Interdisciplinary Science and Engineering

Programme Code: IDSE00

Programme Outcome:

- Radiological and environmental safety have been foundational pillars of the Department of Atomic Energy (DAE) since its inception. Recognizing the critical importance of trained professionals in safeguarding public health and the environment, the discipline of Radiological Safety and Environmental Sciences was established within the BARC Training School to cultivate expertise dedicated to this mission.
- This specialized one-year training programme is meticulously designed to equip young professionals with the scientific knowledge, technical skills, and practical experience necessary to ensure radiological and environmental safety across the entire nuclear fuel cycle.
- The curriculum integrates foundational sciences, advanced core topics, domain-specific electives, practical laboratory training, and a problem-solving mini-project to provide a holistic and application-oriented learning experience.
- By bridging theoretical understanding with hands-on experience, the programme aims to develop a cadre of competent technocrats and scientists who are capable of addressing the complex challenges of radiation protection and environmental stewardship in India’s nuclear programme.

DETAILED COURSE STRUCTURE

Foundation Courses				
S.No.	**Course Code**	**Subject Title**	**Hours (T)**	**Credits**
1	RE 501	Mathematical Methods	45	3
2	RE 502	Nuclear & Reactor Physics	30	2
3	RE 503	Reactor Engineering	30	2
4	RE 504	Radiation Physics and Tutorials	30	2
5	RE 505	Nuclear Power Plant Engineering	45	3
6	RE 506	Radiation Detection and Nuclear Electronics	30	2
7	RE 507	Basic Radiation Dosimetry	15	1
Hours / Credits			**225**	**15**

Core Courses				
S.No.	**Course Code**	**Subject Title**	**Hours (T)**	**Credits**
1	RE 601	Advanced Radiation Dosimetry	30	2
2	RE 602	Environmental Science	45	3
3	RE 603	Operational Radiation Protection and Safety Regulation	45	3
4	RE 604	Accelerator Laser Physics and Radiation Safety	15	1
5	RE 605	Emergency Preparedness	15	1
6	RE 606	Environmental Modelling	45	3
7	RE 607	Radiological Safety Analysis	15	1
8	RE 608	Industrial Hygiene and Safety	15	1
Hours / Credits			**225**	**15**

Elective Courses (Any Two)				
S.No.	**Course Code**	**Subject Title**	**Hours (T)**	**Credits**
(Any Four)				
1	RE 701	Nuclear and Analytical Techniques	30	2
2	RE 702	Application of Radioisotopes and Radiation Technology	30	2
3	RE 703	Radioactive Waste Management	30	2
4	RE 704	Medical Physics	30	2
5	RE 705	Radiological Safety in Front End and Back End Nuclear Fuel Cycle	30	2
	ELECTIVE TOTAL		**60**	4

NON-SUBJECT ASSIGNMENTS				
S.No.	**Course**	**Course Code**	**Hours (T)**	**Credits**
1	Viva Voce	RE591	NA	NA
2	Practical	RE592		6
3	Mini Project	RE593	NA	6
4	Research Methodology & Publication Ethics	RE609		2
Total Hours / Credits				**14**

SUMMARY				
S.No.	**Course**	**Quantity**	**Hours (T)**	**Credits**
1	Foundation Courses	8	225	15
2	Core courses	8	225	15
3	Elective Courses	2	60	4
4	Viva Voce		NA	NA
5	Practical			6
6	Mini Project		NA	6
7	Research Methodology & Publication Ethics	1		2
Total Hours / Credits			**510**	**48**

PROGRAM COORDINATORS

Chief Coordinator: Dr. Manish Chopra

Foundation courses coordinators:

Course	Coordinators	E-mail
Mathematical Methods	Dr. Manish Joshi	mjoshi@barc.gov.in
Nuclear & Reactor Physics	Dr. Tej Singh	t_singh@barc.gov.in
Reactor Engineering	Shri Mithilesh Kumar	mithiles@barc.gov.in
Radiation Physics and Tutorials	Dr. Palani Selvam	pselvam@barc.gov.in
Nuclear Power Plant Engineering	Shri Mithilesh Kumar Dr. A. K. Singh Dr. Suchismita Mishra	mithiles@barc.gov.in aksingh@barc.gov.in suchim@barc.gov.in
Radiation Detection and Nuclear Electronics	Shri M. K. Sharma	mksharma@barc.gov.in
Basic Radiation Dosimetry	Dr. S. K. Singh	bhusunil@gmail.com

Core courses coordinators:

Course	Coordinators	E-mail
Advanced Radiation Dosimetry	Shri Sachin Mhatre	sachingm@barc.gov.in
Environmental Science	Shri I.V. Saradhi	ivs@barc.gov.in
Operational Radiation Protection and Safety Regulation	Dr. M.K. Suresh Kumar	smk@barc.gov.in
Accelerator Laser Physics and Radiation Safety	Dr. A. K. Singh	aksingh@barc.gov.in
Emergency Preparedness	Shri Bathula Sreekanth	bathulas@barc.gov.in
Environmental Modelling	Dr. (Kum.) Roopashree Shrivastava	roopa@barc.gov.in
Radiological Safety Analysis	Dr. S. Anand	sanand@barc.gov.in
Industrial Hygiene and Safety	Smt. Garima Singh	garima@barc.gov.in

Elective courses coordinators

Course	**Coordinators**	**E-mail**
Nuclear and Analytical Techniques	Dr. Aditi C. Patra	aditic@barc.gov.in
Application of Radioisotopes and Radiation Technology	Dr. K. Tirumalesh	tirumal@barc.gov.in
Radioactive Waste Management	Shri K. C. Pancholi	keyur@barc.gov.in
Medical Physics	Dr. S. D. Sharma	sdsharma@barc.gov.in
Radiological Safety in Front End and Back End Nuclear Fuel Cycle	Shri J. P. N. Pandey	jpnpandey@barctara.gov.in

FOUNDATION COURSES

RE 501: Mathematical Methods (45 Lecture Hrs)

Coordinators: Dr. Manish Joshi

(mjoshi@barc.gov.in)

Course Details:

Solutions of Linear Systems by direct methods, gauss elimination, LU factorization, Linear systems. Matrix inverse, ill conditioned matrices, sparse matrices, Eigen values. Data Approximation: curve fitting, least square lines, Least square polynomials. Iterative Techniques Jacobi and Gauss – Seidel iteration, successive over Relaxation – SOR, Interpolation Function, Lagrange interpolation, upwind shape function, Classification of PDE, Analytical solutions, Laplace transformation and Fourier transformation, Application to Advection – dispersion equation. Numerical analysis: Analytical and numerical methods, Errors, Taylor's series, Derivation of numerical differentiation formula, Numerical Integration: Newton-Cotes quadrature: Trapezoidal rule, Simpson's rule, Gauss quadrature, Solutions of Ordinary Differential equations: Methods of Euler, Adams–Bash forth–Moulton Method, Runge–Kutta Methods, Predictor-Corrector, Stability of solutions, Root finding methods: Bracketing and non-bracketing methods

Finite Difference Approximation in 1-D and 2-D, Solution of steady and unsteady diffusion equations, Finite Element Method, Energy Theorem and integral equations, Weighted Residual Approximations, Galerk in Method, Variational Principles, Lagranges multipliers, Numerical solution of one dimensional advection diffusion equation, Computational fluid dynamics: Basics and applications, Probability distributions, estimation of summary parameters of distribution, Sampling techniques and methods for selecting sampling locations and times, Environmental data analysis, analysis of trend in environmental data, ANOVA, Tests of hypotheses, parametric tests, Special tests of significance for small samples, Upper Confidence Limits (UCL) and Lower Confidence Limits (LCL), Regression and correlation analysis, Kolmogorov-Smirnov test, Kolmogorov-Smirnov test, Wilcoxon Signed-Rank test, Kruskal-Wallis test, Runs test.

