basics of nuclear chemistry, radiation chemistry, applications of radioisotopes in industry, applications in biochemistry, biology and medicine, radiation protection.
**Introduction into nuclear environmental protection** including interaction between radiation and matter. Dose concepts, principles of dosimetry and types of dosimeters. Biological effects of radiation. Basic principles of radiation protection.

**Nuclear methods with applications in biology** including the review of the basics of nuclear chemistry, application of radiation for diagnostic purpose and for its radiation effect, radioimmunoassay, nuclear medicine.

**Radiation protection** with focus on the purpose and subject of radiation protection. Dose concepts, dosimetry, and hazardous effect of ionizing radiation on humans.

1.2. **Budapest University of Technology and Economics (BME, Budapest)**

Radiation science oriented courses such as radiochemistry and radiation chemistry are given at BSc and MSc level, mainly for physics students under the specialization of nuclear techniques at the Faculty of Natural Sciences, Institute of Nuclear Techniques (NTI) (detailed information is available at the [http://www.reak.bme.hu/en/home.html](http://www.reak.bme.hu/en/home.html) web site.

The NTI runs a research reactor for education purposes, mostly with focus on the education of specialists for nuclear energy industry, i.e. in reactor physics and technology. A five years program is given to students in engineering physics, which contains courses in nuclear methods, nuclear reactors, nuclear measuring techniques, radiation and environmental protection.

1.3. **Óbuda University (ÓE, Budapest)**

Courses on radiation chemistry and in material sciences with respect to radiation sciences are given to BSc (two semesters) and PhD (one semester) students.

1.4. **University of Pannonia (PE, Veszprém)**

The Institute of Radiochemistry and Radioecology ([http://radio.mk.uni-pannon.hu](http://radio.mk.uni-pannon.hu)) of the university offers radiation science related education at undergraduate (BSc, MSc), postgraduate and at PhD level (chemist, chemical-, material- and environmental engineer). BSc courses are given in Environmental Engineering, while MSc courses are given in Environmental Engineering and in Chemical Engineering. The BSc courses involve topics like basics in radiation, radioecology, nuclear energetic, natural and artificial radiations and sources, dosimetry, radiation protection, application of radioisotopes, nuclear metrology. The MSc courses involve environmental radiations, radiation protection, nuclear chemistry and application of radioisotopes, radiation chemistry and technology, dosimetry, radiation accident management, etc.

In average 8 students are graduated annually with the BSc degree; both programs at MSc level are new, started at 2009. Furthermore, there are 6 PhD projects under radiation science related fields. The department has 5 permanent staff members and 5 PhD students participating in teaching. Research activities – coupled with PhD works - involve the study of (1) contamination and corrosion processes in nuclear reactors and (2) radioecology and dose assessments in the environment (drinking and mineral waters, buildings, foods).
1.5. Debrecen University (DE, Debrecen)

Radiation science related education is mainly given in the Department of Colloid and Environmental Chemistry (Isotope and Environmental Chemistry Group). Basic radiochemistry (3 ECTS) course is obligatory for BSc studies in chemistry, environmental science and chemical engineering. Basic radiochemistry (2 ECTS, included in obligatory physical chemistry) and radioanalytical chemistry (3 ECTS) courses are offered for MSc students in chemistry. The main subjects are: radiation interactions with matter; radioanalytical methods for humans and for industry; high energy radiations; neutron measurements methods; age determination; chemical separation methods.

In addition, at the Institute of Nuclear Research/Department of Environmental Physics a course on radiopharmacy (2 ECTS) is taught for MSc students in Pharmacy.

In average 70 students are attending annually the first and 20 students the second basic course in radiochemistry. Furthermore, there is possibility to do PhD studies in radiation science related fields, e.g. storage of radioactive wastes, interactions of isotopes with the geological formations. Four permanent staff members are participating in teaching these subjects in the department.

2. Education courses on radiation sciences at the Hungarian Academy of Sciences, Centre for Energy Research (MTA EK, Budapest)

MTA EK, in cooperation with universities discussed above, participate in the education on radiation sciences teaching basics of nuclear and radiation chemistry, nuclear analytical methods, radiation technology, radiation dosimetry, environmental protection, environmental technologies, radiation protection, nuclear safety, nuclear security (forensics), nuclear technologies. These educations, which involve both theoretical and practical parts, are given both for Hungarian as well as for foreign students in the frame of bilateral (HUNEN program) or multilateral (IAEA, EU JRC institutions) programs for shorter (1-2 weeks) or longer (3 months) periods.

For the initiation of the Hungarian Government a detailed three months long nuclear training programme (HUNEN) was worked out in cooperation with MTA EK and Hungarian universities (BME, ELTE, ÖE, PE, DE) for international education and training purposes for the request of countries like Vietnam, Saudi Arabia, etc. For the request of EU JRC institutes and of the International Atomic Energy Agency training courses for foreign students are organized in radiation technology, radiation dosimetry and nuclear forensics at MTA EK.

3. International Atomic Energy Agency (IAEA) assistance in Hungary on radiation sciences education

The IAEA plays a significant role in these education programs both by utilizing its regional technical cooperation programs and by the fellowship programs. In the frame of the Technical
Cooperation Programmes of the IAEA technical courses have been given as part of the European Regional Programmes in radiation technologies, radiation process control and in saving our cultural heritage, i.e. to preserve cultural objects by using ionizing radiation. A Regional TC project called „Introducing and Harmonizing Standardized Quality Control Procedures for Radiation Technologies” has been performed during the last ten years educating several mostly young scientists and operators from 25 European countries on QA/QC methods and applications, safe operation of irradiation facilities, feasibility studies to establish new irradiation facilities/technologies, process control for EB/gamma facilities, microbiology, etc).

Technical IAEA sponsored training courses are held frequently at MTA EK on nuclear technics, nuclear forensics, radiation technologies. MTA EK often hosts IAEA sponsored fellowships (2 -4 months) in radiation sciences and security.

Since these programmes contribute to a significant extent to the existence and technical upgrading of these technologies worldwide and specifically in Hungary as well, the role, assistance and efforts of the IAEA is highly appreciated!

4. Review of needs for IAEA assistance, definition of problems and gaps

Severe problems to ensure the necessary well educated manpower to run all these programs involve the substitution of the present older generation due to resignation forseen in the near future, the lack of the financial sources for infrastructure and the declining position of radiation research. Therefore the efforts of the IAEA to strenghten the education in these fields, as well as to help to keep the necessary infrastructure running is of basic importance.

4.1. The following components of the education system should be considered and supported:

- To keep and secure the present knowledge due to generation changes by collecting and editing the available lecture and laboratory exercises notes, materials;
- To utilize the available IAEA sources, e.g. QA/QC, e-learning material dissemination for all regions;
- Information, motivation, involvement of new generation by goal-oriented education programs, cooperation with universities;
- To find the substitutes for the „lost” research institutes in the region by utilizing the capabilities of IAEA collaborating centers, regional/interregional centers;
- To help the establishment of new irradiation centers worldwide;
- To strengthen research activities by international cooperation programmes, e.g. Horizon 2020, bilateral cooperation.
4.2. Need for radiation science education in Hungarian research and application

4.2.1 Research at MTA EK:

- radiation chemistry;
- radiation technology;
- environmental applications;
- radiation dosimetry;

4.2.2 Applications:

- Radiation technologies:
  - Dispomedicor Co. Ltd (Debrecen), 60-Co gamma irradiation facility
  - Agroster Co. Ltd. (Budapest), 60-Co gamma irradiation facility;
  - MTA EK (Budapest), 60-Co gamma irradiation facility and 4 MeV EB;

- Nuclear technologies:
  - Paks Nuclear Power Plant;
  - MTA EK, 10 MW research reactor
  - NTI/BME, education reactor;

Radiation chemistry related problems at Paks NPP:

- Radiation tolerance of structural materials (cables, wires, electronic devices);
- Corrosion problems (aqueous systems, primary circuits);
- Dosimetry problems;
STATUS OF EDUCATION & RESEARCH ON RADIATION SCIENCES IN INDIA

Dr K. Indira Priyadarsini

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1. Summary

Bhabha Atomic Research Centre (BARC), as a premier multi-disciplinary national research centre, has full-fledged programmes on all the areas of radiation sciences and technology. New centres have also been established by the government of India in different parts of the country on related research areas. Institutes like Advanced Centre for Training, Research, Education in Cancer (ACTREC; under Tata Memorial Centre, an autonomous Institution under the Dept of Atomic Energy), and National Centre for Free Radical Research (NCFRR), Pune and Inter-University Accelerator Centre (IUAC), Delhi have dedicated research programmes on different areas of radiation sciences. A few other universities teach radiation chemistry and biology as a part of the post-graduation curriculum. Additionally, some independent professional bodies like Indian Society for Radiation and Photochemical Sciences (ISRAPS), Indian Nuclear Society (INS) and Indian Association of Nuclear Chemists and Allied Scientists (IANCAS) help in promoting education and research in radiation sciences in academic institutions and universities.

BARC has a state-of-art infrastructure for pursuing R & D, covering the entire spectrum of nuclear science & engineering programme. It has an excellent orientation course (previously known as training school), initiated by the founder of Indian atomic energy programme, Dr Homi Bhabha, to educate and train newly recruited bright young post-graduates and engineers, nearly 150 to 200 in number, on all the aspects of nuclear energy programme. This training programme spanning over a year has been very successful and brought out world class researchers in the last 58 years. As a part of this one-year orientation course, topics related to radiation sciences, like charge particle interactions, radiation chemistry, radiolysis of water, isotope applications, radiation technology, radiation biology, radiation protection, dosimetry, radiation polymerization, applications, accelerators, radiation sources etc, are taught in detail along with relevant experimental work. The programme has a high teacher to student ratio, taught by active researchers in the respective areas. With the inception of Homi Bhabha National Institute (HBNI) in 2005, an autonomous institute under DAE, many of these training courses are now conducted by HBNI. HBNI comprises ten constituent institutes and seven Board of studies: Chemical sciences, Engineering sciences, Health sciences, Life sciences, Mathematical sciences, Physical sciences and Strategic studies. Under these different disciplines degrees and diplomas awarded include PhD, M. Sc. (Engg), M. Phil., M. Tech., PG Diploma, M.Sc., MD, DM, Diploma in Radiation medicine (DRM), Diploma in Radiation physics (DipRP) etc.

In the last 25 years, BARC has produced more than 500 research articles and more than 50 PhDs exclusively in the fields of radiation chemistry and radiation technology.

Board of Research in Nuclear Sciences (BRNS), another organisation under DAE has been conducting several outreach programmes on radiation technology and medicine in several universities and institutions. Experts from BARC regularly participate in these outreach programmes.
The researchers from this organisation are regularly invited in several international meetings on radiation chemistry and technology either as experts or as mentors. The young investigators received awards and travel support to attend these meetings. With the continuous inputs from R & D on radiation chemistry and technology, the researchers from this center have been able to demonstrate many new technologies in the areas of polymers, nanomaterials, food irradiation, radiation sterilization and new health care products and some of these have been transferred to industries successfully. The researchers from DAE have regular collaboration with the industries in the country & developed many new technologies like hydrogels for wound dressings, irradiated cables, coloured gem stones, biodegradable natural polymers, new radiation processed polymers with improved properties, urban sewage sludge hygienisation plants etc.

2. India - IAEA cooperation

India is an active member of all IAEA programmes in general and RCA activities in particular, and has been participating as experts/consultants in technical meetings, workshops and training courses organized by IAEA. In some of the regional training programmes conducted at the collaborating centers in the Asian region on radiation technology, several members from DAE gave lectures as experts or attended the training courses like for example, e-beam applications in polymer processing, food irradiation and environmental pollutants, etc. India is one of the first few countries in the region to have initiated research in these areas. BARC-DAE has excellent trained manpower and expertise on various areas of radiation sciences and will continue to make available its expertise, as required for IAEA activities and events.

3. Suggestions for enhancing education in radiation sciences

In order to explore the full potential of radiation technology for societal up-lift, she opined that there is a need for developing trained manpower on radiation technology all over the world. This will not only expand the radiation technology to more industries, but would also act as a public outreach programme. Other than BARC, there is no full-fledged programme on radiation chemistry & technology as a special course in any institute or university in India. Therefore it may be useful to conduct IAEA approved workshops in universities and other institutions in India in co-ordination with BARC experts. It would be useful to create an International Radiation Learning Centre in India for users from nearby member countries. The researchers from BARC/DAE can help in teaching and conducting these courses. Their expertise can be used to bring out monographs and course materials.

A one year post-graduate diploma course on use of radiation in material science, polymers, medicine, nanotechnology, food and industry would be ideal for this, so that the programme on radiation technology could find appropriate impact that it needed in the society currently.
4. Some important features that could be included in such course

A Trimester course covering applications in polymers, advanced materials biotechnology & environment

4.1. Common courses:

Interaction of radiation with matter, charged particles, electromagnetic radiation, definitions, dose, exposure, activity, units, LET & Dose-depth profile, radiation chemistry, LET effects, dose-depth, water radiolysis, gas phase radiolysis, G-value calculation, chain reactions, detection of radicals by pulse radiolysis, electron density differences, non-homogeneous kinetics, etc. Experimental techniques in radiation chemistry, radiation technology

Radiation sources, accelerators, e-beam facilities

Radiation biology, biochemical changes, effects on DNA, direct & indirect effects, effects on bacteria, virus, living beings. Radiation harnessing, adaptive response

Nuclear instrumentation & radiation detection

Dosimetry, primary, secondary dosimeters, standard & internal dosimeters

Radiation safety and radiation protection & radiation detection

Current developments in radiation technology, advantages, societal benefits, per-capita growth thro’ radiation technologies, industry needs.

4.2. Specialized courses on polymer technology, nanotechnology, food technology, biotechnology, environmental chemistry, green technologies.

4.3. Specialized courses on radiation effects on polymers, food irradiation, Nuclear agriculture, Radiation nanotechnology

4.4 Compulsory three months internship at an institution or industry. Preparation of project report

Organizing institution should provide e-learning facilities, course materials, video conferencing facilities, regular evaluation systems, exchange programmes.

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Indian association for Nuclear and Allied Sciences http://www.iancas.org

Advanced Centre for treatment, education and research on cancer (ACTREC), Kharghar, Mumbai (http://www.actrec.gov.in)

Inter-University Accelerator Centre, New Delhi Inter-University Accelerator Centre, New Delhi (http://www.iuac.res.in)

National Centre for Free Radical Research (NCFRR), University Campus, Pune (http://www.unipune.ac.in/dept/science/chemistry/chemistry_webfiles/ncfrr.htm)

Board of Research in Nuclear Sciences: https://daebrns.gov.in
1. The structure of high scientific education in Italy

Higher scientific education in Italy is mainly covered by universities and superior graduate schools (Schools of Excellence), with very few professional or vocational school following the secondary education. State-funded public universities are by large the most represented in Italy, particularly among the largest institutions. Since 1999, the Universities issue the following qualifications, corresponding to the “Bologna Process” structure (three cycles):

- Laurea (L), corresponding to a first-cycle qualification (BSc), issued at the end of a three-year course of study (180 credits - CFU);
- Laurea Magistrale (LM), corresponding to a second-cycle qualification (Master Degree), issued at the end of a two-year course of study (120 credits - CFU) or to a 5-6-year single course (300-360 credits - CFU);
- Dottorato di ricerca (PhD) or scuola di specializzazione (specialisation courses), corresponding to a third-cycle qualification.

