WORLD NUCLEAR UNIVERSITY

SCHOOL ON RADIATION TECHNOLOGIES

The World Nuclear University is a global network committed to enhancing international education and leadership in the peaceful uses of nuclear energy and the applications of nuclear science and technology. The WNU founding supporters are the IAEA, OECD/NEA, WANO and World Nuclear Association.

The School on Radiation Technologies (RT School) is a leadership development programme for professionals in the radiation technologies field.

Objective

The RT School aims to:

- Provide a broad overview of the field of radioisotopes production and radiation technologies as well as the trends and main issues encountered by practitioners in this area.
- Develop essential skills for leadership, communication and project management
- Provide a unique opportunity to develop a worldwide network of radiation specialists.

Target participants

Target participants are professionals from radiation technology facilities, nuclear research centres, radioisotope supply chain companies, regulators and representatives of governmental bodies concerned with radiation technologies.

Methodology

The WNU RT School intensive two-week programme features:

- Lectures by prominent experts in radioisotopes and radiation technologies, mentors and distinguished speakers. Lecturers are encouraged to focus on key points and draw out relevant issues for further discussion.
- Small-group work led by mentors, where participants analyse case studies and develop proposals for resolving RT-related issues
- Technical visits to RT-related sites including medical and industrial facilities.

All teaching is in English. Book: WNU Advanced Radiation Technology; selected topics of Curated Reference list at https://www.world-nuclear-university.org/publications

Topics

Developed in consultation with an expert Programme Committee, the RT School curriculum ranges across a wide spectrum of topics relevant to radiation technologies. The curriculum covers:

i) Operations and regulatory frameworks, including sources of radiation, radiological protection, production of radioisotopes and sealed sources, quality assurance and control, safety and security, packaging and transport of radioactive materials, waste management and decommissioning, economics of RT programmes, and communications

ii) Current and future applications, including nuclear techniques in health care, industrial process management, food and agriculture, environmental protection, and life sciences.

RT School Standard Curriculum

I - Status of Radiation Technologies 1 Unit

1. Review of global status and trends in the application of radiation technology
    a. IAEA programmes in the applications of radioisotopes and radiation
        i. Current research and development
        ii. Technology transfer programme
        iii. Service (preparation of reference materials, plant varieties and insect strains, audit missions, dosimetry)
    b. Review of essentials for human life and current global living situation with respect to the human development index, utilisation of electricity and access to water, the UN Sustainable Development Goals
    c. The future – opportunities and targets for radiation technology

II - Production of Radioisotopes and Radioactive Sources 3 Units

1. Basic properties of isotopes, radioisotopes and radiation
    a. Radioactivity. Radioactivity decay. Equilibrium parent-descendant.
    b. Ionizing radiation. Energy spectrum. Interaction of radiation with matter. Photoelectric and Compton effects; pair formation.
    c. Nuclear reactions, including fission, fusion
    d. International estimates of global radiation levels (UNSCEAR)
    e. Special properties of radiation: material penetration, heat source, particle emission, transmutation/activation, change molecular structure, cell destruction, decay time, luminescence, ionization
    f. Basic radiation detection methods: Gas filled detectors; Scintillation detectors; Semiconductor detectors; thermoluminescent detectors; other types detectors relevant for radiation technologies
    g. Measurement techniques
2. Overview of a typical research reactor and facilities used for production of radioisotopes and radiation sources
    a. For open sources of radioisotopes
    b. For sealed sources of radioisotopes
3. Overview of accelerators and facilities used for production of radioisotopes and radiopharmaceuticals
4. Review of radionuclide generators and future trends
5. Review of quality control and quality assurance practices as applied in radioisotope/radiopharmaceuticals production, including specific regulatory aspects
6. Case study for production of radioisotopes and radioactive sources. Each group is assigned to study an isotope (Co-60, Mo-99, F-18, Ac-225, etc.) to prepare a 5 min presentation.
7. Technical visit to a radioisotope production facility
8. ***(Final Project) Network for Nuclear Innovation (options)***:
    a. **Install or not a research reactor or accelerator to produce radioisotope**. A broad issue having to address - real need of local supply vs external supply from the world market (cost-benefit)- choice of a multipurpose facility vs dedicated facility for specific applications, and the capacity of the installation. Definition of objectives including a large spectrum of applications and R&D program as well as education and training in nuclear applications. Is the decision to build a facility taken before having made a thorough full analysis of all the possible applications?