Tutorials: Application of Python, MATLAB, R etc. for problem solving

Course Outcomes:

- The students will be able to apply various analytical and numerical methods to solve scientific and engineering problems.
- They will gain proficiency in effectively utilizing tools/softwares for such problems.
- They will also be able to analyze data using statistical techniques.

- Tutorials will assist the students to solve real scale problems requiring the coupling of basic understanding and softwares.

References:

1. Kreyszig, E. (2011). Advanced Engineering Mathematics (10th ed.). Wiley.
2. Chapra, S. C. (2018). Applied Numerical Methods with MATLAB for Engineers and Scientists (4th ed.). McGraw-Hill Education.
3. Burden, R. L., & Faires, J. D. (2011). Numerical Analysis (9th ed.). Brooks/Cole.
4. Rao, S. S. (2007). The Finite Element Method in Engineering (4th ed.). Elsevier.
5. Smith, I. M., Griffiths, D. V., & Margetts, L. (2014). Programming the Finite Element Method (5th ed.). Wiley.
6. Ferziger, J. H., & Perić, M. (2002). Computational Methods for Fluid Dynamics (3rd ed.). Springer.
7. Montgomery, D. C., & Runger, G. C. (2010). Applied Statistics and Probability for Engineers (5th ed.). Wiley.
8. Allen, B. (2021). The Science and Art of Learning from Data. Springer.

RE 502: Nuclear & Reactor Physics (30 Lecture Hrs)

Coordinators: Dr. Tej Singh
(t_singh@barc.gov.in)

Course Details:

Nuclear Fundamentals: Nuclear binding energy and mass defect, Nuclear forces and nuclear stability, Radioactivity and decay laws, Neutron-induced reactions, Nuclear fission process and energy release

Neutron Interactions: Interaction of neutrons with matter, Neutron sources and production mechanisms, Maxwell-Boltzmann distribution and non-Maxwellian behaviour, Microscopic and macroscopic cross-sections, Measurement of cross-sections (Transmission and Activation methods), Reaction rates and mean free path, Energy dependence of cross-sections (Fast region, Resonance region, Thermal region), Elastic and inelastic scattering and High-energy neutron cross-sections

Nuclear Fission Physics: Liquid drop model of fission, Fission cross-sections and fission rate, Reactor power generation, Fissile, fertile, and fissionable materials, Prompt and delayed neutrons, Fission gamma rays and fission products, Fission product inventory and residual decay heat, reactor concept on Burners, converters, breeders, Neutron life cycle and Neutron flux and current concepts

Neutron Diffusion Theory : Concept of neutron transport in the non-multiplying and multiplying regions , One-speed Transport and diffusion model, Continuity equation and Fick's law, Neutron diffusion equation, Diffusion coefficient and diffusion length, Boundary conditions and extrapolation distance, Solutions for : Point source, Infinite planar source, Finite slab, cylindrical source, Chain reaction theory, Infinite and effective multiplication factor, Material and geometric buckling, Non-leakage probability, Critical mass and critical size and Flux distribution in bare and reflected reactors: Slab, Sphere and cylinder

Neutron Moderation and Slowing Down: Elastic scattering kinematics, Energy loss per collision, Average logarithmic energy decrement, meaning of Lethargy concept, Slowing-down power and moderating ratio, Slowing-down in infinite media, Resonance escape probability, Resonance absorption (homogeneous & heterogeneous systems), Fermi age theory, Migration length, Two-group diffusion model and Reflectors and reflector savings

Reactor Kinetics and Control : Time-dependent diffusion equation, One-group kinetic equation, Prompt neutron lifetime, Role of delayed neutrons, Point kinetics model, Reactivity and reactor period, Burn-up equations, Fission product poisoning (Xe-135, Sm-149), Xenon transients and oscillations, Temperature and void reactivity coefficients, Fuel management schemes, types of reactivity/power control devices and Neutron monitoring at all state of reactor

Reactor Physics Design & Applications : Physics design considerations of: PHWR, PWR, BWR, HTGR, FBR, and Research reactors, approach to criticality, Reactor physics experiments, **Modern Reactor Concepts of** Small Modular Reactors (SMRs), Gen-IV reactor physics characteristics, Molten Salt Reactors (MSR), Advanced fuel cycles, Accelerator Driven Sub-Critical reactor (ADSS), Comparative reactor physics characteristics and Computational Methods in Reactor Physics: Diffusion, Transport and Monte Carlo Methods

Course Outcomes:

- Develop capability to explain fundamental nuclear properties, radioactivity, neutron interactions, and fission processes.
- Analyse neutron interactions with matter and evaluate cross-sections across energy ranges.
- Apply neutron diffusion theory to determine flux distribution and criticality conditions.
- Evaluate neutron moderation, resonance absorption, and slowing-down phenomena.
- Analyse reactor kinetics, reactivity control, burn-up, and neutron poisoning effects.
- Compare physics design aspects of various reactor systems (PHWR, PWR, BWR, FBR, SMRs, ADSS, HTGR, research reactors).
- Assess reactor safety parameters including temperature/void coefficients and shutdown mechanisms.

References:

1. Glasstone, S., & Sesonske, A., Nuclear Reactor Engineering: Reactor Design Basics, Fourth Edition, Vol. 1. Springer. ISBN: 978-1-4899-5753-5, 2004
2. Duderstadt J. J. and Hamilton L. J. (1976). Nuclear Reactor Analysis, John Wiley and Sons, New York.
3. John R. Lamarsh and Anthony J. Baratta. Introduction to Nuclear Reactor Theory.
4. Weston M. Stacey (2007).Nuclear Reactor Physics, Wiley, Weinheim.
5. Elmer E. Lewis (2008).Fundamentals of Nuclear Reactor Physics, Academic Press.
6. Serge Marguet (2017).The Physics of Nuclear Reactors, Springer.
7. J. Robert Lamarsh. Introductory Nuclear Reactor Statics.

RE 503: Reactor Engineering (30 Lecture Hrs)

Coordinators: Shri Mithilesh Kumar (mithiles@barc.gov.in)

Course Details:

Reactor Engineering:
Introduction to reactor system & Indian Nuclear power programme, Station schematic line diagram to indicate inter links between reactor, turbine, generator, grid & auxiliary systems Classification of reactors, characteristics of research, test & power reactors with examples.
Core configuration & cycle diagrams thermal reactors (BWR, PWR, PHWR, AGR, HTGR, AHWR etc.), Fast reactors Research reactors (CIRUS, DHRUVA etc.) Characteristics, selection criteria & comparison of different reactor materials & structural materials for reactor internals. Basic principles of heat generation, heat sources and distribution Steps involved in heat removal from reactor systems. Heat flow & temperature distribution in plate & solid cylindrical, fuel elements Temperature distribution in clad for the above type of fuel elements. Significance of Kd-T Axial clad surface & coolant temperature distribution in fuel channel maximum clad surface temperature and its location.
Brief description of various types of fuel: metallic (DHRUVA, CIRUS) Oxide (PWR, BWR, PHWR, AHWR) & Coated Fuel (HTGR). Boiling in reactor system critical heat flux & Burn out phenomena in water reactors Heat and mass balance in a BWR boiling height in a BWR core.
Nuclear Fuel Cycle
Concept of Nuclear Fuel Cycle, ¾open and closed fuel cycles. Global options of fuel cycles. Issues related to Resources, Long-lived radioactive waste, Proliferation, and Advanced Technologies, Mineral resources and nuclear fuel cycle strategies of Indian Nuclear Power Programme, 3-stage nuclear fuel cycle, Thorium utilisation, Indian capabilities in managing nuclear waste, long lived radioactive waste and fuel cycle technologies. Advanced fuel cycles, Role of ADS.