A limited number of programmes (dentistry, human medicine, pharmacy, veterinary, architecture, law), are defined One Cycle Degree Courses (one-block L + LM courses of 5 or 6 years).

In addition, Universities may organise courses (higher continuing education studies) leading to the following qualifications:

- First-level University Master issued at the end of 1+ year course of study (60 credits - CFU);
- Second-level University Master issued at the end of a 1+ year course of study (60 credits - CFU).

These Courses are highly specific or advanced scientific courses open to the holders of a 1st cycle (L) and 2nd cycle (LM) degree, respectively. They are finalised to the education and training of professionals, often with a strong involvement of industry and/or public bodies.

Universities autonomously determine educational contents of individual degree courses. Individual institutions, however, when establishing a I or II cycle degree programme they have to adopt a few general requirements fixed at national level in relation to groups (“classi”) of similar degree courses that should not bind more than the 2/3 of each curriculum, allowing some flexibility especially for elective courses.
2. Regular courses on Radiation Science at Italian Universities

In this contest, a number of regular courses or course modules on topics that pertain to broad field of “Radiation Science and Technology” are taught in several Italian Universities, mainly as part of Laurea Magistrale Programmes in the area of Physics, Chemistry and Chemical Technologies, Biology and Biotechnology, Chemical Engineering, Nuclear Engineering and Ionising Radiation Applications, Medicine (e.g. LM in Medical Radiology Techniques, Medical Imaging and Radiotherapy) and Pharmacy, and in the Specialisation Course in Radiology and Imaging Diagnostics. The most relevant courses for education in the field of Radiation Science and Technology related to radiation processing applications are represented by two groups:

1) Radiation Physics, Radiation Biophysics, Radiobiology, Dosimetry, and to some extent Medical Physics;

2) Radiation Chemistry and Radiation Processing.

The first group of courses is taught mainly by Physicists and Biophysicists to LM students of specific programmes or curricula in Physics, Nuclear Engineering and Medicine of several Universities; the second group, which is the most relevant to purpose of the present survey, is represented by only two elective courses that are offered to students of LM in “Photochemistry and Molecular Materials” (course title: “Radiation Chemistry”) and LM in “Biologia della Salute” (course title: “Ionizing Radiations and Living Matter”) at the University of Bologna.

The course content in Radiation Chemistry (6 CFU) covers the following topics: sources of ionizing radiation; water and water solution radiolysis; radiolysis in other solvents; solid state and gas state radiolysis; dosimetry; application of high energy radiation in healthcare (diagnostics), industry, for environmental remediation, for historical/cultural heritage preservation and food treatment. The course in “Ionizing Radiations and Living Matter” (4 CFU) is developed accordingly to the following outline: three types (electromagnetic waves and particles) of high energy radiation; high energy sources; water and aqueous solution radiolysis; origins of life: some hypotheses; dosimetry and dosimeters; applications of high energy radiations in medicine, in the industrial field, for the environment, in cultural heritage and for food treatment.

The University of Palermo proposes a course module (1 week) on “Radiation engineering of polymer nanoparticles” as part of the elective course on “Functional Nanostructured Materials” offered to students enrolled in the Chemical Engineering LM Programme. This module provides some basic information on the type of interaction between ionizing radiation and matter, water radiolysis, radiation chemistry of aqueous organic systems, to focus on the different strategies for the radiation-synthesis of polymer nanoparticles.

In addition, courses on Radiation Safety, Radiation Protection and Ionizing Radiation Metrology, which cover important aspects of nuclear and radiation science and technology, are often provided as part of the Programmes in Nuclear Science and Engineering. Although the stated educational objectives of the programmes in Nuclear Engineering include the application of radio-isotopes in medical diagnostics and therapy, the use of isotopes and ionizing radiation in food and safety
technology, in agriculture, water management and all associated necessary fields of expertise, the use of ionizing radiation for non-power and non-medical applications (radiation processing) is not proposed as a self-standing, regular course.

Radiochemistry is often offered as an elective course to LM students of Chemistry and Chemical Technology or Pharmacy. General contents of the course are: Principles of radioactivity and radiochemistry: fundamental types of radiation (alpha, beta and gamma) and the radioactive decay; Radiation/matter interaction and radiation detectors; Elements of dosimetry; Effects of radiation on biological materials; Application of radioactivity in analytical chemistry, life sciences (medical, biological, agricultural and food), dating techniques, industry, science and technology, and energy production.

Health Physics and Radiation Protection courses are provided as part of Laurea in Medical Radiology Techniques, Medical imaging and Radiotherapy Programmes (that is a BSc course to licentiate Radiologic Technologists) and in the Specialisation Courses in Radiology and Imaging Diagnostics.

3. Non-regular Educational Activities organised by Academic Institutions

The most remarkable initiative of a higher education programme fully devoted to the Nuclear and Radiation Science and Technology relevant to human welfare and socio-economic development in Italy is represented by European School of Advanced Studies on Nuclear and Ionising Radiations Technologies, organized by the University Institute for Advanced Studies (IUSS), which is an emanation of the University of Pavia and the Italian Ministry of Education and Research (MIUR), in cooperation with IAEA. It was lunched as a pioneering initiative in 1998 and run every year until the 2009/10 and for two more years in 2012/2013 and 2013/14. It has not run in the year 2014/1. The programme was structured to have one academic year (60 ECST) duration. It comprised theoretical lectures and laboratory activities for 400 h with intermediate exams, a six months training stage in one of the participating institutions and a final exam with the dissertation of a thesis based on project work carried out by the students during their six months training. Students who passed the final exam were awarded with a post-graduate, 2nd level short specialisation degree (Master degree) issued by the University of Pavia. It was characterised by a strong link with industries, academic institutions and research centres and by the participation in the educational activities of specialists from different Countries. It was offered to both Italian and foreign students; about 50 % of the students every year were awarded with a tuition weaver and reimbursement of lodging expenses, also through IAEA fellowships.

Other, non-regular educational activities in radiation science and technology-related fields are being organised by many Academic Institutions, e.g. within the framework of the Erasmus International Mobility programmes; with the support of the Ministry of Instruction, University and Research (MIUR) or supported by the same Universities as part of International Cooperation for Research and Education Programmes (e.g. CORI at the University of Palermo). They consist in students exchange for project thesis, intense courses and seminars held by experts from foreign Universities.

One very recent activity is the Erasmus+, Key Action 2 – “Cooperation for Innovation and the Exchange of Good Practices, Strategic Partnerships for Higher Education” project, funded by EU to
support a “Joint innovative training and teaching/learning program in enhancing, developing and transfer knowledge of application of ionizing radiation in materials processing”, which involves the University of Palermo together with Universities and Research Institution in Lithuania, France, Poland, Romania and Turkey. Objectives of the project are:

- to enhance teaching/learning education level in radiation chemistry and radiation processing of materials in higher education sector through intensive lectures delivered by world recognized scientists active in this field;

- to increase students competence through the visit and training in industrial radiation facilities;

- to strength international cooperation and reputation between leading institutions in radiation science.

The expected outputs will be two intensive 9 ETCS courses on “Radiation processing of materials” to be delivered in fall 2015 and in fall 2016 open to 35 students each year from the different participating countries; the write-up of a book and the organisation of a number of dissemination events.

4. Definition of problems and gaps and recommendations

This survey has highlighted that education on Radiation Science related to Radiation Processing is a component that has almost disappeared from higher scientific education in Italy.

This is the result of a number of factors: political decisions; aging of scientific community; shrinking of research/teaching staff groups; low visibility of the field (to students and to society); dominance of “closed” groups in the field of Radiation Science and Radiation Applications; fewer and fewer facilities available for students hands-on training and research activities.

To counteract this process, actions to be taken must involve all the relevant players (IAEA, Universities and the Scientific Community) at an International level.

1. The institution of an International Academy in Radiation Science and Technology, involving outstanding experts in the field to form an International Stirring Committee (elective and non-permanent) and as Lecturers. This initiative could achieve several objectives:

PROVIDE A WORLDCLASS SCIENTIFIC EDUCATION IN THE FIELD OF RADIATION SCIENCE

- by continuously developing curricula for the education and training of scientists and technologists who can drive innovation in the field of Radiation Science and Technology for non-power applications;

- by organizing and promoting a Post-graduate Professional Master Courses of 1 year duration to be delivered by a single University or by a cluster of Universities, in collaboration with the IAEA Collaborating Centres and Industries. This Programme should be possibly run every time in a different Region and offered to the best Master graduate students, world-wide;
• by elaborating and providing short education courses in specific areas on demand (to educate technicians, qualified experts, etc.);

• By seeking and advertising job opportunities world-wide.

LEAD INNOVATION IN TEACHING MODALITIES

• by developing innovative teaching modalities that can increase the attractiveness of the field for students;

ISSUE CERTIFIED REFERENCE MATERIAL

• by designing and developing peer-review course materials;

EXPAND THE FIELD

• by exploiting information and communication technologies to enable fruition of the courses contents also by non-enrolled students, even from remote locations (e.g. by streaming videos, e-books, e-learning platforms);

• by organizing dissemination and outreach events to increase awareness and visibility outside the community;

• by identifying other scientific areas where radiation science can establish profitable cooperation.

In the contest of this initiative, the role of IAEA should be to support teaching staff and student mobility, and to cover fully or in part students’ tuition fees; to organize CRPs devoted to develop course contents, innovative teaching modalities and peer reviewed supporting material, also in electronic format.

2. IAEA should support the creation “open-access” ionizing irradiation facilities (at least one per Region) that scientists from all over the world can access by submitting proposals that are evaluated on the basis of pure scientific merit and potential impact.

3. IAEA should sponsor Conferences that have sessions dedicated to young scientists and encourage the organization of workshops on education in “Radiation Science and Technology” and Intensive Courses on the fundamental aspects of Radiation Science within these Conferences.

4. IAEA should consider expanding the existing fellowship scheme to make it available to students and researchers from all Countries, including those that are not eligible for TC projects.

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RADIATION SCIENCES AT UNIVERSITIES IN JAPAN AND CONTRIBUTION OF TAKASAKI ADVANCED RADIATION RESEARCH INSTITUTE TO EDUCATION

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Status of the lectures on radiation sciences in Japanese university is investigated from the viewpoint of radiation chemistry involved in our institute. The lectures on radiation science corresponded to radiology in medical department and contain radiation chemistry as a part of lecture contents in Japan. The lecture on radiation chemistry mainly has been given in the department engineering of graduate school. In the department of science, there is not so much difference in the contents of lecture on radiation chemistry and radiation science. Experts in our institute have given the lectures on radiation chemistry, radiation biology and accelerator physics to develop human recourse of next generation in the universities. There are several purposes of lectures for contribution to accumulate knowledge for national qualification examination for radiological technologist, extensive knowledge of nuclear energy science, comprehensive knowledge of radiation applications, topics of radiation applications in industry, biology and ion beam technology. Notes of lectures in nuclear professional school of the University of Tokyo were published as textbook. Japanese textbooks of 11 subjects were already published and 2 textbooks were translated into English. Dissemination of radiation chemistry through lectures is profitable for human resource development in Japanese universities since participating students notice the advantages of radiation chemistry after attending the lecture. Students were all attention to the technology transfer of radiation application and patent strategy. As a contribution to IAEA regional and domestic training courses, Japanese experts gave the lectures on grafting technology, its environmental and industrial applications, and up-scaling for technology transfer of grafting. Demonstration and experiment of grafting promote the understanding of grafting technology and its technology transfer. The expert noted that discussion should be added in training course program to promote the management of technology for grafting to overcome the political and economic problems in their countries.

1. INTRODUCTION

Takasaki advanced radiation research institute (TARRI), Japan Atomic Energy Agency (JAEA) was established as a core institute for radiation chemistry in 1963. In TARRI there are three major irradiation facilities of gamma-ray, electron beam and ion beam as shown in FIG. 1. Gamma-ray irradiation facility is the first large-scale facility and supplies the five-digit range of dose rate to users in various research areas such as biotechnology, material evaluation and material development.

Electron beam irradiation facility has similar specifications to that used in industrial process. Developed materials using this electron beam machine are easily applicable for industrial production process. In these facilities, the characteristics of materials modified by irradiation can be monitored by data acquisition through connecting sleeves. Ion beam irradiation facility was composed of 4 kinds of
accelerators; cyclotron, tandem accelerator, ion implanter, and single-ended accelerator. The combination of 4 accelerators covers the both wide ranges of ions from proton to gold and energy from 0.02 to 1,030 MeV. Microbeam, 10 μm in spatial resolution\(^1\), large-area uniform beam\(^2\), 10 cm in square, single pulse of ion beam\(^3\), and 1 μs in time pulse were used in the research for low fluence radiation effect on biological cell, ion track etched membrane production, and radiolysis mechanism of water, respectively. Recently term of “Quantum beam” is defined as "artificially generated and highly-controlled radiation beam" and university and research institute used to apply this term to “radiation”.

In quantum beam irradiation there are three major functions of “Observe”, “Create (Modify)” and “Cure”. Function of “Observe” can realize the imaging of tiny tumors\(^4\), some mm, using novel RI-labeled compound and nitrogen fixation in root nodules of soybean using positron\(^5\). Various new features were given to produce high performance metal adsorbent for scavenging\(^6\), plant activator from chitosan in crab shell\(^7\), biodegradable dummy lens\(^8\), and rice absorbing low cadmium\(^9\) ion beam mutation breeding as the functions of “Create (Modify)”. Radiation resistance of semiconductor for aerospace\(^10\) and materials used in accelerator\(^11\) were evaluated as well. In the case of “Cure” function, effect of heavy ion microbeam on biological cell has been investigated for radiotherapy. These outputs were achieved by utilization of quantum beams on the basis of radiation chemistry and biology.

The radiation science at university in Japan and contribution of TARRI to university education were discussed for the sake of technical meeting of enhancing education programmes on radiation sciences. The following sections deal with the term of “radiation science” in Japan, lectures related with radiation chemistry, our contribution to lectures on radiation chemistry, and our contribution to IAEA training courses.
2. RADIATION SCIENCES AT UNIVERSITY IN JAPAN

2.1. Term of “radiation science” in Japan

Japanese “Radiation Science” is a name of organ of national institute of radiological science (NIRS) and this term is usually used in the meaning of medical radiation science or radiology in Japan. However, we consider that “Radiation Science” is a scientific area related with ionizing radiation and covers the following research areas such as radiation chemistry, radiation physics, radiation biology, and radiology as shown in TABLE 1. Each scientific area has corresponding academic society through there is no corresponding society for radiation science.