b. **New radiopharmaceuticals or new applications to existing ones**: 2 different issues but often linked: new isotopes are depending on new production process and availability of production facilities – new applications are depending on the isotopes availability but also on radiopharmaceutical compounds properly tested for specific treatments. Sustainability to be the key driver. Products to meet real clinical management needs.

III - Radiological Protection 3 Units

1. The international radiation protection system
   a. Scientific consensus: The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR)
   b. Globally accepted paradigm: The International Commission on Radiological Protection (ICRP)
   c. Intergovernmental radiation safety standards: The International Atomic Energy Agency IAEA) and other relevant organizations within the UN family.
2. Radiation quantities and units: Exposure (rate); kerma (rate); energy imparted; absorbed dose (rate); linear energy transfer (LET), lineal energy; organ dose; equivalent dose (rate); radiation weighting factor (w_R); effective dose, tissue weighting factor (w_T); operational quantities: ambient dose equivalent; directional dose equivalent; personal dose equivalent; intake; committed dose.
3. Radiation health effects
   a. Biological elements
   b. Early deterministic effects
   c. Late stochastic effects; epidemiological estimates of stochastic effects in populations.
   d. Gynecological and obstetrical and pediatric considerations
   e. Attributability of radiation health effects
   f. Inference of radiation risks
      i. Quantitative uncertainty analysis
      ii. Sources of uncertainty
      iii. Allowing for the uncertain possibility of a threshold
      iv. Nominal risk coefficients
3. Radiation protection paradigm
   a. Basic considerations
      i. The Linear Non Threshold (LNT) model
      ii. Detriment adjusted nominal risk coefficients
      iii. Human phantoms and standardization
      iv. Hormesis
   b. Exposure situations and protection approaches
      i. Occupational exposure
      ii. Public exposure
      iii. Medical exposure
      iv. Planned exposure situations
      v. Emergency exposure situations: planning, preparedness and response
      vi. Extant exposure situations
   c. The basic principles of radiation protection: Justification; Optimization of protection; Individual dose restrictions: dose limits; dose constraints; reference levels; Protection of future generations and the environment
   d. The ethical basis of the radiation protection principles
4. Radiation safety standards
   a. The BSS
   b. Basic information for a practitioner
   c. Top table exercises:
      i. Calculation of a radiation shielding

ii. Calculation of a ventilation system
iii. Calculation of exhaust filtering

5. Demonstration of radiation protection vestments and radiation detection equipment (e.g. simulation of search for a lost source)

IV - Safety, Security and Regulations 2 Units

1. Principles of safety culture
2. Overview of general safety objectives
3. Review of legally binding undertakings
    a. Conventions
        i. Early Notification of an Accident
        ii. Assistance in the case of a Nuclear Accident or Radiological Emergency
        iii. Nuclear Safety
        iv. Safety of Spent Fuel and Safety of Radioactive Waste Management
    b. IAEA Code of Conduct on the Safety and Security of Radioactive Sources
    c. International Labour Organisation (ILO) Conventions
4. Security of radiation sources and facilities
    a. Objectives and definitions
    b. IAEA nuclear security programme
    c. Security of high activity radioactive sources
    d. X-ray scanning techniques against malicious acts
5. Safety analysis
    a. Integrated safety analysis objectives (nuclear and non-nuclear); the scope of safety analysis; strategy of defence in depth; safety assessment, legal framework as applied to various aspects of the production and use of radioisotopes
    b. Deterministic and probabilistic approaches to analysis of hazard and safety margins
    c. Regulatory control: licensing, inspections, enforcement
    d. Operating procedures: QA manual and procedures; standard operating procedures; emergency procedures
    e. Management responsibility
    f. Environmental Impact Assessment
6. ***(Final Project) Network for Nuclear Innovation***: **An insight on potential overregulation**. Some applications require licence from several governmental agencies, for example, nuclear regulatory body, health authority, environmental agency, agriculture and commodities control, etc.
    The process can be very long and costly for the radiation facility, the capital investment is very high in the beginning, for example for industrial irradiators, without an assurance that all the operational licenses will be issued in due time. This is an issue very sensitive: due to the over-enthusiasm to be 'very safe' the regulations could be so stringent that it would be impractical to follow. A holistic approach will be needed to balance between the 'safety' and 'benefit', with awareness of the consequences on the public health of regulatory delayed decisions.
    How to improve the effectiveness of the regulatory control over the same radiation facility?