Course Outcomes:
Introduce and develop basic knowledge about types of nuclear reactors, engineering aspects, types of fuels, nuclear cycle and programs in the country.

References:

1. Glasstone, S., & Sesonske, A., Nuclear Reactor Engineering: Reactor Design Basics, Fourth Edition, Vol. 1. Springer. ISBN: 978-1-4899-5753-5, 2004.
2. Duderstadt J. J. and Hamilton L. J. (1976). Nuclear Reactor Analysis, John Wiley and Sons, New York.
3. John R. Lamarsh and Anthony J. Baratta. Introduction to Nuclear Reactor Theory.
4. G. Kessler, ‘Nuclear Fission Reactors’, Springer- Verlag, 1983.
5. J.N. Lillington, ‘Basic Features of Light Water Reactors’, Chapter 2, in Light Water Reactor Safety, Elsevier, 1995.
6. Wakil M.EI, "Nuclear Power Engineering", McGraw- Hill, 1962.
7. Lewis E.E., "Nuclear Power Reactor Safety", Wiley Inter Science, 1977.

RE 504: Radiation Physics and Tutorials (30 Lecture Hrs)

Coordinators: Dr. Palani Selvam (pselvam@barc.gov.in)

Course Details:

Interaction of Radiation with Matter:

Classification of radiation – ionizing radiation, non-ionising radiation, classification of charged particles – light and heavy charged particles, ***c***oncepts of ionization, excitation and specific ionization

Interaction of light charged particles with matter

Elastic and inelastic scattering, bremsstrahlung, thin and thick target Bremsstrahlung characteristic x-rays, Cerenkov radiation, linear and mass stopping powers, range energy relationship.

Interaction of heavy charged particles with matter

Elastic and inelastic scattering, nuclear interactions, charged particle multiple scattering theory, energy transfer mechanism in medium, concepts of Range (mean range, extrapolated range), and path length, energy straggling, Range energy relationship, Bethe-Bloch formula for heavy charged particles with density and shell corrections

Interaction of Gamma Photons with matter

Gamma photons: Interaction Mechanisms (Thompson scattering, Rayleigh scattering, Photo electric effect, Compton scattering and Pair Production). Attenuation coefficients (linear and mass attenuation coefficients), concept of buildup.

Interactions Neutrons with matter
Classification of neutrons, elastic scattering, inelastic scattering, neutron capture, nuclear interactions, spallation, fission, neutron attenuation

Radiation Transport Theory
Cross Section Definitions, Particle Streaming - Particle Distributions, derivation of time-dependent/time-independent Boltzmann transport equation for neutral particle.

Deterministic Method
Discrete ordinate technique – discretization of angle, space and energy

Monte Carlo Methods
Random number generator, properties of random numbers, discrete and continuous random variables, probability density function, cumulative probability function, random sampling techniques – inversion and rejection techniques with worked examples, photon Monte Carlo simulation, variance reduction techniques.

Course Outcomes:

- Acquisition of knowledge on interaction mechanisms of neutral and charged particles, transport theory and Monte Carlo methods

References:

1. James E. Turner, Atoms, Radiation, and Radiation Protection, Third edition, WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim, 2007.
2. Herman Cember and Thomas E. Johnson, Introduction to Health Physics, Fourth edition, The McGraw-Hill Companies, 2009.
3. Frank Herbert Attix, Introduction to Radiological Physics and Radiation Dosimetry, WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim, 2004.
4. Glenn F. Knoll, Radiation Detection and Measurement, Fourth Edition, John Wiley & Sons, New York, 2010.
5. Glasstone, S., & Sesonske, A., Nuclear Reactor Engineering: Reactor Design Basics, Fourth Edition, Vol. 1. Springer. ISBN: 978-1-4899-5753-5
6. Murthy, K. P. N., *Monte Carlo: Basics.* Indian Society for Radiation Physics. (Original work published 2000, updated version available as arXiv:cond-mat/0104215)

RE 505: Nuclear Power Plant Engineering (45 Lecture Hrs)

Coordinators: Shri Mithilesh Kumar,
Dr. A. K. Singh,
Dr. Suchismita Mishra
(mithiles@barc.gov.in,
aksingh@barc.gov.in,
suchim@barc.gov.in)

Course Details:

Thermal Reactors

Description of schematic of NPP: site requirements, Layout of Nuclear Power plant-Zoning requirements, layout within Reactor Building Reactor components/systems: Calandria, End-shield, Coolant Channel and End fitting. Reactivity control mechanisms: Zone control/Regulating rods, Absorbers, Shutdown System. Fuel Transfer System: Primary Heat Transport System including Steam Generators, Shut Down Cooling, Emergency Core Cooling System, Moderator System.
Auxiliary systems: Ventilation, Annulasgas, Process water & Firewater systems, Secondary System: Description off low sheet and major components, comparison operating conditions Thermal Cycles and Major components of thermal and nuclear units.

Power Plant Control and Instrumentation

Reactor power control (Neutronic and thermal signals) Coolant and Steam pressure control
Integration with grid for base load operation, Control and protection channels with typical examples.

Nuclear Power Plant Safety

Design principles for providing nuclear safety, Basic Principles (Reliability, Single failure, Redundancy and Diversity) Process systems, Safety Systems and Support Systems. Defence in depth approach, Design basis accidents, Beyond DBA. Safety Evaluation and Safety Criteria: Description of Deterministic and Probabilistic approaches.

Safety Monitoring of Operating Plants

IAEA Classification, NUSS Codes, Safety systems, Description of role of defense in depth, Exclusion zone Design Principles-Reliability, Single Failure, Redundancy, Diversity.

Description of a typical Design Basis Accident Scenario

build up event tree to describe sequential role of safety features. Broad description of

TMI, Chernobyl accidents& NAPS fire incident.

Advanced reactor concepts with passive safety features

Nuclear Architecture

Design of integrated layout of Equipment, Piping, Electrical / Instrumentation Cables etc. to provide Operation and Maintenance Convenience (to minimize man rem and meet safety objectives). Non propagation of incidents / accidents.

PWR Module

Comparison of PWR/PHWR core, comparison of core components, major primary system components, comparison of safety philosophies for handling LOCA/station black out etc. Important comparative features of PWR (KK Project) with typical western PWR.

Fast Breeder Reactors Introduction

Breeding, definition & reactions Breeders as Inexhaustible Energy Source Fast reactors as breeders. Classification of power reactors Characteristics& types of fast reactors Comparison of some characteristics of fast and thermal reactors Role of Fast Reactors in Indian Nuclear Power Programme.

Reactor Physics and Safety

Neutronic Aspects: Neutron spectrum, Reaction cross-section, core characteristics, blanket characteristics Breeding potential and performance characteristics. Breeding ratio, breeding gain, doubling time, performance characteristics (effect of core size, core composition, type of fuel, different fuel cycle etc.). Reactivity effect and Safety consideration, Effective delayed neutron and prompt neutron life time, fuel expansion and bowing, sodium void reactivity effect, Doppler reactivity effects, long-term reactivity effects

Shielding Principles

Special feature s of sodium cooled reactor shielding, reactor shielding, shield for activation products, shielding for fuel management.