<table>
<thead>
<tr>
<th>Name of Scientific area</th>
<th>Scientific area</th>
<th>Corresponding society</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiation chemistry</td>
<td>Chemistry of substance changes induced by irradiation. Basic concept of radiation processing. Radiation processing of polymer is based on the reactions of crosslinking, graft polymerization, and degradation.</td>
<td>Japanese society of radiation chemistry</td>
</tr>
<tr>
<td>Radiation physics</td>
<td>Physics of interaction of radiation and substance.</td>
<td>Subcommittee of The physical society of Japan</td>
</tr>
<tr>
<td>Radiation biology</td>
<td>Biology of action of irradiation on living things.</td>
<td>Subcommittee of the biophysical society of Japan</td>
</tr>
<tr>
<td>Radiology</td>
<td>Medical science of imaging for diagnosis such as X-ray radiography and positron emission tomography (PET) and cancer therapy.</td>
<td>Japan Radiological society</td>
</tr>
</tbody>
</table>

Internet search of “Radiation science” + “University” in Japanese hit many home pages of medical departments in Japanese universities. This is the reason why “radiation science” may mislead the research area of radiology owing to the organ name of NRIS. There are 79 medical departments in Japan. Almost of all medical departments have the faculties related with radiation therapy and nuclear medicine. In this aspect, 74.3 thousands students in 79 medical departments have an opportunity for lecture on radiation science such as radiation therapy and nuclear medicine as regular courses. In this lecture, they learn the fundamental radiation chemistry, radiation biology and radiochemistry. This student number is 2.9 % of university students since all universities in Japan have 2.552 thousands students.

2.2. Lectures on radiation chemistry in Japanese universities

Our institute covers the research fields of radiation chemistry, radiation physics, and radiation biology. One of our major contributions to IAEA is RCA collaboration in radiation processing of polymers. Radiation processing of polymers is based on radiation chemistry. Our interest comes to "Where is the lecture of radiation chemistry in university?" To solve this question, I tried to make the cross search of radiation chemistry and science in the home pages of Japanese university. TABLE 2 shows the keyword subjects of lectures in the departments of engineering and science in terms of radiation
chemistry and radiation science. Japanese language has an ambiguous expression between science and chemistry. This is because science and chemistry are pronounced in the same way of “kagaku” in Japanese. Writings are different way using distinguishable kanji letters. Therefore, lectures in the radiation chemistry and the radiation science may not be distinguished by subject names but also by the kinds of departments in university. Almost of all lectures related with radiation chemistry were given in graduate school of engineering department. Term of “Quantum” was often used instead of radiation in department engineering. Even in department engineering, lecture on radiation science includes medical engineering and nuclear and energy safety engineering as well as quantum science and energy engineering. In the case of department of science, radiation chemistry means other areas such as radiochemistry, radiation protection chemistry, and positron analysis. Lecture on radiation science are related with radiochemistry, radioisotope, nuclear physics, and radiation biology. There is not significant deference of subjects in radiation chemistry and radiation science in the department of science.

3. CONTRIBUTION OF TARRI TO EDUCATION

3.1. Contribution to lecture on radiation chemistry in universities

TARRI has many experts in radiation sciences including radiation chemistry, radiation biology and accelerator physics. For the human recourse development of radiation scientists in next generation, the experts have given the lectures on radiation science in various universities. There are several purposes of lectures for contribution to accumulate knowledge for national qualification examination for radiological technologist, extensive knowledge of nuclear energy science, comprehensive knowledge of radiation applications, topics of radiation applications such as applied biology and ion beam technology, and environmental radiation processing as current topics. The lectures on radiation chemistry is focused in the following sections.
First the lecture on radiation chemistry is given in Gunma Prefectural college of Health Science. This regular course lecture is composed of the following 14 items and examination, 90 min/item, in the semester. The lecture covers the major contents of radiation chemistry for knowledge accumulation for national qualification examination for radiological technologist. The level of lecture is consivehensible for undergraduates. No introductory book covering all contents is a problem for lecturers.

1. What is radiation chemistry
   Peculiar features of radiation chemistry and historical background

2. Radiation sources
   Alpha, beta, gamma, and charged particles and emission sources

3. Interaction between radiation and substance
   Adsorption of ionizing radiation and energy distribution in substance

4. Unit and definition
   SI units and definitions used in radiation chemistry

5. Yield of reactive products
   Definition and calculation of G value

6. Physical dosimetry
   Technology of physical dosimetry and calculation of dose

7. Chemical dosimetry
   Technology of chemical dosimetry and calculation of dose

8. Initiation process
   Reaction induced by excited molecular, ion, and radical

9. Detection of intermediate active species
   Detection technology for intermediate active species

10. Polymer and Radiation-induced polymerization
    History of polymer chemistry and peculiar features of radiation polymerization

11. Practical applications of radiation chemistry
    Irradiation facilities of gamma-rays, electron beam, and ion beam and industrial application

12. Radiation synthesis and industrial applications

13. Current topics of radiation chemistry

14. Examination for credit
Next the regular course lecture is "Quantum Energy Technology" for extensive knowledge of nuclear energy science in graduate school of engineering, university of Fukui. Lectures from 7 to 11 are given by our experts. Other lectures didn't were given by expert in TARRI but by those in other sites of JAEA.

1. Development of fast breeder reactor
2. Nuclear and industrial applications of high-intensity laser
3. Photon science research and fundamental technologies
4. High intensity laser and intense field research
5. Synchrotron radiation and its contribution to development of nuclear energy
6. Development of a high-intensity proton accelerator complex (J-PARC)
7. Research of radiation processing and its industrial applications
8. Principle and equipment of radiation generation
9. Development of genetic resources
10. Development of novel functional materials
11. Medical biology applications
12. Development of high temperature gas-cooled reactor
13. Research on hydrogen production
14. Research of fusion reactor
15. Guideline for report submission

A special graduate school, nuclear professional school of the University of Tokyo was launched for systematic inquiry education of atomic energy in 2005. The enrollment is 15 students in this graduate school. Preferable admission applicants have more than 2 years' work experience. Students choose the subjects out of the lecture courses of chief technician of nuclear reactors, chief engineer of nuclear fuel, and administrative technician. Chief technician of nuclear reactors and chief engineer of nuclear fuel are national qualifications for the operation of the reactor's safety and nuclear fuel processing and reprocessing of spent nuclear fuel, respectively. The students receive the degree of master, professional school, after taking the credits of the lecture, seminar, and experiment in two semesters. Regular course of the nuclear professional school contains

- Fundamental subject of atomic energy: Radiation safety, Nuclear and radiation measurements, Nuclear laws and regulations, Reactor physics, Nuclear hydraulics engineering, Nuclear structural engineering, Nuclear fuel materials science, and Nuclear fuel cycle engineering;
• Practical subject of Atomic Energy: Nuclear power plant engineering, Nuclear safety engineering, Nuclear management engineering, and Waste management engineering;

• Business subject of Atomic Energy: Human factors, Risk perception and communication, Organization and management, and Special lecture on nuclear power;

• Advanced subject: Reactor design, Radiation shielding, Radiation application, and Nuclear crisis management;

• Seminar: Radiation safety and radiation measurement, Nuclear regulatory practice, Reactor physics, Reactor core design practice, Heat hydraulics and nuclear power plant engineering, Atomic energy management engineering, Materials dynamics and nuclear structural mechanics, Nuclear fuel materials and nuclear fuel cycle engineering, Nuclear safety engineering and safety analysis, Radiation shielding, Waste engineering, Technology ethic, Risk communication and media support, and General nuclear matters;

• Experiments and practical training: Atomic energy experiments, Nuclear experiments and practical training, Internship, Nuclear reactor and nuclear reactor management.

Radiation application is a lecture of advanced subject category in nuclear professional school of the University of Tokyo. The first half of lecture on radiation applications deals with the fundamental knowledge of radiation science. The latter half from the following 8 to 14 are practical knowledge such as radiation processing of polymer, material evaluation, flue gas treatment, inorganic material, radiation biology, and agricultural and medical applications. Student can learn both fundamental and practical knowledge of radiation science by attending this lecture course. Lectures from 8 to 14 are given by our experts.

1. Kinds of radiation and radiation source
2. Interaction of radiation and matter
3. Dosimetry
4. Radical and Electron Spin Resonance
5. Pulse radiolysis
6. Radiation effects on aqueous solutions
7. Nuclear engineering and radiation effects
8. Radiation processing technology of polymers and its applications Techniques such as grafting, degradation, crosslinking and current status of technology transfer.
9. Radiation resistance evaluation of materials and its application Evaluation and modification of semiconductor in aerospace and polymer materials in nuclear facilities
10. Radiation effect in gas phase and its environmental application Removal technology of environmental pollutants using radiation technology
11. Preparation of inorganic functional materials by ion beams, Fabrication technology such as photocatalyst and ceramic material

12. Biological effects of radiation: Target theory, DNA damage and repair, cellular and individual effects, mutations, apoptosis, hormesis, etc.

13. Radiation biological research using ion beam: Ion beam breeding, Biological application of micro-beam, functional analysis of plant by positron emission


Lecture notes of the following eleven subjects were published as textbook series for nuclear professional school by Ohmsha, Ltd in Japan. Book of radiation application was published in 2011. Two subjects were already translated into English.

Japanese Version

2008/3  Dynamics and plant control of Nuclear
2009/2  Nuclear power plant engineering reactor
2009/3  Nuclear heat flow engineering
2009/4  Structural engineering of nuclear reactor
2009/11 Human factor introduction
2010/2  Engineering of Nuclear safety management
2010/3  Radiation shielding
2010/7  Nuclear reactor design
2011/1  Engineering of radioactive waste
2011/2  Radiation application
2012/3  Reactor physics

English version

2010/7  Super light water reactors and super-fast reactors (Springer)
2010/11 Advances in light water reactor technologies (Springer)

Intensive course in graduate school of Gunma university was given as lecture on environmental radiation processing 5 h/d in 3 days. Titles of 3 parts of the lecture are syntheses of environmental materials by using radiation and its application, reaction mechanism of radiation-induced activated species and environmental conservation application, and electron beam processing of gaseous
substances by using radiation. The lecture entitled syntheses of environmental materials by using radiation and its application is composed of radiation processing of polymer and its applications, applications for collection of significant metals, and industrial applications and patents. Students have special interest in the commercialization step of technology transfer to a private company. Students noticed the importance of patent application, registration, and licensing. Their impressions to the lecture are as follows:

- Radiation processing has been used for many products such as radial tire, car interior mat, and watch battery which are used in daily life,
- Radiation processing can modify the commercially available polymers by ionizing irradiation even at room temperature and lower,
- Better understanding and appropriate usage of irradiation brings socio-economical benefit to our life
- Dissemination of radiation processing technology plays important roles in the promotion of the technology transfer
- Fitting of industrial needs and target of radiation processing causes the effective application research and technology transfer of radiation processing
- Technical visit to radiation facilities of gamma ray and electron beam help us promote the understanding of radiation processing,

These opinions covers the advantages, expected strategies for technology transfer, and research motivation of radiation processing.

3.2. Contribution to IAEA training course

Several regional training courses were held in RCA program of RAS1014; Supporting Radiation Processing for the Development of Advanced Grafted Materials for Industrial Applications and Environmental Preservation (2013-2015). Japanese experts were dispatched to two regional training courses of “Advanced Radiation Grafting Polymeric Matrices for Environmental and Industrial Applications” 14-18 April 2014 in Ho Chi Minh city, Vietnam and “Regional Training Course on Application and Up Scaling of Radiation Grafting for Environmental and Industrial Applications” 13-

![FIG.2. Participants and technical visit in regional training courses; (a) Examination for better understanding of grafting technology and its application in Vietnam, (b) Technical visit to 1 MeV electron beam accelerator in China, and (c) Examination for better understanding of up-scaling](image)
17 April 2015 in Xianning, China. The numbers of participants were 21 and 50, respectively as shown in FIG.2.

Regional training course in Vietnam, 14-18 April 2014 provided all aspects of radiation grafting onto polymeric materials by means of lectures and discussion on grafting technology. Pre- and mutual irradiation grafting and the evaluation of graft products were demonstrated for their industrial and environmental applications. For better understanding of grafting technology, participants took the exam prepared by the experts. This training course noted as follows; Two experts are not enough to complete the all missions requested by IAEA. One more lecturer is recommended to accomplish all tasks. Subjects of local lecturers should be chosen not to overlap the contents in expert lecture. Training program should be announced to experts at least 1-3 month in advance to prepare the informative documents and slides.

In regional training course in China, 13-17 April 2015 experts gave the lectures on optimization strategies, adsorbents for toxic gas, managements for up-scaling for environmental applications and fuel cell membranes, adsorbents for metal ions, and examples of commercialization for industrial applications. Participants could obtain technical overview and related knowledge very efficiently beyond contents in textbooks from lecture, experiments, and Q&A. Especially, this training gave important opportunities of hands-on activities on up-scaling of grafting. Additionally, participants could build a future relationship among the other countries’ researchers in radiation processing of polymers. The expert recommended that discussion should be added in training course program to promote the management of technology for grafting to overcome the political and economical problems in their countries since lecture-based training reach the limitation of dissemination for up-scaling of grafting. Each country is requested to make own up-scaling strategy from viewpoint of industrial scale expected for the developed materials in advance.

Two domestic training courses were held in Thailand, 20-24 January 2014 and in Indonesia, 24-28 February 2014 for RAS1014. The mission of Japanese lecturer is to set up a vacuum line for pre-irradiation process in grafting, to give advice for grafting technique and to set up the evaluation instrument for adsorbent prepared by grafting as shown in FIG.3. There are environmental needs of metal adsorbents to purify the soil contaminated by cadmium from old mines in Thailand and removal of arsenic and cadmium contamination in soil and river in Indonesia. Thirty participants attended domestic training course in each country to promote the applied research of grafting. Informative lecture and demonstration was given to the participant usable skill and knowledge of grating. Direct Q&As such as the decay of radicals created by pre-irradiation and the suitable density of functional group in grafted materials with lecturer led the better understanding of grating technique.

Lecture noted that the irradiation time for training courses should be scheduled not to disturb the radiation experiments of other staff since irradiation facilities of cobalt-60 gamma and/or electron beam were used for researchers only one week a month in Thailand and one day a week in Indonesia and other irradiation time was occupied by private companies.
4. CONCLUSION

Investigation for lecture status on radiation science in Japanese university showed the lecture contents of radiation science corresponded to radiology in medical department although radiation science is considered to be a general scientific area covers radiation chemistry, radiation physics, radiation biology, radiology, and so on. This is because Japanese “Radiation Science” is a name of organ of national institute of radiological science and this term is usually used in the meaning of medical radiation science or radiology in Japan. In this situation, 74.3 thousands students (2.9 % of university students) in 79 medical departments learn the fundamental radiation chemistry, radiation biology and radiochemistry in the lecture on radiation science such as radiation therapy and nuclear medicine as regular courses. It was found that the lecture on radiation chemistry mainly had been given in the department engineering of graduate school.