V - Packaging and Transport of Radioactive Materials 1 Unit

1. Overview of radioactive material (RAM) transport in terms of its position as classified dangerous goods (DG), its relative position and safety record in the overall transport of DGs

2. Review of the regulatory framework affecting RAM: IAEA SSR-6 and related international and national regulations; Supporting guides related to RAM transport
3. Review of packaging for the transporting of radioactive material
   a. Selection and testing of package
   b. Package segregation, dose rate / contamination limits, Transport Index (TI)
   c. Labelling and placarding
   d. Security
   e. Insurance and liability
4. Crisis management: Dealing with shipment issues like delays and denials
5. Case Study: transportation of Co-60 sources to a different continent

VI - Decontamination, Waste Management & Decommissioning 1 Unit

1. Classification of radioactive waste
2. Segregation, immobilisation process (e.g. Synrock), packaging, labelling and storage of radioactive waste
3. Treatment of biomedical radioactive waste
4. Management of spent sealed sources
5. Overview of decontamination and decommissioning techniques and the areas of application
6. Controlled discharge of effluents

VII - Management of Radioisotope Production and Distribution 3 Units

1. Review of definitions and concepts related to: Radioisotope production and applications programmes; economics; and socio-economics
2. Examination of the main economic tools
   a. Laws of supply and demand and market failure
   b. Price, cost, value, present value and discount rate
   c. Supply chain analysis
3. The economics of medical isotopes reviewed, including full-cost recovery
4. Overview of the significance of Molybdenum-99/Technetium-99m (^{99}Mo/^{99m}Tc) in health care globally and the global supply chain
   a. Review of the history of supply security concerns and the role of the OECD/Nuclear Energy Agency (NEA) and the High-Level Group on the Security of Supply of Medical Radioisotopes
   b. Definition and example of Outage reserve capacity
   c. Review of Low Enriched Uranium (LEU) and High Enriched Uranium (HEU) targets for Molybdenum-99 production
   d. Future steps for long-term security of Molybdenum-99 supply, including new production routes
   e. Possible alternate radioisotopes for ^{99m}Tc
5. Setting up Radioisotope Production and Application Programmes
   a. Review of basic elements of radioisotope production and application programmes
      i. Specific business features
      ii. Examples of type of services that could be provided by these programmes
   b. Project planning; facility considerations; regulatory aspects and other factors for establishing these programmes.
   c. Presentation of case studies
6. ***(Final Project) Network for Nuclear Innovation***: Planning the Start-up of a company in the radiation technology field. To prepare the plan, the group will go through market analysis,

resources/services required, strategy and implementation timeline, marketing, organization structure, costs/potential revenues.