Fast Reactor Core Design

General features of fast reactor core; Introduction, specific power, linear rating, burn up, fluence etc., operating Condition, Requirement and choice of core materials Coolant, structural material, fuel Reactor Power: Test reactor, commercial fast reactors Linear heat rating, maximum temperature of clad, coolant velocity, out let temperature of coolant, pressure drop-in core, core height / diam. ratio, blanket thickness etc

Fuel

Fuel pin diameter, no. of pins per sub-assembly, reactivity worth sub-assembly, Sub-

assembly outlet temperature.

Coolant for Fast Reactor

General requirements for fast reactors coolant Comparison of various coolants & choice of Naas coolant Properties of sodium purification & purity control, Cold & hot traps, Oxide measuring & indicating devices.

Heat Transport System

Primary sodium loop, secondary sodium system, emergency cooling system, inert gas system etc Sodium pumps: Mechanical pumps, Electromagnetic pump, Valves etc Intermediate Heat Exchanger, Steam Generator: Types, concept, once-through, recirculation etc. (horizontal Vs vertical), material requirement, safety, leak detection Heat transfer in Liquid Metal: Mechanism of heat transfer, decay heat removal corrosion & Mass Transport: Brief outline.

Instrumentation & Control

FBR instrumentation requirements, Neutronic Instrumentation and failed fuel detection methods Reactor protection instrumentation and process instrumentation.

Applications of Nuclear Technology

I. Application of radiotracers in industry and environment

Concept of radiotracer, selection criteria of radiotracer, estimation of amount of radiotracer, preparation of radiotracer. Basic concept of Residence Time Distribution (RTD), calculation of moments, RTD analysis procedure, ideal and non-ideal reactors, flow modelling, case study. Flow measurement using radiotracer (background, pulse velocity method, dilution method, case study), general concept of leak detection, leak detection in processing plants and heat exchangers, leak detection in underground pipelines, case study. Principle of sediment transport study, transport parameters, case study.

II. Sealed source applications in industry

Types of sealed radioisotope sources, machine based radiation sources, radiation detectors and nucleonic instrumentation, measurement techniques, gamma ray absorption techniques, thickness measurement, density measurement, level measurement, voidage measurement, gamma radiometry. Principle of Industrial Radiography (IR) using Gamma rays and X-rays, source projectors, X-ray equipment, image recording media, principle of radiographic exposures, defects and class of defects, interpretation of radiographs. Principles of computed tomography methods for non-destructive evaluation of industrial specimen, sealed radioisotope source based gamma tomography, image analysis and interpretation.

III. Radioisotope applications in healthcare

General introduction about nuclear medicine, radiopharmaceuticals, general structure

of a radiopharmaceutical, classification of radiopharmaceuticals, carrier moieties for radiopharmaceuticals, characteristics of diagnostic and therapeutic radiopharmaceuticals, methods of radio labelling, thernostics, SPECT and PET. Brachytherapy, teletherapy and radionuclide therapy, therapeutic radiopharmaceuticals for some specific applications.

IV. Radioisotope applications in food and agriculture

Food irradiation (Basic principles and Radiation sources), applications of food irradiation in food preservation, disinfestation, sprout inhibition, delay in ripening, increasing shelf-life, mutation breeding of crop, benefits of mutation breeding in cereals, pulses and oilseeds, achievements made at BARC.

V. Nuclear forensic science

Introduction to nuclear forensics (NF), fuel cycle operations, categorization of nuclear materials and radioactive sources, potential nuclear/radiological events
Physical and chemical basis of nuclear forensics, various processes involved in nuclear forensics, onsite assessment and categorization, forensic signatures (predictive and comparative), radio-chronometry
Laboratory analytical techniques for NF signature analysis, techniques for physical characterization, non-destructive and destructive techniques for elemental and isotopic characterization, SNM characterization techniques, chemical characterization techniques, small signatures and micro analysis
QA & QC in Nuclear Forensic Analysis, Nuclear forensic reference database, Source and route attribution, case studies in Nuclear Forensics.

Course Outcomes:

- This course provides basic understanding of fast breeder reactor technology including fuel characteristics, inherent safety features, coolant selection principles governing fast reactors including sodium coolant behaviour and safety-related reactivity effects and analyze fast reactor core design considering thermal, mechanical, and hydraulic aspects, sodium void coefficient, bowing phenomena, and safety margins.
- Understanding of fundamental concepts of radioisotopes, radiotracers and their multidisciplinary applications in industry, healthcare and agriculture,
- Acquire knowledge on sealed source applications, for non-destructive testing and measurements in various industries and radiotracer techniques for industrial process evaluation and optimization
- Gain foundational knowledge of nuclear forensics, fuel cycle operations, and categorization of nuclear materials.
- The course will also foster interdisciplinary skills in chemistry, physics, environmental science, and data analysis, facilitating innovative research and development of forensic methods.

References:

1. IAEA. (2004). Radiotracer Applications in Industry — A Guidebook (Training Course Series No. 38). Vienna.
2. IAEA. (2015). Radiation Technology for Food Preservation. Vienna.
3. Pant, H. J. (2022). Applications of the radiotracers in the industry: A review. Applied Radiation and Isotopes, 182, 110076.
4. ICRU. (2002). Nucleonic Gauging and Industrial Applications. ICRU Reports.3. Sanwick, A. M., & Chaple, I. F. (2025). Radiocobalt theranostic applications: current landscape, challenges, and future directions. Frontiers in Nuclear Medicine, 5.
5. Xu, S., Liu, G., Wei, Q., Liu, H., Wu, J., Liu, Y., & He, Z-X. (2025). Recent advances in radionuclide medical imaging techniques. Frontiers in Medicine, 12, 1662020.
6. 10. Cherry, S. R., Sorenson, J. A., & Phelps, M. E. (2012). Physics in Nuclear Medicine (4th ed.). Elsevier Saunders.
7. DeVol, T. A., & Wernick, M. N. (2004). Emission Tomography: Fundamentals of PET and SPECT. Academic Press.
8. 16. Farkas, J. (1985). Food Irradiation. Elsevier Science Publishers.
9. Prajapati, H., Agrawal, A., & Gupta, A. K. (2020). A review on importance of radioisotopes & radiotracer techniques in agriculture. Research & Reviews: Journal of Agricultural Science and Technology, 9(1), 1-9.
10. K. J. Moody, I. D. Hutcheon, P. M. Grant. Nuclear forensic analysis, CRC Press, Boca Raton, Fla. 485 p. ISBN 0849315131. (Edn 1 and 2.)
11. The New Nuclear Forensics - Analysis of Nuclear Materials for Security Purposes. Ed. V. Fedchenko, p. 47–73, Oxford University Press, ISBN: 978-0-19-873664-6.
12. Handbook of Radioactivity Analysis. Nuclear Forensics, M. J. Kristo, Chapter 21, . Page 1281-1304. DOI: http://dx.doi.org/10.1016/B978-0-12-384873-4.00021-9.
13. IAEA Nuclear Security Series No. 2, Technical Guidance, Reference Manual, Nuclear Forensics Support.
14. IAEA Nuclear Security series No. 2-(G) (Rev.1), Implementing Guide. Nuclear Forensics in support of Investigations.
15. IAEA-TECDOC-2029. Establishing a Nuclear Forensic capability: Applications of Analytical Techniques.