Staff of our institute gave the lecture on radiation chemistry, radiation biology and accelerator physics in regular course in the universities to develop human recourse of next generation in the radiation science. Those lectures contribute to accumulate knowledge for national qualification examination for radiological technologist, extensive knowledge of nuclear energy science, comprehensive knowledge of radiation applications, topics of radiation applications such as applied biology and ion beam technology. Outcome in dissemination of lecture contents is to publish the 11 series of textbooks prepared by lecture notes in nuclear professional school of the University of Tokyo. Two subjects were translated into English and published as English textbook. Students attending the lecture on radiation processing noticed the advantages of radiation chemistry and gave all attention to the technology transfer of radiation application and patent strategy.

Japanese experts in regional and domestic training courses in RAS1014 gave the lecture on grafting technology, its environmental and industrial application, and up-scaling for technology transfer of grafting. They performed demonstration and experiment of grafting to promote the understanding of grafting technology and its technology transfer. The expert noted that shortage of number of lecturer and preparation time for the informative documents and slides which are not overlapped with those prepared local lecturers. Discussion among the participants should be added in training course.

FIG.3. Missions of lecturer in domestic training courses; (a) Seminar on grafting technique and its applications, (b) Grafting reaction using oven, and (c) Setup of the evaluation instrument for adsorbent prepared by grafting.
program to promote the management of grafting technology to overcome the domestic obstacles related with political and economical problems.

REFERENCES


CURRNET STATUS AND EDUCATION AND TRAINING PROGRAM FOR RADIATION TECHNOLOGY IN KOREA

Keun Bea Oh

Korean Atomic Energy Research Institute, Advanced Radiation Technology Institute

1. Introduction

Recently, electron beams have been employed that new materials include high strength and lightweight composite materials, components and materials such as permanent batteries, biomedical polymer materials, adding to the overall value of the products. The demands for novel materials with radiation technology are going to increase in developing countries, the application of electron beams to these industries will also grow to produce products of higher quality.

Education and training of radiation technology in Korea aims to improve the quality of environment and living conditions to the people in the world and the quality of agricultural products as well as industrial products through facilitating and maximizing the application of the innovative technology of electron beam accelerators by transferring technology, knowledge and practical experiences of trainees and students.

2. Education and training activity of Advanced Radiation Technology Institute (ARTI) in Korea Atomic Energy Research Institute (KAERI)

Advanced Radiation Technology Institute of the Korea Atomic Energy Research Institute (ARTI) was officially designated as collaborating center for IAEA in the radiation technology. The inauguration ceremony for the IAEA designation of the ARTI as an IAEA Collaborating Centre was held at ARTI International Cooperation Centre on May 15, 2012. Through strategic collaborations with IAEA, the institute is going to play a central role in spreading, developing, training and education three areas of Radiation technology such as environmental preservation treatments and development of new materials, food irradiation technology.

The main training activities of IAEA collaborating center are to promote the use of electron beams in food industry, industrial products and environment conservation. The training programmes are especially focus radiation technology as following (2012 ~ 2015)

- 2012.05.13. WNU School on Radiation Technologies
  - World Nuclear University Radiation School
  - Period : 3 weeks
  - Training field :
    - Radiation technology status, Radiation utilization of industry, medical treatment,
agriculture, International safety system etc.

- **2012.08.22.** Held Konicof / KAERI Atomic PR capacity building course work
  - Konicof / KAERI Atomic PR capacity building course work
  - Training field :
    - Development of atomic popularization for understanding of PR and practice capability
    - Overall understanding and strengthening practice capability of Press promotion
    - Through sharing of related organizations' success stories, practice-level of benchmarking and networking between the working-level person

- **2012.10.08.** RCARO/KAERI Regional Workshop on Radiation Application Technology
  - Period : October 8~19, 2012 (2week)
  - Meeting content :
    - Radiation processing of industry and medical treatment and agriculture

- **2012.10.22.** IAEA/RCA Workshop on Best Practice for Phytosanitary Applications of Food irradiation
  - Period : October 10~26, 2012 (5 days)
  - Meeting content :
    - Phytosanitary Applications of Radiation Food irradiation

- **2012.10.29.** IAEA Second Research Coordination Meeting of the Coordinate Research Project on “Radiation Treatment of Wastewater for Reuse with Particular Focus on Wastewaters Containing Organic Pollutants”
  - Period : October 10~26, 2012 (5 days)
  - Meeting content :
    - Progress meeting on Radiation Treatment of Wastewater project

- **2012.11.01.** IAEA/KOICA/KAERI Interregional Training Course on Nuclear Energy Policy, Planning and Project Management
  - Period : November 1~29, 2012
  - Training field :
    - Atomic policy, planning, management of project

- **2012.11.03.** IAEA/RCA Regional Training Course on “Monte Carlo simulations for CT, RPT,
SPECT and design of radiotracer experiments

- Period: November 3~7, 2012
- Training field:
  - Monitoring technology related to design of radiotracer

- 2013.08.19. RCARO REGIONAL TRAINING COURSE in Basic Knowledge and Hands-on Experiment On Electron Beam Application for Value Addition to Industrial Products
  - Period: August 1~23, 2013
  - Training field:
    - Advanced materials on radiation processing
    - Electron Beam technology status in Korea
    - Electron Beam utilization of industry

- 2013.10.07. RCARO REGIONAL TRAINING COURSE in Basic Knowledge and Hands-on Experiment On Electron Beam Application for Value Addition to Environmental Remediation
  - Period: October 7~11, 2013
  - Training field:
    - Environmental protection engineering
    - Electron Beam technology status in Korea
    - Electron Beam utilization of Environmental protection

- 2013.10.07. RCARO/KAERI REGIONAL Workshop on Research Reactor, Radiation Application, Small and Medium-Sized Reactor Technology
  - Period: October 7~25, 2013
  - Training field:
    - Nuclear Policies and R&D in Korea
    - Radioisotope utilization and application
    - Linear Accelerator and Electron Beam
    - Small sized Reactor

- 2014.04.14. RCARO REGIONAL TRAINING COURSE in Basic and Advanced Knowledge and Hands-on Experiment on Electron Beam Applications for Advanced Material in Asia Pacific Region
➢ Period: April 14~25, 2014
➢ Training field:
  - Radiation chemistry on new materials
  - Experiment on radiation usage and amount
  - New materials application field

● 2014.06.16. RCARO REGIONAL TRAINING COURSE in Basic and Advanced Knowledge and Hands-on Experiment on Electron Beam Applications for value addition to food products in Asia Pacific Region
➢ Period: June 16~20, 2014
➢ Training field:
  - Basic theory regarding radiation chemistry which is applied food irradiation
  - Understanding radiation
  - Experiment using gamma rays and electron beam

● 2014.10.21. Open an educational course 2014 RCARO/KAERI Regional Workshop on Radiation Technology and its Applications
➢ Period: October 21~23, 2014
➢ Participants: 3 trainers and 15 trainees
➢ Training field:
  - Status of radiation industries in Korea
  - Radiation Biotechnology
  - Human Effect of Radiation
  - Radiation Technology application for agriculture
  - Drug Evaluation using Radioisotope
  - Cyclotron and its application
  - Radiation measurement instrument
  - Radiation application for environment conservation
  - Radiation processing for polymeric materials and its industrial applications

● 2015.05.11. RCARO REGIONAL TRAINING COURSE on Electron Beam Applications for Environmental Pollutants in Asia Pacific Region
- Period: May 11~22, 2015

- Training field:
  - Radiation Protection and Safety
  - Application of ionization radiation to environmental conservation
  - Waste Treatment and Recycling using Radiation
  - Overall of the radiation measurements with different type of radiation detectors
  - Water and Wastewater Treatment using Radiation
  - Livestock Waste and Wastewater Treatment using Radiation
  - Global Warming Gas Treatment using Electron Beam
  - Hazardous air pollutant treatment using radiation hybrid technology
  - Treatment of swine wastewater pre-treated by E-beam using an ion-exchange membrane biological reactor
  - Micropollutant Treatment using Radiation
3. Education and training activity of RCARO

The RCA Regional Office (RCARO) was established in 2002 in Korea for the purpose of providing enhanced visibility for the RCA and developing partnerships with other organizations. The government of Korea has financed the operation of the RCARO since its inauguration. Education and training programmes of RCARO/KAERI, RCARO/KAIST and RCARO/ARCCNM to improve the quality of environment and living conditions to the people in the Asia-Pacific region (the RCA region) and the quality of agricultural products as well as industrial products through facilitating and maximizing the application of the innovative technology of electron beam accelerators by transferring technology, knowledge and practical experiences of developed countries to developing countries. The RCARO is implementing the RCA/KAERI training course related to information on the status of radiation technology and its application, since 2008. Through this workshop, 100 trainees were supported from 12 countries. The RCARO is also implementing the RCA/KAIST master’s degree programme, which is education and training to the excellent student from the Government Parties aiming to preserve and enhance nuclear technology for RCA GPs. This programme supported Airfares, admission fee and tuition for 3 students during 2 years. RCARO/ACCMM training course also is supported to educate nuclear medicine physicians and scientists in developing and less developed Asian countries.

- **RCARO/KAERI Regional Workshop**
  - To provide information on the status of radiation technology and its application
  - Supported 100 trainees since 2008
  - BGD(10), CPR(7), IND(5), INS(9), MAL(10), MON(6), MYA(8), PAK(9), PHI(9), SRL(8), THA(9), VIE(9)

- **RCARO/KAIST Nuclear Engineering Master Degree Course**
  - To educate and train the excellent students from the Government Parties (GPs) aiming to preserve and enhance nuclear technology for RCA GPs
  - 28 students have received the degree since 2003
  - BGD(6), CPR(1), INS(6), MAL(1), MON(1), MYA(5), PAK(5), PHI(2), SRL(1), VIE(2)

- **RCARO/ARCCNM Training Course**
  - To educate nuclear medicine physicians and scientists in developing and less developed Asian countries
  - Supported 25 young scientists in the region every year (total 150 trainees) since 2008

* ARCCNM: Asian Regional Cooperative Council for Nuclear Medicine
4. Education programmes of University in Korea

University of Science and Technology (UST) is supported by Ministry of Science, ICT and Future Planning in Korea since 2004. UST is the unique graduate university based on National Research Institutes in Korea. The 30 national research institutes campuses in the nation focus on-site education in order to foster creative R&D professionals. UST creates an ecosystem of professionals attracting global excellent students through the practical R&D education by the top qualified faculty of National Research Institutes and state-of-the-art research facilities and equipment. KAERI is the one of on-site 30 National Research Institute campus of UST. 100 KAERI researchers are appointed UST professor. Among 100 KAERI-on-site professors, 19 professors are acting to adviser for UST students. In KAERI campus of UST, to develop of outstanding and oriented human resource in Nuclear Technology, 17 Ph.D course and 12 Master course students are educated for Responsibility for R&D on nuclear technology and nuclear activities in applied areas such as medicine, agriculture, food and life sciences.

Also, to educate and train the students for nuclear power plants and radiation for diagnosis and treatment, theoretical knowledge and get hands-on experience with generation logics of nuclear power, application of nuclear power, radiation and the effect and protection of nuclear power. 8 universities run subject related in nuclear engineering and radiation for under graduated students. And they also supports Master and Ph.D program in Korea.

- University of Science and Technology (UST)
  - KAERI on-site 30 National Research Institute campus of UST
- Seoul National University
  - Nuclear Engineering
- Korea Advanced Institute of Science and Technology (KAIST)
  - Nuclear & Quantum Engineering
- Dongguk University
  - Nuclear energy system Engineering
- Hanyang University
  - Department of Nuclear Engineering
- Chosun University:
  - Department of Nuclear Engineering

- Kyung Hee University:
  - Department of Nuclear Engineering

- Sejong University:
  - Department of Nuclear Engineering

- Ulsan National Institute of Science and Technology (UNIST):
  - Nuclear Engineering
5. Summary

In IAEA collaboration center in ARTI, since 2012, IAEA/KOICA/KAERI interregional training course, IAEA/RCA Regional Training Course, WNU and KONICOF/KAERI course work were held to technology transfer, Radiation technology status, Atomic policy, Monitoring technology related to design of radiotracer etc. The RCARO is also implementing the RCA/KAIST master’s degree programme, which is education and training to the excellent student from the Government Parties aiming to preserve and enhance nuclear technology for RCA GPs. RCARO/ARCCNM training course also is supported to educate nuclear medicine physicians and scientists in developing and less developed Asian countries and supported 25 young scientists in the region every year (total 150 trainees) since 2008. University of Science and Technology (UST) is supported by Ministry of Science, KAERI is the one of on-site 30 National Research Institute campus of UST. 100 KAERI researchers teach that responsibility for R&D on nuclear technology and nuclear activities in applied areas as medicine, agriculture, food and life science. In Korea, to educate and train the students for nuclear science and Technology and relative applications, 8 universities manage related department for under graduated and graduated students.
THE STATUS OF EDUCATION ON RADIATION SCIENCES RELATED TO RADIATION PROCESSING APPLICATIONS IN MALAYSIA

Khairul Zaman Hj Mohd Dahlan

INTRODUCTION

Radiation science is a basic knowledge prerequisite for pursuing the application of radiation in various fields such as agriculture, medicine and industry. Therefore it is very important for the basic knowledge to be incorporated in the curriculum of university based on disciplines such as Chemistry, Physics and Biology. Unfortunately, the subject of radiation sciences is not well thought at the University. Currently, the subject of radiation is introduced at the university either as part of nuclear sciences program or in relation to health and safety.

Radiation protection and radiation safety are of prime importance in any activity related to the use of ionizing radiation and radioisotopes. It is required by law for any institution or companies that having such activity to have radiation protection personnel that are qualified and certified by the Atomic Energy Licensing Body. As such radiation protection and radiation safety training courses are well developed and become popular courses organized by several private training institutions as well as by the government training centers. The support of IAEA in this area is very significant. IAEA has been supporting Malaysia as the Regional Training Center for the Post Graduate Educational Course in Radiation Protection & The Safety of Radiation Sources (PGEC) since in the year 2000. In 2015, Malaysia is organizing the 12th PGEC Training Course.

The requirement of radiation protection and radiation safety in Malaysia is clearly shown in Fig. 1.0. A total of 1205 no of License Holders awarded by the Atomic Energy Licensing Board are still in operation. Nuclear gauge is the main applications of radiation sealed sources and followed by NDT. With regards to radiation processing applications, there are 11 irradiation plants established in Malaysia, 5 of Co-60 gamma irradiation plants (Table 1.0) and 9 units of electron accelerators (Table 2.0). Therefore, beside the health and safety aspects of radiation workers, the basic knowledge of radiation sciences and its related application are also of prime importance, especially to the staff who are looking after the quality control, processing and R & D. One of the challenges face in educating the personnel especially from the industry on radiation sciences and its applications is the absence of law and regulation.