VIII - Effective Public Communications 1 Unit

1. Presentation of communication types, communication models and components of communication plan
2. Presentation of strategy to improve the effectiveness of communication; specific emphasis on
    a. Definition of communication objectives
    b. Identification of target audience
    c. Identification of key messages and communication tools
3. Crisis communication
4. Simulation of Press Conference on a radiological accident

IX – Radiation Technologies for Health Care 4 Units

1. External and Internal beam Radiotherapy
    a. Background information on cancer – types of cancer; distribution of cancer types globally; characteristics of cancer cells; radiobiology (side effects, effects of radiation on skin)
    b. Review of cancer treatment using radiation
        i. External beam radiotherapy
        ii. Internal beam radiotherapy
2. Nuclear Medicine
    a. In-vitro analytical techniques
    b. Nuclear medicine - principles and practice in, use of in-vivo radiopharmaceuticals for diagnostic imaging and therapy
    c. Physics and instrumentation, PET, SPECT and hybrid images
    d. Overview of radiopharmaceutical production and chemistry with examples of applications
    e. Historical review of radionuclide therapy
    f. Current applications and prospects for future development, including Theranostics with new radionuclides; Imaging techniques to diagnose Alzheimer's disease; effects of drug addition or substance abuse; gender dysphoria, criminal and personality disorders
    g. Case study – the development of a radiopharmaceutical from concept to commercial product
3. Dosimetry – Importance and nuances;
4. Radiation based techniques for health care
    a. Sterilization of medical tools/prosthetics, cosmetics and pharmaceutical products/devices
    b. Sterilization of biological tissues and bones
    c. Blood irradiation
    d. Preparation of radiation processed hydrogels for wound dressing, non-bedsore mats and coolants
    e. Production of artificial joints
    f. Synthesis and efficacy evaluation of new drugs using radioisotopes
    g. Irradiation of Vaccines
5. Specific regulatory aspects
6. Hot Topics in R&D in Life Sciences
7. ***(Final Project) Network for Nuclear Innovation [options]***:
    a. **Medical over exposure:** the discussion should address the origin of accidental overexposure, lessons learned and corrective actions, criteria for notification and public information. International cooperation.

b. Radiation dose to patients from routine checkups and the awareness of this does for both patients and physicians.
c. Use of new radiopharmaceuticals for Theranostics

X - Radiation Technologies in Industry 4 Units

1. Nuclear techniques in industry
   a. Process control, assessments and optimization: nuclear gauges, radiotracers
   b. Non-destructive testing of components, structures, etc. by industrial radiography (gamma, X or neutron based radiography), computed tomography
   c. Radiation modification of polymeric materials; high performance materials: irradiation of cables and wires, preparation of heat shrinkable tubes, foams, coatings and curing processes
   d. Modification of semiconductors' properties (doping with neutrons/ions)
   e. Enhancement of colours of gemstones by irradiation
   f. Decontamination and preservation of cultural heritage objects damaged by fungal/bacterial infection
2. Industrial Radiation Dosimetry
3. The future prospects for the use of radioisotopes and radiation in industry
4. ***(Final Project) Network for Nuclear Innovation***:
   a) A review of radiation technologies in industry (make an opinion survey, prepare a folder, video, or any other means for public information)
   b) Isotopic techniques (both radioactive and stable ones) in Water Resources Management Science of Isotope Hydrology making impact by addressing real world issues on water availability and quality - also, case studies

XI – Radiation Technologies in Agriculture and Food 1 Unit

1. Food irradiation
   a. disinfestation (seeds, spices and meat/fish)
   b. Extension of shelf-life (all grains/potatoes, onions, strawberries etc.)
   c. avoid quarantine of exported perishable goods such as mangoes
   d. sterilization of food for immune challenged patients
   e. crop mutants' scope to address specific needs
2. Control of Pests (Sterile Insect Technique-SIT)
3. Soil disinfestation (peat-based substrate)
4. Packaging, decontamination and development of advanced packaging materials
5. Natural polymers applications (plant growth promoter, coating)

XII - Radiation Technologies for Protecting the Environment 1 Unit

1. Breaking down harmful chemicals in flue gases/wastewater from dye industry/waste water from pharma industry/used transformer oil.
2. Treatment of drinking water
3. Disinfection of medical wastes/ municipal sluge
4. Treatment of agro-industrial wastes (bioethanol production)
5. Environment assessment