RE 506: Radiation Detection And Nuclear Electronics (30 Lecture Hrs)

Coordinators: Shri M. K. Sharma (mksharma@barc.gov.in)

Course Details:

Radiation Detection Principles and General Properties of Radiation Detectors

Radiation Detection Principles, Simplified Detector Model, Modes of detector operation, Pulse height spectra, Counting curve and Plateaus, Energy Resolution, Detector Efficiency, Dead Time.

Gas Filled Radiation Detectors
Basic detection mechanism, Various regions of detector operation, Detection mechanisms of Ionization chambers, Proportional counters, and GM counters, Different variants of detectors- sealed, flow type, high pressure, multi-wire, position sensitive, Applications of gas filled detectors, Direct Ion Storage (DIS) type of detectors.

Scintillation (organic/inorganic) and Semiconductor Detectors
Radiation detection mechanism of organic and in-organic scintillators, Properties of ideal Scintillator, Types of scintillators for various applications, Basic electronics blocks in Scintillator detector setup, Working principle of Photo Multiplier tubes & Photo Diodes and their comparison,
Principles of detection mechanism in semiconductor detectors and its application for gamma and alpha spectrometry, Radiation detection by TLD.

Neutron detectors
Neutron detection by activation, Nuclear track detectors, Self Powered Neutron Detectors (SPND), Working principle of BF3, He3, Bubble detectors etc.

Nuclear Electronics for Radiation Detectors
Introduction to Preamplifiers, types of preamplifiers and selection of proper pre amplifier for specific detector. Application of shaping amplifier, types of shaping amplifiers, bias amplifier and log amplifier. Pulse counting systems, SCA, and Pulse height analysis systems – MCA, Coincidence and anti-coincidence circuit blocks, rate meters-diode pump.

Gamma Spectrum Analysis and Measurement Techniques
Methods of analysis of complex gamma spectra obtained using NaI (Tl) and HPGe, spectrum stripping, simultaneous equation method, least square method, auto peak search, background radiation and compton correction, calibration of spectrometry system, effects of shielding, secondary radiation, effect of geometry, counting techniques, testing and calibration.

Course Outcomes:

- The course content is designed to equip students with the fundamental principles of radiation detection and the characterization of radiation detection systems.

- It introduces the design principles and configuration of the building blocks of radiation measurement systems.
- The course covers the working mechanisms, operating regions, and applications of different types of radiation detectors.
- Furthermore, it includes standard measurement techniques and gamma spectrometry methods for spectral analysis.

References:

1. Knoll G. F. (2010). Radiation Detection and Measurement, Wiley, Hoboken.
2. Gilmore G. R. (2008). Practical Gamma Ray Spectrometry, John Wiley and Sons, England

RE 507: Basic Radiation Dosimetry (15 Lecture Hrs)

Coordinators: Dr. S. K. Singh (aksingh@barc.gov.in)

Course Details:

Radiation Quantities and Units

Radiometric Quantities – Particle Number, Radiant Energy, Flux and Fluence
Interaction Quantities – Linear attenuation coefficients, Mass attenuation coefficients, Mass energy transfer coefficient, Mass energy absorption coefficients, Stopping power and LET (Linear Energy Transfer).
Dosimetric Quantities – Energy Imparted, Absorbed Dose, Kerma, Exposure, Air Kerma Rate Constant, Charged Particle Equilibrium (CPE), Relationship between Kerma, Absorbed Dose and Exposure under CPE and Transient Charged Particle Equilibrium (TCPE).
Protection Quantities – Equivalent Dose and Effective Dose
Operational Quantities – Ambient, directional [(H*(d) and H'(d)] and Personal dose equivalent [Hp(d)].

Dosimetric Standards for Exposure, Air kerma & Dose

Bragg-Grey principle, relation between exposure and dose, build up factors, calculation of dose from radiation sources, Free air ionization chamber (Primary standard for X-ray beams), Ionization chamber (Photons Primary & Secondary standard), Extrapolation chamber for surface dose measurements (Beta), Water / graphite Calorimeter (Primary standard), Calibration facility for radiation monitors and use of phantoms for calibration of personnel dosimeters.

TL/OSL Dosimetry

Introduction, luminescence as a phenomenon, different types of luminescence, fluorescence, phosphorescence, thermoluminescence (TL), optically stimulated luminescence (OSL) etc. Different readout mechanisms of TL/OSL. Understanding TL/OSL, inorganic crystal structure, imperfections and defects in crystal, band diagram, Configurational co-ordinate diagram, explanation of various aspects of TL/OSL with its help. Requirements for good TL/OSL phosphors Probability relation for luminescence, TL/OSL kinetics, Determination of trap parameters by different methods viz. isothermal, initial rise, different heating rates, peak shape method etc. Effect of elevated temperatures on stability of TL signal. Factors affecting the TL sensitivity.
Luminescent properties, TL/OSL mechanisms of different TL/OSL phosphors.
Applications of TL/OSL dosimetry in Personnel Monitoring, Environmental monitoring, Patient dosimetry, food irradiation dosimetry etc.

Course Outcomes:

- This course provides a clear understanding of the fundamental quantities used in radiation dosimetry (exposure, absorbed dose, equivalent dose, effective dose, kerma, etc.), along with the identification and correct use of SI and non-SI units relevant to various kinds of ionizing radiation measurements.

- It also covers the concepts of calibration hierarchy and traceability in radiation measurements.

- The course further explains the working principles, characteristics, and applications of thermoluminescence (TL) and optically stimulated luminescence (OSL) phosphor materials.

- Additionally, the course focuses on precise dose estimation using luminescence dosimetry for radiological applications such as personnel, environmental, and clinical dosimetry, thereby supporting high standards of radiological protection in diverse radiation environments."

References:

1. Fundamentals of Ionizing Radiation Dosimetry by Pedro Andreo, David T. Burns, Alan E. Nahum, Jan Seuntjens, and Frank H. Attix.
2. ICRU REPORT No. 85: Fundamental quantities and units for ionizing radiation (revised).
3. Optically Stimulated Luminescence by Yukihara and McKeever
4. Thermoluminescence of Solids by S. W. S. McKeever

CORE COURSES

RE 601: Advanced Radiation Dosimetry (30 Lecture Hrs)

Coordinators: Shri Sachin Mhatre
(sachingm@barc.gov.in)

This three part course consists of neutron Standards and Dosimetry, Radiation Chemistry, Chemical Dosimetry & Radiation Processing Applications and internal dosimetry

Course Details:

Neutron Standards & Dosimetry

Primary Standards - Manganese bath facility, recoil proton telescope, Standard Thermal Assembly in Graphite (STAG) facility. Secondary Standard - Precision long counter, Portable transfer standard, Neutron rem counter, Flux monitors, Electronic Personnel dosimeters etc. Type testing and calibration of neutron monitors. Neutron spectrometry techniques -Threshold detectors and Bonner's sphere. Neutron dosimetry techniques: Solid State Nuclear track dosimeters, Albedo neutron dosimetry using Luminescence based dosimeters and Bubble dosimeters etc.