RADIATION SCIENCES AT LEARNING INSTITUTION

Subject on radiation sciences are being thought at the University in Malaysia as indicated in Table 3.0. From the main 5 Public Universities, only the Universiti Kebangsaan Malaysia (UKM) that offers Bachelor of Science (BSc) in the field of Nuclear Science. This program started since 1978 with an average of 30 students annually. Subjects related to radiation are being thought throughout 4 years degree program which include radiation chemistry, radiation biology and radiation physics. UKM is also offering MSc courses on Nuclear and Radiation Safety since 5 years ago. New MSc course on
Safety, Security & Safeguard will be launched soon too. Chemistry and Radiation Safety Management for executive is being organized during weekend and received strong support from industry.

In the other 4 Universities, Universiti Malaya (UM), Universiti Putra Malaysia (UPM), Universiti Sains Malaysia (USM) and Universiti Teknologi Malaysia (UTM), subject on radiation science is offered only by the Department of Physic. The subjects are radiation physics, radiation protection and radiation safety.

It is clearly shown that the formal teaching of radiation sciences at the University level is insufficient. It is therefore recommended that more courses to be organized in collaboration with the Universities since University have the authority to issue and award Diploma and Degree. For short training course with certificate issued by the international body such as IAEA is also recommended and can be organized by the National Atomic Energy Authority or with the participation of the Private Training Centre.

RADIATION SCIENCES AT R&D INSTITUTION: IAEA Collaborative Centre.

Malaysian Nuclear Agency (Nuclear Malaysia) was first designated as the IAEA Collaborating Centre (ICC) on Radiation Processing of Natural Polymer on the 31st October 2006 for a period of 3 years, until 2009. The ICC was extended for another 4 years from 2010 to 2014 with the expansion of scope of activity to Radiation Processing of Natural Polymer and Nano-materials. This was to take advantages of the newly established nano-materials laboratory and facilities at the Radiation Processing Division of the Nuclear Malaysia in 2010.

In relation to the education on radiation sciences, the ICC has conducted the first IAEA Regional Training Course (RTC) on Radiation Processing for Basic and Medium Level of Personnel from 6 to 10 August 2007. The RTC provided the basic knowledge on radiation chemistry and processing as well as the up to date applications including natural polymers in healthcare and agriculture. Seventeen participants from eleven member states in the region, namely, Bangladesh, China, India, Indonesia, Malaysia, Mongolia, Myanmar, Philippines, Sri Lanka, Thailand and Vietnam attended the training course. Five local lecturers from Nuclear Malaysia and one invited lecturer from the Philippines delivered lectures in various related fields.

In 2007, the ICC received 2 IAEA fellows from Saudi Arabia for training in polymer processing, testing and dosimetry for a period of 2 months. The fellows were trained on the basic knowledge and practices of blending and processing of agro-fiber polymer composites and nanoclay polymer nanocomposites.

In 2008, the construction of a new building for nano laboratory begun and several equipment related to nano materials have been installed namely dynamic laser light scattering, static laser light scattering, zeta potential and transmission electron microscope. It followed with the installation of the following equipment namely dynamic light scattering for nanosize particles analyzer, scanning probe microscope (SPM), static light scattering for absolute molecular weight determination and radius gyration measurement and Asymmetry Free Flow Fractionation (AF4) for nano to macro size molecules separation and molecular weight determination and gas permeation chromatography (GPC).
The establishment of the Nano laboratory was to complement and expand the functions of the radiation processing of polymer, testing laboratory and pilot scale facilities. The building and the facilities completed on 11 February 2010.

In 2008, there were total of 63 local and foreign students from 8 local universities attached to the ICC, undertaking research in various areas related to the application of radiation processing, out of which, 39 were postgraduate students, namely, 13 PhD and 26 MSc. The ICC also provided fellowship training to 3 fellows from Sudan Atomic Energy Commission for duration of 2-3 months in the field related to radiation processing under the IAEA Fellowship and Scientific Visit Program.

In 2009, there were total of 58 local and foreign students from 8 local universities were still continuing their research at ICC in various areas related to the applications of radiation processing technology. Out of which, 41 were postgraduate students, comprising 12 PhD and 29 MSc and the rest was 17 industrial training undergraduates. The ICC and local universities such as UKM, UPM and UTM are jointly providing training and supervision to students from Sudan, Myanmar, Iran, Indonesia and Yemen registered under the Universities MSc and PhD program. The ICC has also received 4 IAEA scientific visitors from Philippines, South Korea, Morocco and Bangladesh and a fellow from Egypt for 3 month training and research attachment at the radiation curing laboratory.

In 2012, there were total of 70 local and foreign students from 10 local universities attached at the ICC, comprising 12 PhD and 18 MSc and 40 BSc final project including industrial training undergraduates. ICC has also received 2 IAEA fellows from the Irradiation Centre, Vietnam Atomic Energy Agency for 3 months training on Radiation Processing Facilities and Applications.

ICC together with the private company and Malaysia Automotive Institute (MAI) under Malaysian Industry Government Group for High Technology (MIIGHT) has organized 2 training courses with 2 days period for each training, on compounding and testing of green composites to 30 un-employed graduates. During the training, the graduates had demonstration on the preparation for blending and compounding of green and synthetic materials, and sample preparation for testing.

In 2013, ICC received postgraduate student comprising of 13 PhD and 20 M.Sc., and 34 BSc students doing final year project and industrial training. The summary of the number of education activities concerning human capital development undertaken by the ICC in Malaysia is given in Table 4.0.

---

**Fig.1.0 No of Atomic Energy License Holders in Malaysia, as of January 2015, (courtesy of AELB)**

<table>
<thead>
<tr>
<th>License Activity</th>
<th>License Holders</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irradiation facility/plant</td>
<td>11</td>
</tr>
<tr>
<td>NDT</td>
<td>77</td>
</tr>
<tr>
<td>Nuclear Gauge</td>
<td>769</td>
</tr>
<tr>
<td>Supplier</td>
<td>270</td>
</tr>
<tr>
<td>R &amp; D</td>
<td>49</td>
</tr>
<tr>
<td>NORM</td>
<td>25</td>
</tr>
<tr>
<td>Medical</td>
<td>10</td>
</tr>
</tbody>
</table>
Table 1.0. No of Cobalt-60 industrial irradiation facilities for sterilization and food irradiation, as of 2015

<table>
<thead>
<tr>
<th>Name of company</th>
<th>No. of Facility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malaysian Nuclear Agency</td>
<td>2</td>
</tr>
<tr>
<td>(SINAGAMA &amp; RAYMINTEX)</td>
<td></td>
</tr>
<tr>
<td>Ansell NP Sdn. Bhd., Malacca</td>
<td>1</td>
</tr>
<tr>
<td>(4.0 million Curie design capacity)</td>
<td></td>
</tr>
<tr>
<td>Synergy Sterilization Rawang (M) Sdn Bhd.</td>
<td>1</td>
</tr>
<tr>
<td>(8.0 million Curie design capacity)</td>
<td></td>
</tr>
<tr>
<td>Synergy Sterilization (M), Kulim</td>
<td>1</td>
</tr>
<tr>
<td>(8.0 million design capacity)</td>
<td></td>
</tr>
<tr>
<td>Grand Ten Holding Sdn Bhd (Wembly Rubber Products/WRP),</td>
<td>1 (2014)</td>
</tr>
<tr>
<td>(8.0 million curie design capacity, installed 3MCi)</td>
<td></td>
</tr>
</tbody>
</table>

Table 2.0. No of industrial electron beam accelerators in Malaysia as of 2015

<table>
<thead>
<tr>
<th>Name of company</th>
<th>Machine specification</th>
<th>Manufacturer</th>
<th>Purpose of Irradiation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuclear Malaysia</td>
<td>200 kV, 20 mA</td>
<td>NHV, Japan</td>
<td>CURETRON (research and services) – mainly for curing of surface coatings</td>
</tr>
<tr>
<td>Nuclear Malaysia</td>
<td>3.0 MeV, 30mA</td>
<td>NHV, Japan</td>
<td>ALURTRON (research and services) for crosslinking of tubes, heat shrinkable tubes, crosslinking of wire insulation</td>
</tr>
<tr>
<td>Sumitomo Electric Interconnect Products, Johor</td>
<td>800 kV, 100 mA</td>
<td>NHV, Japan</td>
<td>Cross-linking of wires insulation</td>
</tr>
<tr>
<td>Sumitomo Electric Interconnect Products,</td>
<td>2.0 MeV,</td>
<td>NHV, Japan</td>
<td>Crosslinking of wire insulation</td>
</tr>
<tr>
<td>Location</td>
<td>Acceleration</td>
<td>Current (mA)</td>
<td>Company/Country</td>
</tr>
<tr>
<td>------------------------</td>
<td>--------------</td>
<td>--------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>Johor</td>
<td>100 mA</td>
<td></td>
<td>Cross-linking of heat shrink packaging film</td>
</tr>
<tr>
<td>Cryovac, Kuantan</td>
<td>550 kV, 60mA</td>
<td>6 units</td>
<td>ESI, USA</td>
</tr>
<tr>
<td>S.K.Polymer, Klang.</td>
<td>150 kV, 460mA</td>
<td></td>
<td>Meditop, BBB</td>
</tr>
</tbody>
</table>

Table 3.0. Status of Education Program on Radiation Sciences at Higher Learning Institution in Malaysia

<table>
<thead>
<tr>
<th>University/Research Institution</th>
<th>Education level</th>
<th>Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>University Malaya (UM)</td>
<td>Undergraduate – BSc (physics) MSc in Applied Physics</td>
<td>• Radiation Physics (2nd year – elective) • Radiation Protection • Radiation Technology</td>
</tr>
<tr>
<td>Universiti Kebangsaan Malaysia (UKM)</td>
<td>Undergraduate – BSc in Nuclear Science MSc by course work PhD by research</td>
<td>• Applied Radiation Biology • Radiation Chemistry • Radiation Processing Laboratory</td>
</tr>
<tr>
<td>Universiti Sains Malaysia (USM)</td>
<td>IAEA Post graduate Educational Course in Radiation Protection &amp; The Safety of Radiation Sources (PGEC)</td>
<td>• Radiation Protection • Radiation Safety</td>
</tr>
<tr>
<td>Universiti Putra Malaysia (UPM)</td>
<td>Undergraduate – BSc (Physics)</td>
<td>• Radiation Physics • Radiobiology</td>
</tr>
<tr>
<td>Universiti Teknologi Malaysia</td>
<td>Undergraduate – BSc (Physics)</td>
<td>Radiation safety and protection</td>
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<td>Malaysian Nuclear Agency R&amp;D</td>
<td>IAEA Collaborative Centre</td>
<td>Radiation X-liking</td>
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<td>IAEA Collaborative Centre Training courses</td>
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<td>Radiation grafting</td>
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<tr>
<td>PGEC in collaboration with USM</td>
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<td>Radiation curing</td>
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<td>Radiation degradation</td>
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<td>Radiation Mutation</td>
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<td>Food Irradiation</td>
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<td>NDT</td>
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<td>Nuclear Gauging</td>
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<td>Tracers</td>
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<td>Radiation Protection</td>
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<td></td>
<td></td>
<td>Radiation Safety</td>
</tr>
</tbody>
</table>

Table 4.0. Education related activity under the IAEA Collaborative Centre of the Malaysian Nuclear Agency, 2007 – 2014.

<table>
<thead>
<tr>
<th>Year</th>
<th>PhD/MSc research students</th>
<th>BSc project and Industrial training</th>
<th>IAEA fellows and SV</th>
<th>Training Course</th>
</tr>
</thead>
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<tr>
<td>2007</td>
<td>42</td>
<td>18</td>
<td>-</td>
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<tr>
<td>2008</td>
<td>39</td>
<td>24</td>
<td>3 fell</td>
<td>-</td>
</tr>
<tr>
<td>2009</td>
<td>41</td>
<td>17</td>
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<td>2013</td>
<td>33</td>
<td>34</td>
<td>-</td>
<td>-</td>
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<tr>
<td>2014</td>
<td>37</td>
<td>27</td>
<td>-</td>
<td>-</td>
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</table>

**SUMMARY**

Education on radiation sciences have been accepted and incorporated in the University curriculum for undergraduate studies in all 5 main public Universities in Malaysia. However, there is still area for
further improvement and enhancement to cover a wide range of radiation sciences in relation to chemistry, physics, biology and environment. Efforts to expand the radiation sciences fields to MSc and PhD program are commendable and should be supported and strengthened with more basic knowledge on radiation sciences be thought at the degree level. The application of radiation sciences should also be given emphasized especially that related to industry, environment and wellbeing. Radiation sciences should not always be seen in defensive way, i.e. protection, safety and safeguard aspects but instead as means for wealth creation.

In this regards, research and development on radiation sciences should be encouraged and supported by the Member States at the National level and International Organization such as the IAEA. Consequently, more staff of Nuclear Agency should be exposed via official training on radiation sciences organize systematically that can impact a good knowledge and initiate radiation science research project. As has been demonstrated that, the ICC in Malaysia is very active in receiving students, local and foreign for postgraduate research and industrial project attachment.

ACKNOWLEDGMENT

Author wishes to thank the Atomic Energy Licensing Board of Malaysia for providing the data on the Atomic Energy License Holder, Malaysian Nuclear Agency and the following individual, i.e. Prof. Dr. Elias Saion of UPM, Prof Dr. Muhamad Samudi Yasir of UKM and Prof Dr. Mohd Yusof Mohd Amin of UM, that provide some of the data and information that lead to the completion of this article.
THE STATUS OF EDUCATION ON RADIATION SCIENCE RELATED TO RADIATION PROCESSING APPLICATIONS IN THAILAND

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Department of Materials Science, Faculty of Science, Kasetsart University,

Bangkok, Thailand

Education of radiation science in Thailand

There are three main institutions providing the education and performing the courses related to radiation science and technology, i.e., (i) Department of Nuclear Engineering, Faculty of Engineering, Chulalongkorn University (CU), (ii) Department of Applied Radiation and Isotopes, Faculty of Science, Kasetsart University (KU), (iii) Department of Materials Science, Faculty of Science, Kasetsart University (KU).

Besides the education sectors, there are other organizations who play responsibility and work related to radiation science and technology in Thailand. Office of Atom for Peach (OAP) serves as the main authority for nuclear regulatory in the country. Thailand Institute of Nuclear Technology (TINT) is a public organization since 2006. TINT serves as a research and development body on nuclear science and technology. Radiation science and applications are also distributed in Department of Physics, where perform some researches but not operate the course. Synchrotron Light Research Institute (SLRI) is a public organization performing the research and development and providing the service on synchrotron radiation for characterization. Synergy Health (Thailand) is a well-known industrial sector mainly providing gamma-irradiation service for sterilization. There is another big sector on nuclear medicine in the Universities of Hospital.