Radiation Chemistry, Chemical Dosimetry & Radiation Processing Applications

Radiation Chemistry
Concept of free radical, free radical reactions, radiolysis products, g-value, effect of pH, LET, dose rate on systems, radiation chemistry of solids, water and aqueous systems, radiation chemistry of gases, reactions of dosimetry interest, radiation polymerization, applications of radiation chemistry in industry, ozone and NOx production mechanism and mitigation.
Chemical Dosimetry
Dosimetry principles, Beer Lamberts law, absorbed dose calculations, dose evaluation in different medium, concept of electron buildup, Fricke dosimeter, FBX (inhouse developed low dose) dosimeter, Ceric cerous dosimeter, inhouse developed free radical dosimeters, other high dose dosimeters used in industry, introduction to ESR, use of alanine ESR as a gold standard in dosimetry.
Dose Assurance Program (BARC)
Dose inter-comparison and Dose verification program for radiation processing facilities carried out by RSSD, BARC. Dosimetry in operational gamma & e-beam radiation processing facilities.

Internal Dosimetry

BASICS: Introduction to fundamental concepts (reference man,intake, excretion,

retention, biological and effective half life), terminology (Committed equivalent/effective dose, ALI, DAC) and units for internal dose estimation. Internal dose estimation and evolution of its methodology.

BIOKINETIC MODELS: Introduction to biokinetic quantities and their application in dose computations.

Revised Human Respiratory Tract Model (HRTM): Salient features, physiology and applicable parameters, regional deposition of inhaled radionuclides, gases and vapours, clearance of material deposited in HRT by particle transport and absorption. Various absorption classes.

Human Alimentary Tract Model (HATM): Salient features, physiology and applicable parameters. Retention and clearance of material from HAT.
Alimentary tract transfer factor (fA).

Element specific systemic models: Fundamentals, unidirectional and recycling models for various elements. Age dependent biodistribution.

DOSIMETRIC MODELS: Introduction to dosimetric quantities such as S-values, SEE values. Concepts of source and target organs.
Computational phantoms such as voxel and mesh phantoms and their applications for dosimetric quantities.
Challenges in skeletal and skin dosimetry.

DOSE COEFFICIENTS: Introduction to computational methodology for dose coefficients and its implementation.

MONITORING PROGRAMME:
Requirement of internal contamination monitoring programme and associated details.
Different types of monitoring and monitoring frequency. Reference levels and derived reference levels.
Direct (in-vivo) and indirect (in-vitro) methods of individual monitoring and their philosophies.
Phantoms for efficiency estimation of direct monitoring systems.
Sample collection, Methodology and analytical techniques for ultra trace level detection of radionuclides in bioassay samples.
Uncertainties in internal dose assessment and Bayesian methods for their quantification.
General aspects of retrospective dose assessment and dose verification. Development and applications of dose assessment software.
Decorporation of internally deposited radionuclides. Internal dosimetry of radon and thoron in mining facilities and related concepts.

Course Outcomes:

- The course will provide an overall understanding and in-depth knowledge
- About neutron metrology activities.
- An overview of general radiation chemistry and its applications in radiation processing

industry.

- An insight of chemical dosimetry techniques used worldwide and role of BARC in providing global traceability.
- The course will provide an overall understanding and in-depth knowledge of internal dosimetry, covering theoretical foundations, modelling techniques, and practical applications in radiation protection.
- The students will gain interdisciplinary skills in radiation physics, biology, and computational modelling, preparing them for careers in radiation protection, nuclear medicine, environmental monitoring, or regulatory compliance.

References:

1. H. Beckurts, K. Wirtz, Neutron Physics, Springer Berlin, Heidelberg, 1964.
2. F. Knoll, Radiation Detection and Measurement. 4th Edition, Wiley, Hoboken, 217
3. D J Thomas et al., 2011 Metrologia 48 S225.
4. Dosimetry for Radiation Processing" by W.L. McLaughlin, A.W. Boyd, et al. (1989):
5. An Introduction to Radiation Chemistry J. W. T. Spinks and R.J. Woods, Wiley, New York, 1990, 3rd Edition.
6. Standard Practice for Dosimetry in Radiation Processing, ISO/ASTM52628:2020
7. ICRP Publication 130. Occupational Intakes of Radionuclides: Part 1. Annals of the ICRP 44(2), International Commission on Radiological Protection, 2015.
8. ICRP Publication 78. Individual Monitoring for Internal Exposure of Workers. Annals of the ICRP 27(3–4), International Commission on Radiological Protection, 1997.
9. AERB Safety Guide: Medical Management of Persons Exposed in Radiation Accidents, GUIDE NO. AERB/NRF/SG/NRE-4.
10. Upgradation of internal dosimetry facilities at BARC Trombay, KA Pendharkar, S Bhati, IS Singh, Pramilla D Sawant, N Satyabhama, Minal Y Nadar, P Vijaygopal, HK Patni, GN Kalyane, Supreetha P Prabhu, BARC Newsletter, Issue No. 296, 2003

RE 602: Environmental Science (45 Lecture Hrs)

Coordinators: Shri I.V. Saradhi (ivs@barc.gov.in)

Course Details:

Part I: Environmental Chemistry

Environmental Factors affecting the behaviour and distribution of Contaminants, soil physico-chemical characteristics, soil texture, soil horizon, ion exchange capacity, soil organic matter, Mineralogy - Definition of minerals, types of minerals, basic silicate structures, clay minerals structures, Ion-exchange properties; Sorption-desorption processes, weathering effects, physico-chemical parameters of soil and water like competing ions, carbonates, hydroxides etc., speciation and fractionation, techniques for elemental analysis, Quality assurance.

Basic concept of oceanography, Surface current, surface wind, waves, upwelling and down welling, El-Niño, tides, seawater temp etc,. Physical Parameters of the Oceans, Composition of the Oceans, Major, minor, trace elements
Distribution of elements in the marine environment, Variations in sources: land, seafloor, in situ, atmosphere/cosmos (& man), Physico-chemical speciation: ions, carbonates, hydroxides, etc, Biogeochemical behaviour: conservative, nutrient-like, scavenged, redox-controlled, Influence of in situ processes: physical, chemical and biological ,Interactions between particles & trace metals in seawater: distribution; Processes affecting radionuclide concentrations and inventories in the marine environment. Biogeochemistry of radionuclides in marine environment.

Chemical composition of atmosphere, source of air pollution, Types of pollutants, their behavior and fate on local, regional and global scale, monitoring of pollutants and instrumentation. Effects of air pollutants on human health. Ambient air quality standards. Chemical and photochemical reactions in atmosphere. Ozone depletion, Acid rain, Greenhouse Effect, Formation of photochemical smog, CFCs-Nomenclature, carbonaceous aerosols. Vehicular pollution, emission norms and control techniques e.g. catalytic convertors.

Water Pollution Chemistry (Physico-chemical properties of water, effluent water quality standards, Types and sources of water pollution, major water quality parameters and monitoring. Brief methodologies of wastewater and drinking water treatment. Chromatographic methods for monitoring of air and water quality parameters i.e. basic introduction to chromatography (capacity factor, separation factor, resolution, theory of band broadening/ van Deemter equation), gas chromatography (GC), high performance liquid chromatography (HPLC), hyphenated techniques e.g. GC-MS.

Soil Pollution Chemistry Nature and importance of soil, soil classification, soil pollution, soil/solution interference, Acid-base and ion-exchange reactions in soil, soil acidity. Micro and macro nutrients in soil. Fertilizer and other soil amendments. Soil Pollution: Waste pollutants in soil, heavy metals and radionuclides in soil. Remediation of contaminated soil. Reduction, treatment and disposal of hazardous waste.