Department of Nuclear Engineering, CU focuses on Nuclear Engineering. The education emphasizes on nuclear reactor & power plant, nuclear instrumentation, nuclear industry (e.g., non-destructive testing, NDT) and nuclear safety, security and safeguard. There are three degrees on M.Sc. (Nuclear Technology), M.Eng. (Nuclear Engineering) and Ph.D. (Nuclear Engineering). Department of Applied Radiation and Isotopes, KU focuses on nuclear science. The education emphasizes on radiation for agriculture, radiobiology, radioecology and radiation protection. There are three degrees, i.e., B.Sc. (Radiation Bioscience) and B.Sc. (Nuclear Science) and M.Sc. (Applied Radiation and Isotopes). Department of Materials Science, KU focuses on polymers, materials and nanomaterials science and technology. It is important that to note that in the present time this is the only one academic institution of Thailand who provides the course in the field of radiation chemistry and processing for polymer synthesis, modification and fabrication.

All of the academic institutions not only provide the education but also work in collaborating with OAP and TINT. The academic institutions produce the human resource to serve OAP and TINT; otherwise, OAP or TINT sends their staffs to study in these academic institutions. OAP and TINT provide and support irradiation facilities for research and development not only Academic Institution
but also Industrial sector. OAP provides gamma-irradiator. TINT provides (i) Research Reactor, (ii) Irradiation Center for insect and food irradiation and (iii) Gem Irradiation Center providing gamma, electron and neutron irradiation service for particularly gemstone including R&D.

**Education of radiation processing and applications in Thailand**

There are 3 eras of education on radiation processing in Thailand. The 1\textsuperscript{st} era started in 1979 in the Department of Nuclear Engineering, Faculty of Engineering, CU by Associate Professor Chayagrit Siri-Upathum. He prepared the course not only on nuclear chemistry but also radiation chemistry and processing. This course was not active in 2010. In the 2\textsuperscript{nd} era, the selective course on radiation and chemistry and processing was then established in 2010 in Deapartment of Applied Radiation and Isotopes, Faculty of Science, KU. In 2010, Faculty of Science operated the interdisciplinary program on M.Sc. and Ph.D. on Nanomaterials Science, Department of Materials Science, KU. Thus the administrative division rearranged the course to be more appropriate for each curricular and suited for each Department. Therefore the course on radiation chemistry and processing was not active in the Department of Applied Radiation and Isotopes. In conclusion, the course related to radiation processing for materials was improved and newly established only in the Department of Materials Science in the 3\textsuperscript{rd} era in 2012.

Department of Materials Science, KU provides two curricula, i.e., M.Sc. and Ph.D. in Nanomaterials Science and 5 research units (RU), i.e., RU1-advanced materials, RU2-biomaterials, RU3-renewable energy and environment, RU4-functional polymers and bioplastics and RU5-nanomaterial characterization. For RU4, it composes of two laboratory, i.e., (i) chemical synthesis laboratory and (ii) radiation processing laboratory. In 2014, a center of radiation processing for polymer modification and nanotechnology (CRPN) was established in order to make radiation processing technology more visible in the public than only in course. CRPN is expected to be a center for educating, introducing and transferring the technology of radiation processing and applications to not only students but also other scientists and all researcher in the country.

For the course in M.Sc. and Ph.D. (Nanomaterials Science), it is important to note that 20% of the core course, i.e., synthesis and fabrication of nanomaterials, is irradiation technology. This means that it is a chance to introduce radiation technology for nanomaterial development to all post-graduate students in the program. In addition, there are 2 selective course on “Modification of Polymer and Nanomaterial using Radiation” for M.Sc. program and “Advanced Fabrication of Polymeric Nanomaterial using Radiation” for Ph.D. program and the detail of the course are as follows:

**Modification of Polymer and Nanomaterial using Radiation (for M.Sc.):**

- Introduction to radiation science
- Radiation sources used in polymers and nanomaterials modification
- Interactions of electromagnetic radiation and charged particles in polymers
Basic radiation chemistry of polymers in aqueous system
- Effects of radiation on polymers
- Polymerization, grafted copolymerization, polymeric degradation and cross-linking by radiation induction
- Radiation fabrication of polymer-based nanomaterials and applications

Advanced Fabrication of Polymeric Nanomaterial using Radiation (for Ph.D):
- Advanced radiation chemistry for polymeric nanomaterial fabrication by bottom-up and top-down processes
- Advanced radiation methods for nanoscale size control of polymeric nanomaterials
- Radiation-induced ion track, surface grafting, coating, blend and composite
- Properties and characterizations of radiation-fabricated polymeric nanomaterials

To increase the capability of the students and young researchers in doing research, they have been trained not only inside the University but also in abroad, such as, Tokyo Institute of Technology (TIT) supported by Faculty of Science, KU (2011); Takasaki, Japan Atomic Energy Agency (JAEA) supported by MEXT researcher exchange program (2013) and Department of Chemistry, Hacettepe University supported by Synchrotron Light Research Institute (SLRI) and Faculty of Science, KU (2015). The students are supported to attend the international conference both in the radiation science and applications colonies but also in the polymer and material groups in order to introduce radiation processing technology.

To fulfill and improve the course on “Modification of Polymer and Nanomaterial using Radiation”, the visiting professor from this field was invited to share the knowledge in the course in 2013 and 2014 supported by visiting professorship program from Faculty of Science, KU. Besides outbound activity, the academic staff also attended the workshop/training course organized by Joint ICP-IAEA and IAEA/RCA. On the other hand, we also provide the technology transfer to the researchers in the country.

The research activities on radiation processing of polymers and nanotechnology can be categorized in to three applications, i.e. agriculture, medicine and industry. For agricultural application, the radiation processed chitosan nanoparticles have been developed as postharvest substance, pest protective film, bioactive compound controlled release, and fertilizer controlled release. For medical applications, the improvement of antioxidant activity and the preparation of drug nanocarrier, scaffold, hydrogel and nanogel have been studied using gamma and electron beam irradiation. For industrial purpose, the polymer-inorganic nanoparticles and composites have been developed as antimicrobial additives, coating and painting, and radiation dosimeter. Radiation-processed bioplastic, i.e. PLA has also focused.
To accomplish the research, the irradiation facilities have been supporting by Gamma Irradiation Service and Nuclear Technology Research Center (NTRC) (Cs-137, 0.78 kGy/h), Office of Atom for Peace (OAP) (Co-60, 4 kGy/h) and Thailand Institute of Nuclear Technology (TINT) (Co-60 GammaCell, 4.5 kGy/h and Gamma room, 8 kGy/h), E-beam accelerator (8-20 MeV).

Problem analysis on radiation science related to radiation processing and education in the country

Problem of the country is lack of knowledge in radiation science and applications. It may be analyzed into two groups. The 1st group is person who lack of knowledge and misunderstand in radiation science and applications but they would like to approach this technology. This brings about incorrect conditions for radiation utilization and unsuccessful results and products. The 2nd group is person who lack of knowledge and unaccept the technology. Therefore they refuse to use and to support this technology. They give the reason in lack of irradiation facilities or they can utilize other well-known or competitive technology. Because of these two groups based on lack of knowledge of course, the utilization of radiation processing applications is ineffective and not widely used. It can be therefore concluded that the main problem is lack of knowledge; however, if we provide enough area of knowledge, we also need to provide enough facilities. That is the reason for taking effort to solve such two problems in order to expand this technology in the country.

SWOT analysis of radiation science related to radiation processing in Thailand

S-Strengths

S1-Radiation processing for polymer modification and nanomaterial synthesis techniques compost of 5E, Efficient, Enable, Economic, Energy saved, Environmentally friendly (Green process), which is essential for sustainable technology.

S2-The country continuously develops radiation processing technology through education and research operation over 35 years.

S3-The country has productivity indicated from graduated students, ISI-indexed publications, patents, products.

S4-This technology in the country has been strongly supported by world-class specialist organization (IAEA).
W-Weaknesses

W1-Unacceptable technology for people who lack of knowledge.

W2-Lack of facilities (i.e., irradiation facilities).

O-Oportunity

O1-Radiation processing is an emerging and competitive technology.

O2-Radiation processing is a green technology for sustainability.

T-Threats

T1-There are other acceptable used processes and competitive technologies.

Review the needs to IAEA assistance and suggestion for the future education and research developments

One of the solution to overcome the weakness (W1) that can be assisted by IAEA is to support the education for young and new-wave researchers, scientists and students who work relevant to radiation processing technology in terms of academic activity supports:

• Visiting professorships
• Master and doctoral scholarships
• Exchanged research students/researchers
• Post-doctoral fellowships
• Research and researcher for industry

  • To support research and researcher who perform the research in collaborating between university and the industrial sector

This action would help to improve knowledge and to support and encourage students, young scientists who study or work in this field. With these support, we will develop to be CLASS.

• C-Continuous
• L-Large scale
• A-Applicable
• S-Strength
Another solution to overcome the weakness (W2) of this technology in terms of lack of facility is to develop an alternatively accessible and low-cost irradiator.

RECOMMENDATIONS

- IAEA should provide Visiting Professorship to fulfill the existing course for each country
- IAEA should suggest good education materials, e.g., e-books, text books, references.
- IAEA may help to provide the support for young and new-wave researchers, scientists and students who work relevant to radiation processing technology in terms of academic activity supports:
  - Master and doctoral scholarships
  - Exchanged research students/researchers
  - Research and researcher for industry
    - To support research and researcher who perform the research in collaborating between university and the industrial sector
HISTORY AND EDUCATION OF THE NUCLEAR SCIENCE AND RADIATION SCIENCE & TECHNOLOGY IN TURKEY

M. Sen

Hacettepe University Department of Chemistry, Polymer Chemistry Division, 06800, Beytepe, Ankara, Turkey

1. History of the Nuclear Science and Radiation Science & Technology in Turkey

The history of the Nuclear Science and Radiation Technology in Turkey was started in 1956. In 1956, General Secretariat of Atomic Energy Commission was established in Ankara by the law numbered 6821, as an organization affiliated to the Prime Ministry. In 1982, the Commission was restructured as Turkish Atomic Energy Authority affiliated to the Prime Ministry by the law numbered 2690 [1].

In 1956, 760,000 TL (~ 270,000 $) was allocated from the state budget for establishment of a research reactor and to pay for its first charges. For that purpose, the land by the Küçükçekmece Lake in İstanbul was expropriated. In 1957, “American Machine and Foundry (AMF)” was chosen among the five firms submitted bid for construction of the TR-1 Research Reactor for experimental purposes in nuclear science. The project was on a turnkey basis. TR-1 Research reactor was constructed between years 1959-1962 on the land. On the 6th of January, 1962 the reactor reached first criticality and started operation on 27th of May, 1962. The facility and its environment were named Çekmece Nuclear Research and Training Center (ÇNAEM). Construction of reactor building was finished in November, 1960 and the laboratories and workshop construction was finished in April 1961. The first staff of ÇNAEM was appointed in July, 1961.

In 1962, establishment of Çekmece Nuclear Research and Training Center was finished. The center was affiliated to the General Secretariat of Atomic Energy Commission and its purpose was research, development, application and training activities in nuclear field.

Ankara Nuclear Research and Training Center (ANAEM) was established in 1967.

In 1967, “Decree on Radiation Health” and in 1968 “Regulation on Radiation Health” entered into force on the basis of the Law numbered 6821. As the defined in the Decree, authorization of granting and cancelling licenses in activities involving radiation was given to the Atomic Energy Commission. According to the legislation, those duties were performed by Health Physics Departments of Çekmece Nuclear Research and Training Center and Ankara Nuclear Research and Training Center.

Until 1973, personal dosimetry service was provided for 3550 radiation workers.

In 1979, Nuclear Agriculture Center was established within the structure of ANAEM. In 1999, Nuclear Agriculture Center was restructured and continued its activities inside the organization of Ankara Nuclear Agriculture and Livestock Research Center (ANTHAM) located in Sarayköy.
Lalahan Animal Health Nuclear Research Center was established in 1981 and continued its activities inside the organization of Ankara Nuclear Agriculture and Livestock Research Center (ANTHAM) located in Sarayköy.

In October 1999, Research and Training Center for Turkish Speaking Countries (TÜDNAEM) was established by the decision of Council of Ministers as an affiliated organization of TAEK. TÜDNAEM was established for execution of effective and productive of relations with the Turkish Speaking Countries.

Ankara Nuclear Research and Training Center (ANAEM) and Ankara Nuclear Agriculture and Livestock Research Center (ANTHAM) were consolidated under Sarayköy Nuclear Research and Training Center (SANAEM) by the decision of Council of Ministers published in the Official Gazette on 1st of July, 2005.

TAEK’s activities are being performed by three centers and departments under the authority of TAEK President.

The Mission of TAEK is To be a pioneer in ensuring that our country benefits from nuclear technology and to perform the regulatory and supervisory activities in nuclear field and the Vision is to provide our country to become an arbiter country in the field of nuclear technology and to be a reliable, effective and independent authority in ensuring the protection of human and environment from radiation [1].

The foundation of the Institute of Nuclear Sciences at Ege University starts in 1959 along with other similar initiatives in Turkey and the Radioisotopes Research Center was established in 1966 and continued its activities until 1977. Between 1977 and 1982, it was active as Ege University Nuclear Research and Education Institute. In 1983, it was re-established as Ege University, Institute of Nuclear Sciences [2].

Since 1986, when the post-graduate education was started, 240 Masters, 78 PhD degrees of total 318 graduate students have been awarded, and 210 research projects have been completed. Currently, more than 90 post-graduate students are studying master or PhD, and 45 research projects have been carrying out.

The mission of the Institute is ‘to improve novel methods and techniques by following the advances in technology and science, increase qualified personal in the nuclear field, conduct postgraduate education, training and research activities for benefits of the universal science and society.’

The vision of the Institute is ‘to be a pioneer among organizations that offer education in the fields of nuclear sciences, technologies and applications in Turkey, generate a laboratories chain that will contribute to the regional and national organizations, achieve a level to compete with similar institutions abroad.’

The Institute of Nuclear Sciences is carried out education and research activities, in three main departments as Nuclear Science, Nuclear Technology and Nuclear Applications, with 34 academic staff and 15 administrative personnel in order to achieve targets set in its mission and vision [2].
The Department of Nuclear Engineering, [3] established in 1977 as one of the institutes of the graduate school, initiated its undergraduate program in 1982. The Department of Nuclear Engineering at Hacettepe University is the first and only department in Turkey which offers an undergraduate degree in the field of nuclear engineering. The Main-Science-Branches are Nuclear Sciences and Nuclear Technology [4].

The first two years of undergraduate study serve as a preparatory period for the next two years. During the first two years, students complete the required courses in mathematics, computer programming, classical, modern and nuclear physics, electronics, thermodynamics, and materials science. In the third year, along with numerical analysis, heat transfer and fluid mechanics; introductory courses in nuclear engineering are offered. The fourth year is reserved for detailed analysis of reactor systems; nuclear fuel cycle, nuclear materials and courses in nuclear reactor analysis, control and design are offered.

As of the 2nd year of the educational program, each semester, students are required to take a different project course and encouraged to take active part in research. By use of computer codes such as FLUENT, ANSYS, MCNP and ORIGEN; analyses and simulations of engineering systems are performed and solutions to current problems related to nuclear technology are sought. The technological problems of energy production by fission receive primary emphasis. Practical training for eight weeks is mandated.

Another Energy Institute was established in 1961 with the name of Nuclear Energy Institute in Istanbul Technical University, [5] it was renamed as Energy Institute in 2003, to form a center for advanced research covering the other areas of energy. The aim of our institute is to make and encourage research and development projects in the broad range of energy science and engineering in Turkey. It provides education, research and collaborative opportunities with partner organizations and individuals. Today, the institute includes 5 divisions:

- Nuclear Researches Division,
- Renewable Energy Division,
- Conventional Energy Division,
- Energy planning and Management Division,
- Energy Science and Technology Division.

Besides "Energy Science and Technology" Master and PhD programs, “Radiation Science and Technology” was opened for Masters Degrees in order to develop in the field of nuclear and radiation technologies.

The institute has 20 teaching fellows, 14 research assistants, 2 engineers, 7 technical staffs, 1 physicist, 13 administrative, 10 security staffs and more than 300 graduate students enrolled in Doctoral and Masters Research, of which 7 are supported by industrial projects. The Energy Institute teaching and research programs on graduate level has an interdisciplinary nature involving students and academic staff from the fields of Science, Engineering, Architecture. In this scope, the institute has strong research links with 34 teaching follows from different faculties in ITU [5].
Energy Institute has adopted to be in close relationship with industry since 2012. In this scope, the researches and researches collaborations continue with industry. In this scope, Sectorial Advisory Board was founded by the participation of the World’s and Turkey’s superior companies in energy. The industry sponsored laboratories was established and industry sponsored research assistant ship positions are provided for our students. The recent research and development activities are intensely focused on the technical problems of the industry. These developments have accelerated the growth of the Energy Institute. In order to make the industry-university collaboration stronger and permanent, Energy Technopark building was started to be built with the contribution of Rectorate of ITU and administration of ARI Technopark. The building which will include R&D companies in energy industry, is planned to be opened in 2014. The Mission The Energy Institute is committed to conduct pioneering research, deliver high quality graduate level education and training in the field of energy for preparing academically well qualified engineers and scientists, and pursue a leading role in the energy arena and It’s vision is to become a leading institute dedicated to world class education and research in the field of energy and related issues.

2. Reviewing of regular courses at the University in the Turkey in the field of radiation sciences and technology

Today, nuclear and radiation science courses are being taught in graduate and undergraduate levels in universities and institutes of Turkey.

Regular undergraduate and graduate courses are being conducted in Nuclear Engineering Department of Engineering Faculty, Chemistry Department of Faculty of Science, and Polymer Science & Technology Division of Graduate School of Science and Engineering. Only graduate level courses are being conducted in Istanbul Technical University’s Nuclear Energy Institute and Ege University’s Institute of Nuclear Science.

In fact the given courses in Hacettepe University’s Nuclear Engineering, Ege University’s Nuclear Science Institute and Istanbul Technical University’s Energy Science and Technology (EST) master and PhD programs are focused on nuclear science and applications. Where, Istanbul Technical University’s Radiation Science and Technology (RST) master program and Hacettepe University’s both Chemistry Department’s Polymer Chemistry Division and Graduate School of Science and Engineering’s regular courses at Polymer Science and Technology Department are focused on Radiation Science & Technology. Aside from these programs Nuclear Sciences, Radiation Chemistry, Physics and Technology facultative elective courses are being conducted at both graduate and undergraduate levels.

İstanbul Technical University, Energy Institute was established in 1961 with the name of Nuclear Energy Institute, it was renamed as Energy Institute in 2003, to form a center for advanced research covering the other areas of energy.

In this institute The Radiation Science and Technology (RBT) Master Program has started for training of qualified manpower on radiation science for necessity of the country on advanced industrial
activities, nuclear reactors, nuclear medicine, evaluation of environmental radioactivity, quality supply and quality control and the related activities.

The MSc. program for "Radiation Science and Technologies" in the Institute of Energy is applied for training of expert people as “Radiation Protection Advisers”, “Radiation Workers” and “Radiation Officers”. The program was prepared to meet the requirement of interdisciplinary education on radiation development at graduate level, and to educate and enable engineers and scientists who comprehend environmental, nuclear safety and economic issues generate new solutions in the area of radiation technologies. The main must courses and elective courses in this program which directly related with radiation science and technology are given in Table 1 and Table 2, respectively [6].

**TABLE 1. THE MAIN MUST COURSES IN RADIATION SCIENCE AND TECHNOLOGY PROGRAM OF ISTANBUL TECHNICAL UNIVERSITY, ENERGY INSTITUTE WHICH DIRECTLY RELATED WITH RADIATION SCIENCE AND TECHNOLOGY**

<table>
<thead>
<tr>
<th>Course code</th>
<th>Course Name</th>
<th>Objective</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>RBT501</td>
<td>Radiation Physics</td>
<td>The purpose of this course is to teach the interactions of radiation with matter, which are used in many areas of nuclear research like medicine, industry, agriculture and archaeology, to introduce the tools and systems which are used in nuclear area, to give information about fission and fusion reactions, to teach the improvement of the nuclear techniques by using different types of the interaction mechanisms of radiation with matter.</td>
<td>Fundamentals of radiation physics, types of radiation, decay mechanisms, production of X-rays, kinetics of radioactive decay interaction of charged and uncharged particles with matter and their kinematics, fission and fusion reactions, positron emission mechanisms, and annihilation radiation.</td>
</tr>
<tr>
<td>RBT502</td>
<td>Radiation Detection and Measurement</td>
<td>The purpose of this course is to give the basic information about nuclear area, to teach interactions of radiation with matter, radiation detection and measurement techniques, the types of radiation detectors and their principles and to provide some experiences about radiation detection systems and radiation measurement.</td>
<td>Basics of radiation detection, the principles of alpha, beta and gamma radiation detectors, neutron detection systems, pulse/signal processing, energy resolution, counting statistics and error propagation.</td>
</tr>
<tr>
<td>RBT504</td>
<td>Radiation Protection and</td>
<td>The purpose of this course is to teach fundamental nuclear physics concept</td>
<td>Sources of radiation, biological effects due to acute and chronic</td>
</tr>
</tbody>
</table>
Health Physics is applied to radiation protection issues, analytical methods for internal and external dose assessment problems, elements of applied radiation protection through the study of specialized topics in health physics and to give information about radiation protection regulations.

exposure of radiations, dose monitoring methods, external and internal radiation protection, application of health physics to reduce the health hazards at each stages, radiation workers and their dose limits and public dose limits, health physics procedures for accidents and related principles, evaluation and control of radiation protection barriers, nonionizing radiation and public health, radiation risks and related calculation methods, special topics for radiation protection health physics regulations.

<table>
<thead>
<tr>
<th>Course code</th>
<th>Course Name</th>
<th>Objective</th>
<th>Contents</th>
</tr>
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<tbody>
<tr>
<td>RBT503</td>
<td>Industrial and Medical Applications of Radioisotopes</td>
<td>The purpose of this course is to teach the determination and control of several parameters using isotopes at production and managing steps in industry, to teach the investigation of radioisotopes in medicine, to give information about the production of radioisotopes, radiopharmaceutics and labeling of organic compounds with radiation, to teach the applications of radiography in industry and medicine, to give information about radioisotopes benefits in industry and medicine and the provide the comparison to other methods and the advantages of usage of radioisotopes</td>
<td>Production of radioisotopes, radiopharmaceutics. Labeling of organic compounds with radioisotopes, usage of tracer techniques. Usage of the nuclear measurement for industrial problems. Principles of usage of radioisotopes in medicine. Medical radiography, industrial radiography and related devices, linear accelerators and nuclear reactors for radioisotope production.</td>
</tr>
<tr>
<td>Course Code</td>
<td>Course Title</td>
<td>Description</td>
<td>Materials and Techniques</td>
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<tr>
<td>RBT505E</td>
<td>Radiation Imaging</td>
<td>The purpose of this course is to give the basic principles of nuclear medicine, the components of the system of imaging techniques in nuclear medicine, the characteristics of these components and the effects of them on the image, the other factors which affect the image, the types of medicine image systems and their data acquisition principles and to teach the basic principles of image reconstruction techniques.</td>
<td>Fundamentals of nuclear medicine, digital data acquisition techniques, image quality and control in nuclear medicine, special image techniques. Transmission tomography, emission tomography, radio pharmaceuticals, image reconstruction techniques: iterative techniques, Fourier techniques. Computer application of image reconstruction</td>
</tr>
<tr>
<td>RBT507</td>
<td>Radiological Materials</td>
<td>The objectives of this course are to use of the material in radiation technology, to determine the principles of the material science dealing with the radiation science and its applications and to provide the advanced information on the used materials at radiation applications and nuclear techniques, the information on the bases of material science to the people who work in radiation science and its applications areas, and to know the used special materials and its properties in nuclear technology.</td>
<td>Importance of radiological materials assessments, radioactive materials, essential materials for nuclear and radiological technology, radiation source materials; radioisotopes, radiation device materials, radiation sense and absorbent materials against the radiation, radiation shielding philosophy, quality concept of nuclear and radiological materials, radiation damage on materials.</td>
</tr>
<tr>
<td>RBT509</td>
<td>Radiation Shielding</td>
<td>The purposes of this course are to give fundamental information that is necessary for the shielding of different nuclear radiation types, basic concepts and tools to apply primary safety standards in radiation areas, to teach shielding materials, to teach radiation shielding mechanisms, and principal calculation methods of radiation shielding.</td>
<td>Characterization of radiation fields and sources, preventing mechanisms against different radiation; shield design and calculating for radiation sources; photon and neutron response functions, basic methods for radiation shielding calculations for exposure rooms, special techniques for photons, neutrons, and charged particles, Monte Carlo methods for radiation transport calculations, shielding design for medical</td>
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<tr>
<td>Code</td>
<td>Course Title</td>
<td>Description</td>
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<tr>
<td>RBT511E</td>
<td>Radiometric Techniques in Environmental Analysis</td>
<td>The purpose of this course is to introduce students natural and man-made radiation sources in the environment, to teach related criteria’s of sampling and preparing processes of environmental samples, low-level radioactivity measurement systems, and analyzing methods and applications by using radioactivity for various environmental samples.</td>
<td>Environmental radioactivity, environmental sampling techniques, environmental radioactive indicators, radon and radon daughters, radon measurement techniques, radiometrical and radiochemical measurements, fundamental conditions for the determinations of low-level radioactivity, modeling of soil redistribution rates by using different fallout radionuclides for different land uses.</td>
</tr>
<tr>
<td>RBT513</td>
<td>Radiochemistry</td>
<td>The purpose of this course is to teach about chemical reactions of atoms produced by radiation interaction, fundamentals and mechanisms of radiochemistry, the nuclear fuel material uranium and thorium compounds, uranium isotope separation methods and separation principles, and nuclear fuel reprocessing procedures.</td>
<td>Radiochemical equipment’s, production of radionuclides, radionuclide generators, chemical analysis by nuclear methods, nuclear processes as probes in chemical research, hot-atoms chemistry, radiolysis, polymerization by ionizing radiation, radiochemistry applied to nuclear medicine, nuclear processes in geology and astrophysics, uranium and compounds, thorium and compounds, uranium isotopes separation, fuel reprocessing.</td>
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<tr>
<td>RBT506E</td>
<td>Radiation Dosimetry</td>
<td>The purpose of this course is to provide knowledge on the dose calculation and dose assessment by using radiation in different conditions such as medicine, industry and space applications, to give the basic theoretical information about radiation dosimetry and to teach the basic equations about radiation dosimetry and using them for radiation behaviour on soft tissue, evaluation of ionizing radiations, energy fluence and spectral distributions, absorbed dose, exposure and its measurement, the concept of kerma, exposure and air kerma, cavity theory, electron, photon and neutron dosimetry, the dosimetry of special radionuclides, methods of dosimetry and hypothetical approaches, dosimetry.</td>
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<tr>
<td>Course Code</td>
<td>Course Title</td>
<td>Description</td>
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<tr>
<td>RBT508</td>
<td>Nuclear Techniques</td>
<td>The purposes of this course are to introduce differences and specifications of nuclear techniques which developed for different radiation types and to give knowledge on different application versions of nuclear techniques depend on different application areas and developing nuclear techniques and use in frame of advanced technologies.</td>
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<tr>
<td>RBT510E</td>
<td>Activation Spectroscopy</td>
<td>To teach students activation analysis technique that is one of the analytical applications of radioactivity, introducing different activation methods, evaluation of irradiation, counting and measurements conditions, energy spectrums and evaluation, to provide knowledge on computerized evaluation of spectrum data by using nuclear analysis software,</td>
<td>Methods of activation, activation with neutrons, irradiation and measurements, counting techniques, energy spectrums, nuclide identification, peak assessment, spectrum calibration, quantitative activity determination. Measurements with absolute method, measurements with relative methods, gamma–ray spectrometry with analyzer, computerized analysis of gamma-ray spectra.</td>
</tr>
<tr>
<td>RBT512E</td>
<td>Radioecology</td>
<td>The purpose of this course is to teach the movement and accumulation of natural and man-made radionuclides in ecosystems, the effects of radiation on individuals, populations, communities and ecosystems, and subjects and scope of radioecology, natural and artificial radiation sources, radioactive fallout and properties, radioactivity in aquatic ecosystems, radionuclides of ecological importance, radiosensitivity of ecological...</td>
<td></td>
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<tr>
<td>RBT514</td>
<td>Medical Radio Physics</td>
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<td>The purpose of this course is introducing medical physics, giving the knowledge for the applications, train the engineers, physicists, scientists for working in the medicine, explanation of radiation applications in medicine, supplying of arrangements for working conditions with the minimum radiation doses and taking the results with high efficiency.</td>
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<tr>
<td></td>
<td>Introduction to medical radio physics, diagnostic and therapy techniques and their classifications, radioisotopes for the use of medical applications and their production, definition of radiation workers, dose calculation procedures and dose limits for occupational exposure, radiation safety applications in exposure, definition of dose estimation for patients in the different exposures, basic radiation safety criteria and regulations.</td>
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</tbody>
</table>

Hacettepe University as one of Turkey’s and the world’s most privileged universities has also entered Bolonga process. As its known The Bologna Process is a series of ministerial meetings and agreements between European countries designed to ensure comparability in the standards and quality of higher education qualifications. For this reason, European Credit Transfer and Accumulation System (ECTS) forms for all of the given courses can be found at university’s web page [7].

At Nuclear engineering under graduate program of Hacettepe University, courses like nuclear energy engineering, atomic radiation and physics and radiation detection and measurement are given after two years of general engineering training.

For example course objective of the NEM214 Atomic and Radiation Physics [8] lesson is to teach students basic concepts of radiation physics, radiation sources, radiation interaction with matter and how to use the interaction mechanisms in medicine, industry and science dir. The basic learning outcomes of this lesson is
1. To know radiation interaction mechanisms and to apply them to practical problems,
2. To know sources of radiation,
3. To know methods of radiation detection.
4. To use dose calculations to solve practical radiation protection problems dir.