Aerosol Science, Epidemiology, EIA & Risk Assessment Aerosol Science:

Aerosol: Concentration, Size, Shape, Equivalent diameter, Shape factor, Aerosol chemical composition, Size distribution function, Drag on a single particle (Stokes' law), Slip correction factor, Gravitational settling of aerosol particle, Brownian motion of aerosol particles, Concept of deposition velocity, Aerosol nucleation, Coagulation theory: Smoluchowski's equation, simple solutions, Aerosol filtration, sampling and analysis using filters, Aerosol impaction, Aerosol instrumentation- Inertial impactors, condensation nucleus counters, optical counters, mobility analysers, Introduction to radioactive aerosols, characterisation of radioactive aerosols, Aerosols in nuclear safety- under normal work environments, reactor accident related aerosols.

Epidemiology: Introduction to epidemiology: Risk assessment and limitations, measures of disease occurrence, background cancer death rates, concept of person-time, life tables, cancer registries, variability with respect to population, age standardization and causal models. Epidemiology and study designs: Cross sectional studies, Case-control studies, and cohort studies. Measures of risk: Standardised mortality ratio, Odds ratio, Mantel-Haensel measure, variance estimates, confidence intervals, confounding factors, adjustments for confounding, trend analysis. Biological effects of radiation: Classification of effects, biological indicators and biological bases of radiation protection. Cancer epidemiology: Historical perspectives in radiation epidemiology-Japanese A-Bomb survivor studies. Projection models: Life span studies, additive model, multiplicative model, occupational risk estimations, biological bases of operational quantities and weighting factors, LNT-DRF model for low dose occupational risk estimation, genetic risk estimation, concept of relative detriment and bases of dose limits for occupational workers/public.

Environmental Impact Assessment: What is Environmental Impact Assessment (EIA), What are Aims and objectives of EIA, Guiding principles of EIA, EIA Process: Screening, Scoping, Impact analysis, Mitigation, Reporting, Review, Decision-making, Follow up Monitoring, Public involvement; Impact Analysis Methodology: Ad hoc Method, Checklists Method, Matrices Method, Leopold Matrix, Networks Method, Overlay Methods and Battelle Environmental Evaluation (BEE) System; Considerations in impact prediction; Environmental Management Plan (EMP); Environmental Monitoring Programme; Environmental Impact Statement (EIS); Public participation techniques.

Risk Assessment: Introduction, Basic definitions, concepts of risk, Human health risk assessment methodology, Components of risk assessment – Hazard Identification, Exposure Assessment, Toxicity Assessment, Risk Characterization

Course Outcomes:

- This two part course on Environmental Science covers the processes that govern the gate of contaminants in the environment and the risk posed by these contaminants.
- Part-I of the course with specially designed to introduce young professionals the fate and behaviour of both radiological and non-radiological contaminants in different environments viz., marine, atmospheric, aqueous and terrestrial. The professionals also get acquainted with the types of equipment/techniques/methods used for determination of the radiological and non-radiological contaminants in different matrices.

- Part-II of the course deals with the science and behaviour of aerosols covering the basic laws governing the aerosols in the environment. Additionally, the course also covers the epidemiological and risk assessment methods used for estimation of risk due to exposure of the contaminants. Methodologies used for carrying out Environmental Impact Assessment (EIA) studies are also discussed

- The curriculum integrates foundational topics and advanced methods and practical laboratory training to provide a holistic and application-oriented learning.

References:

1. Radioactivity in the environment: Sources, distribution and surveillance by RL Kathren – 1984
2. Radioactivity: Introduction and History 1st Edition by Michael F. L'Annunziata
3. Environmental Chemistry, 8th Edition by A K De
4. Atmospheric Chemistry and Physics: From Air Pollution to Climate Change, 3rd Edition by John H. Seinfeld and Spyros N. Pandis.
5. Textbook of Soil Science, Second edition. T. K. Biswas and S. Mukherjee. McGraw Hill Education, 2017.
6. Introductory Soil Science. D. K. Das. Kalyani Publishers, 2015.
7. Principles of Soil Chemistry. Fourth edition. K. H. Tan, CRC Press, 2010.
8. The nature and properties of Soil. R. R. Weil and N. C. Brady. Pearson publishers, 2016.
9. Aerosol measurement: Principles, Techniques and Applications by Kulkarni, Baron and Willeke
10. Atmospheric chemistry and Physics: Air pollution to climate change by Seinfeld and Pandis
11. Aerosol Technology: Properties, Behavior, and Measurement of Airborne Particles by William C Hinds
12. Radioactive aerosols by C. Papastefanou
13. Nuclear Energy Agency, committee on the safety of nuclear installations, NEA/CSNI/R(2009)5, State-of-the-art report on nuclear aerosols
14. ICRP 60 (1990)
15. ICRP 103 (2007)
16. Radiobiology for radiologist, E.J. Hall
17. Principles of medical statistics, Hill A. Bradford
18. Environmental Impact Assessment by Larry W. Canter. McGraw-Hill Publication
19. Hazardous Waste Management, Michael D. LaGrega, Phillip L. Buckingham, Jeffrey C. Evans, Mc-Graw Hill Inc. Publication.
20. Introduction to Environmental Engineering and Science, Gilbert M. Masters, Wendell P. Ela, Prentice Hall India Learning Pvt. Ltd. Publication.

RE 603: Operational Radiation Protection and Safety Regulation (45 Lecture Hrs)

Coordinators: Dr. M. K. Suresh Kumar (smk@barc.gov.in)

Course Details:

Fundamentals of Radiation Protection

Protection of the individual and control of the total impact of a source or practice, Deterministic and stochastic effects. Justification, optimisation, individual dose limits, radiation protection in proposed and continuing practices, Types of exposures. Dose limits and its basis, risk projection models, secondary limits, ALI, derived limits, DAC, authorized limits, exposure of women, limits for members of the public, critical group, exposures from multiple sources, upper bounds related to specified sources. Relevance of the collective equivalent dose as an indicator of health detriment, other components of detriment, costing the detriment, optimization in radiation protection, differential cost-benefit analysis techniques for optimization, Potential exposures.

Radiation Monitoring

Exposure control: external-time, distance and shielding, internal-containment, ventilation. Design of hot labs, zoning of areas, concept of controlled area, supervised area. Special work permit, barrier rubber stations, periodic surveillance of radiation installations, exposures authorization. Choice of instruments and methods, film badge, TLD, pocket dosimeter, extremity organ dosimetry, neutron dosimetry, criticality monitors, albedo dosimeters, dose records, collective dose equivalents. Whole body counting, lung counting, principles and techniques bioassay–urine analysis, fecal analysis, breath analysis, analysis of other body fluids, interpretation of results, internal dose calculation. For external radiation levels, air borne contamination, surface and personnel contamination, monitoring instruments, collection of air and swipe samples and counting, control of environmental releases.