Another course given for the Nuclear engineering Department undergraduate students is NEM433 - Radiation Detection and Measurement Lab. This course is one of the courses of students. The course objective of this lesson is to introduce radiation sources, to make students familiar with the radiation measurement methods, to teach applications of radiation detection and measurement, to introduce detector types, to apply radiation detection and measurement methods and the Learning outcomes is

1. To become familiar with the types of radiation and sources,
2. To learn radiation measurements and its applications, selects proper detectors and systems to perform different experiments and analyze the data,
3. To recall, analyze and correct errors in radiation measurement due to statistical uncertainties and nuclear electronics. The main course content of this lesson is special applications of alpha and gamma measurements, neutron detection and measurement, nuclear electronics and methods used to operate nuclear electronics equipments, introduction of the detectors used for experiments, data analysis.

The courses related with radiation science and technology in Nuclear engineering department, undergraduate program generally given with elective lessons The FIZ418 Applied Radiation Physics one of this causes. The objective of these courses is to get detail theoretical and experimental information about radiation detector types such as gas filled detectors, syntillation detectors, semi-conductor detectors and dosimetric systems (film, TLD, ESR, OSL, chemical). To help the graduated students to use this knowledge in their expert areas such as health physics, industry etc. Learning outcomes of the lesson is 1. Concepts of ionized and non-ionized radiation and the detectors types in detail which are using in the detection of ionized radiation. 2. Additional to this theoretical information gained, experimental information and experiences are also gained by the students with the help of 10 different experimental setups (gas filled detectors, syntillation detectors, semi-conductor detectors) in the radiation laboratory. 3. The obtained theoretical and experimental knowledge could be used in the fields such as health physics, industry etc. for these learning outcomes the course contents were determined as Definition of radiation. Ionizing and non-ionizing radiation. Environmental radiation and daily life. Interaction of radiation and matter. Charged particles and gamma spectroscopy. Radiation units.

Properties of radiation measuring systems. Radiation detection systems (gas-filled detectors, scintillation detectors, semiconductor detectors, neutron detectors, dosimeters). Radiation activity. Error analysis in radiation detection. Experiments: photometric law of distance, radiation field of a horn antenna-microwaves, half-life and radioactive equilibrium, alpha energy of different sources with multi-channel analyzer, energy loss of alpha particles in gases, law of distance and absorption of
gamma or beta rays, energy dependence of the gamma absorption coefficient, beta spectroscopy, X-ray dosimetry, contrast medium experiment with a blood vessel model.

As it was mentioned chemistry department of Hacettepe University provides its student with the richest and the most intense radiation science and technology courses at graduate and under graduate levels in Turkey. These courses have been increasingly conducted since 1970. Generally 1-2 weeks class programs of radiation science and technologies are given inside the framework of different courses and also PBT 714 Radiation Chemistry of Polymers and Processing course provides a full course program. The details of this course will be given later.

For example main aim of the KİM436 Polymer Processing [11]. Course is teaching of the students on the basic principles of polymer processing. The main content of course is Introduction of thermoplastics, thermosets and elastomers, Designing with Plastics, Extrusion Process, Injection Molding Process, Blow Molding, Rotational Molding Process, Casting Processes, Foaming Processes, Compression Molding, Transfer Molding and Related Processes, Polymeric Composite Materials and Processes and Radiation Processing of polymers. End of this course the students learn Main polymer processing techniques such as extrusion injection, blow and molding and application of radiation processing technique for the modification of polymers. Another elective course given for the 4th class students is KİM480 - Polymer Technology course. The main aim of this course is teaching of what kind of commodity and engineering polymers mainly use in our daily life and basic principles of polymer processing.

KİM674 Radiation Chemistry [12] is one of the graduate courses given under the framework of Graduate School Science and Engineering of Hacettepe University. The purpose of this course is to inform the students about Introduction to Radiation Chemistry, Radiation sources, Alpha, beta and gamma rays and their properties, Accelerators, Radiation dosimetry, Degradation of polymers by radiation, Radiation technology and applications. Contents of this course is introduction to radiation chemistry and types of radiations, radioactivity and history, Radiation sources and their types, radioisotopes, Alpha-rays and properties, determination of track and distance, Beta-rays and properties, positron and negathron, Bremsstrahlung-rays, X-rays, electron-capture (EC), Gamma-rays and properties, internal conversion (IC), Radioactive decay, X-generators and accelerators-Cockroft-Walton, Van de Graaff, Cyclotron and synchro-cyclotron, synchrotron, Linear electron accelerators, the absorption of electromagnetic radiations by matter, interaction between matter and radiation, interaction of gamma-rays with matter, photoelectric effect, Compton scattering, pair-production, Radiation dosimetry, types of dosimetry, Radioactivity and dose units, Degradation of polymers by radiation, chemical and physical effects, crosslinking and chain scission, Application of radiation technology and examples. Learning outcomes of this lesson is

1) Introduction to radiation chemistry and types of radiations, radioactivity and history.

2) Radiation sources and their types, radioisotopes.

3) Alpha-rays and properties, determination of track and distance.

4) Beta-rays and properties, positron and negathron, Bremsstrahlung-rays, X-rays, electron-capture (EC).
5) Gamma-rays and properties, internal conversion (IC), Radioactive decay.

6) X-generators and accelerators-Cockroft-Walton, Van de Graaff, Cyclotron and synchrocyclotron, synchrotron, Linear electron accelerators, the absorption of electromagnetic radiations by matter, interaction between matter and radiation, interaction of gamma-rays with matter, photoelectric effect, Compton scattering, pair-production, Radiation dosimetry, types of dosimetry, Radioactivity and dose units.

7) Degradation of polymers by radiation, chemical and physical effects, crosslinking and chain scission

8) Application of radiation technology and examples.

**KİM676 Polymer Degradation and Stabilization** [13] is another course given for the 3th and 4th class students of the university. However, generally Chemistry students prefer this course as elective courses. The objective of this course, is the chemical reactions and degradation types on the polymers which induced/initiated by degradation modes as heat, mechanic force, UV radiation, Ionizing radiation, chemicals and bio-chemicals. The determination of mechanism and methods to increase stability of polymers by considering the degradation modes and their effects on polymers. The applications of the polymer degradation and polymer stabilization. It is very well known that the degradation of polymers cause deterioration of physical properties of polymers. So the main content of this course is

1. Degradation of polymers and the factors that cause deterioration of physical properties of polymers by chemical reactions.

2. Thermal degradation and stabilization.

3. Mechanical degradation and stabilization.

4. Photo degradation and stabilization.


6. Chemical degradation and stabilization.

7. Degradation by high energy radiation and stabilization.

8. Applications of polymer degradation and stabilization.


Student will learn the following subjects; Learns; The chemical reactions and degradation types on the polymers which induced/initiated by degradation modes as heat, mechanic force, UV radiation, Ionizing radiation, chemicals and bio-chemicals.

Who can characterize the chemical/physical properties of the polymers, after and before the polymer degradation, by using analytical techniques, Propose, the stabilization methods of the polymers by
considering degradation modes. (For example; who can propose, the addition of antioxidants/light screeners to the polymers for protecting from UV radiation.

Considering the applications of polymer degradation and stabilization: who will know; Irradiation of some polymers by ionizing radiation cause the crosslinking of the polymer chains and which increase the mechanical durability of polymers. Thermal degradation of some polymers gives depolymerization reaction and their monomers can be reused in polymerization, acidic or basic hydrolysis reaction of polyesters and polyamides gives their own monomers.

All these degradation modes can be used for recycling of polymers. Who can apply the polymer degradation modes in the field of recycling.

One of the another course given for the graduate students under the framework of Polymer Science and Technology department is **PBT 714 Radiation Chemistry of Polymers and Processing [14]**.

To teach the concepts of interaction of polymers with radiation and industrial applications of radiation processing are the Course objective of this lesson. In this course, Interaction of high energy radiation (gamma rays, X-rays, accelerated electrons etc.) with polymers, the mechanisms and final effects will be discussed. Investigation and control of crosslinking, chain scission, grafting processes and their consequences will be elaborated. The experimental techniques to be used in understanding and following the radiation effects will be presented. The use of radiation for the formation of nanostructures. Industrial application of ionizing radiation in polymer processing will be illustrated.

Student will learn the following subjects during the course

1. Interaction of radiation with polymers, absorption of radiation
2. Radiation initiated polymerization
3. Crosslinking and its control
4. Chain scission and degradation
5. Grafting
6. Experimental techniques in monitoring radiation effects in polymers
7. Nanostructuring of polymers by using radiation
8. Established and emerging industrial applications

Like the other courses this course is continue 16 weeks in one semester. The topics of each week are given in Table 3.
TABLE 3. WEEKLY TOPICS OF PBT714 RADIATION CHEMISTRY OF POLYMERS AND PROCESSING.

<table>
<thead>
<tr>
<th>Weeks</th>
<th>Topics</th>
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</thead>
<tbody>
<tr>
<td>1.</td>
<td>Absorption of ionizing radiation by polymers</td>
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<tr>
<td>2.</td>
<td>Fundamentals of crosslinking process</td>
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<td>3.</td>
<td>Control and enhancement of crosslinking</td>
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<td>4.</td>
<td>Factors affecting chain scission</td>
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<tr>
<td>5.</td>
<td>Chain scission and oxidation</td>
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<tr>
<td>6.</td>
<td>Midterm exam</td>
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<td>7.</td>
<td>Radiation-induced grafting</td>
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<tr>
<td>8.</td>
<td>Controlling of grafting reactions</td>
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<tr>
<td>9.</td>
<td>Radiation curing of composites</td>
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<tr>
<td>10.</td>
<td>Industrial applications of crosslinking</td>
</tr>
<tr>
<td>11.</td>
<td>Industrial applications of grafting</td>
</tr>
<tr>
<td>12.</td>
<td>Nanostructuring of polymers by radiation-I</td>
</tr>
<tr>
<td>13.</td>
<td>Midterm exam</td>
</tr>
<tr>
<td>14.</td>
<td>Nanostructuring of polymers by radiation -II</td>
</tr>
<tr>
<td>15.</td>
<td>Homework</td>
</tr>
<tr>
<td>16.</td>
<td>Final exam</td>
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</tbody>
</table>

The KİM674 Radiation Chemistry and KİM676 Polymer Degradation and Stabilization and PBT 714 Radiation Chemistry of Polymers and Processing are Prerequisites courses for educating on the radiation chemistry and physics of polymers and radiation science and technology fields.

3. Review of initiatives at the University in the turkey to introduce radiation science and technology courses

Turkey put nuclear energy in its agenda in 1956 and Turkish Nuclear Energy Commission established at that date, and students sent abroad to receive high education in related courses. Prof. Dr. Nejat
Aybers was among these students. At the same time he is the founder of Nuclear Energy Institute of Istanbul Technical University. This institute is the first institute to deal with nuclear energy subjects in Turkey. Triga Mark II research nuclear reactor has been established under Prof. Dr. Nejat Aybers’s leadership and he also leaded the starting steps of building project of Turkey’s first nuclear energy plant “Akkuyu” together with Prof. Dr. Ahmet Yüksel Özemre and Prof. Dr. Ahmet Bayülken in mid90s, which could not be started until 2014 [15].

After the return of those educated scientist in early 60s, they started nuclear energy and radiation technology education in their own universities which together with their first and second generation students laid the bases of established knowledge in this field. Prof. Dr. Yağcı Sanalan established the first ever Nuclear Engineering Master program, followed by undergraduate program at Hacettepe University. He is one of the greatest scientists who had contributed to the development of nuclear radiation science and technology in Turkey, accelerated related research projects and helped to increase both quality and quantity of these projects.

First researches in Radiation Science and Technology in Turkish universities started at 1960 at Middle East Technical University (METU) by Prof. Dr. Bahattin Baysal and at Hacettepe University by Prof. Dr. Çemil Şenvar. Their PhD students have contributed a lot to radiation science and technology. Prof. Dr. Güneri Akovalı one of METU’s first assistances and Prof. Dr. Olgun Güven of Hacettepe’s first assistances have supervised a lot of master and PhD students to develop of plasma polymerization and radiation science and technology at these universities, respectively, and Prof. Dr. Olgun Güven also contributed to the development of Application of radiation science and technology in a lot other countries and Turkey’s first industrial sized gamma irradiation facilities have been established in Ankara Nuclear Research and Training Center (ANAEM) during Prof. Dr. Olgun Güven’s presidency and with Turkish-Hungarian cooperation and IAEA’s assistance.

Establishment of Turkey’s first two lab-type Co-60 gamma radiation chambers (GammaCell 220) assisted by Ford foundation in METU and Marshall support in Hacettepe University, is the main reason behind the non-stop research in this field since 1960s.

In recent years, the rate of these research studies have been decreased despite the increase the presence of well-educated researches on this field. One the main reasons of this decrease, is that Hacettepe University’s Gamma cell is out of order. Also the decrease in dose rate of METU’s gamma cell from 60 kGy/h to 26 kGy/h leaded to a decrease in research rate and narrowing of the research field. It was aimed to accelerate the radiation field researches in Turkey by purchasing a new gamma cell, on the lead of Hacettepe University’s Laboratories of Radiation Science and Polymers and assistance of scientific research unit.

4. Review of the IAEA assistance to the Member States relevant to education;

The main IAEA assistance to the Turkey for the education is of course the training of researchers by using fellowship program under the Technical Cooperation (TC) Project. Up to now, a lot of researches have been trained in radiation science and technology field in Turkish Atomic Energy Authority and Hacettepe University Laboratories of Radiation and Polymer Science. Japan Atomic
Energy Agency, Takasaki Advanced Radiation Research Institute, Harvard University, Rowland Institute, Pavia University, Italy are among these universities and centers.

5. Review of needs for IAEA assistance, definition of problems and gaps;

1. Non-sufficient number of irradiation chamber producers and safety issues related to these chambers

2. Difficulties in supplying Laboratory type irradiation chambers and e-beam courses

3. Lack of direct project support of IAEA to the centers willing to work on Gamma and e-beam

4. Lack of text books for undergraduate and graduate students

5. Lack of international meetings and summer schools for radiation science and technology graduate students.

6. Lack of full support for graduate students to attend scientific meetings

6. Solutions, future actions and implementation plan.

In order to increase research and studies of radiation science and technology and spread its industrial use, future actions and implementation plans must be considered and started by IAEA as emergency action plan as soon as possible.

1. Increasing and spreading the production of safe lab-type Gamma and e-beam irradiation chambers with the help of IAEA

2. IAEA support must be given directly to the Infrastructure projects of universities and research centers in order to purchase lab-type gamma and e-beam irradiation chambers.

3. A network must establish to exchange education and students between research laboratories and a part of country found must be used for educational purposes of these centers.

4. Text books must be prepared to be used for undergraduate and graduate level students and work groups must be form to facilitate the writing of these text books.

5. International meeting must be organized in subjects related to radiation science and technology for the graduate students and students’ attendance to these meetings must be fully supported by IAEA.
7. References

[7]. http://akts.hacettepe.edu.tr/programlar.php?program_duzey=2&submenuheader=1
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TM on "Enhancing Education Programmes on Radiation Sciences in Cooperation with IAEA Collaborating Centres"

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