Radiation Protection Techniques

Sampling and analysis of: radioactive gases and vapors (Iodine, Krypton and Ruthenium), special purpose air samplers and their detection systems, radioactive aerosols in different nuclear fuel cycle operations, impactor and Anderson air samplers, toxic chemicals, vapors and gases: instruments for their automatic sampling and monitoring, indicator tubes, test papers and other physical and chemical methods for their monitoring, major chemical contaminants indifferent units of DAE and their health hazards

Radiation shielding:

Shielding calculations for gamma radiation: primary and secondary radiation, choice of shielding material, influence of source geometries, Shielding for beta radiation and bremsstrahlung, Shielding for neutrons, scattering and absorption, build-up factor for single and multi layer shield, effect of voids and ducts in shield, activation of the shielding materials. Optimisation of shielding, heat effects in shielding materials,

shielding windows for hot cells and irradiation facilities, Shielding containers for high active sources

Criticality safety

Conditions for criticality, critical parameters, methods of criticality control – mass, volume, concentration, geometry, nuclear poisons, Neutron interaction between sub-critical units: their spacing and isolation, safety factors (minimal specifications), magnitude of criticality accidents, criticality monitoring systems, and administrative control, Criticality accident dosimetry

Design of hot laboratories

Types of laboratories, containment systems – fume hood, glove box, shielded glove box, health physics instrument requirement, emergency alarm systems

Safe transport of radioactive materials

Regulations for transport of radioactive / fissionable materials, categories of packages and their test requirements, criticality, analysis, allowable number of packages, transport index, exemption from requirement for fissile consignments, transport of irradiated fuel

Personnel protective equipment

Respiratory hazard- its assessment and control, respiratory protective equipment and their protection factors, chemical cartridges, gas masks, universal gas masks, air-line respirators, self-contained breathing apparatus, positive pressure respirators, tritiated water vapor removing respirators, use and care of respirators, protective plastic suits, ventilated suits

Decontamination

External and internal decontamination procedures with special reference to plutonium, action plan for management of personnel contamination incidents. Objectives, methods of decontamination–general, physical(mechanical), chemical, electrical, special methods for decontamination of concrete, decommissioning of a nuclear facility

RADIOCHEMICAL - METHODS AND TECHNIQUES

Analytical techniques for samples from nuclear facilities and environment

Analysis procedures for fission products, activation products and actinides, procedures for gross radioactivity measurements in effluents, saline water, suspended and dissolved solids in water, soil and sediment samples

Radio chemical analysis of environmental & biological samples

Environmental sample matrices, collection, processing and analytical methodologies; various pre-concentration approaches ;radio chemical techniques for separation and estimation of natural and man-made radionuclides including RNAA, uses of tracer and

carriers in quantitative estimations of beta and alpha emitters. Estimation of tritium in environmental samples; High resolution gamma spectrometry for estimation of radionuclide in sea-water, silt, sediment and marine organisms evaluation of transfer factors in different environmental matrices.

Collection and analysis of urine, stool, etc., estimation of various radionuclides of interest using different techniques

Chemical Biology of Radiation Protection

Radiation chemistry of water, radiolysis products, oxidizing and reducing conditions, oxidative stress, antioxidants, radiation chemical aspects of radiation biology, radio protectors top rotectnormal cells during radio therapy and accidental exposure, biological aspects of radioprotection, thiols and amifostine as radioprotectors and new concepts in the development of radioprotectors.

REGULATORY ASPECTS OF OCCUPATIONAL RADIATION PROTECTION

Radiation Protection Basis

United Nations Scientific Committee on Effects of Atomic Radiation (UNSCEAR), International Commission on Radiological Protection (ICRP), International Commission on Radiation Units and Measurements (ICRU), International Atomic Energy Agency (IAEA), Atomic Energy Regulatory Board (AERB), BARC Safety Council (BSC), Atomic Energy Act, Radiation Protection Rules, Codes, Guides, Manuals, Technical Documents.

Planned Exposure Situations

Generic requirements for Occupational exposure, Public exposure and Medical exposure Emergency Exposure Situations. Generic requirements for Public exposure, Exposure of emergency workers, Transition from an emergency exposure situation to an existing exposure situation. Existing Exposure Situations. Generic requirements for Public exposure and Occupational exposure. Exemption and Clearance

REGULATORY ASPECTS OF EMEREGENCY PREPAREDNESS AND RESPONSE

Disaster Management Act 2005, National Disaster Management Plan, AERB Code and Guide on Emergency Preparedness and Response

General: Goal of emergency preparedness, Goals of emergency response , The emergency management system, Roles and responsibilities in emergency preparedness and response, INES, Hazard assessment, Protection strategy for a nuclear or radiological emergency

Functional: Managing operations in an emergency response, Identifying and notifying and activating an emergency response, Taking mitigatory actions, Taking urgent protective actions and other response actions, Providing instructions, warnings and relevant information to the public, Protecting emergency workers, Managing the medical response, Communicating with the public, Taking early protective actions and other response actions, Managing radioactive waste, Mitigating non-radiological consequences, Requesting,

providing and receiving international assistance, Terminating a nuclear or radiological emergency, Analysing the nuclear or radiological emergency and the emergency response.
Infrastructure: Authorities, Organization and staffing, Coordination, Plans and procedures, Logistical support and facilities, Training, drills and exercises, Quality management
programme

REGULATORY ASPECTS OF SECURITY OF NUCLEAR INSTALLATIONS

Course Outcomes:

This course will familiarize the students with

- The fundamentals principles of radiation protection to be applied for nuclear and radiological facilities to protect the workers, public and the environment from harmful effect of radiation.
- The advanced radiation measurement instruments as applied in field for ambient radiation measurement, personal dosimetry and environmental discharge estimation.
- The technological & regulatory aspects of radiation protection and the systems and techniques available for the same will be.
- Basic radiochemical analytical procedures and radiation emergency handling protocols.

References:

1. J E Martin (2013) Physics for Radiation Protection (3rd Ed) Wiley-VCH Verlag GmbH & Co
2. H Cember, & T E Johnson (2008) Introduction to Health Physics (4th Ed) McGraw- Hill
3. G F Knoll (2022) Radiation Detection and Measurement, John Wiley & sons
4. AERB (2014) Criteria for Planning , Preparedness and Response for Nuclear or Radiological Emergency AERB/NRF/SG/EP-5 (Rev. 1)
5. A Procedure for the Sequential Determination of Radionuclides in Environmental Samples, IAEA/AQ/37: IAEA, 2019.
6. Radiation Biology: A Handbook for Teachers and Students, Training Course Series No. 42,: IAEA, 2010.

RE 604: Accelerator Laser Physics and Radiation Safety (15 Lecture Hrs)

Coordinators: Dr. A. K. Singh
(aksingh@barc.gov.in)

Course Details:

Accelerator radiation safety: Basic principles of charged particle acceleration- Motion under electric and magnetic fields. DC and RF acceleration. Relativistic kinematics, Types of accelerators, Advanced accelerators, Synchrotron radiation sources, Spallation Neutron Source, ADSS, high power accelerators for radiation processing, Accelerator facilities in India

Radiation environment in electron accelerators, Radiation environment in proton/Heavy ion accelerators, Beam loss scenario, Radiation source term, Radiation shielding, Prompt and residual (induced) radiation, Radioactivity in structural components, air, cooling water and soil, Noxious gas production, Non-ionising radiation (RF & MW)

Radiation Safety systems, Radiation monitoring systems (area & personnel), Safety Interlocks, Special radiation safety problems - Skyshine, Scattered dose evaluation, steaming through ducts/penetration/door overlaps, Radiation Emergency scenarios, Radiation accidents in accelerator facilities, Gamma and neutron spectroscopy, unfolding techniques, Monte Carlo techniques in accelerator radiation protection

Regulatory aspects & procedures

Laser radiation safety: Basic concepts-Spontaneous and induced transitions, conditions for light amplification and oscillations, characteristics of laser light. Laser Classification, Biological Effects, Laser Hazard evaluation, Laser hazard Control Measures, Engineering control measures, Personal protective equipment, Administrative controls

Course Outcomes:

- This course provides basics of Accelerator operations, operational accelerators in India and the possible accelerator radiation environments.
- Possible beam loss scenarios and its impact for different accelerators like proton, electron and heavy-ion accelerators.
- Prompt, residual radiations sources, noxious gas production and induced activation of the structural materials
- Radiation monitoring, safety systems and the radiation shielding for the accelerators
- Regulatory aspects and procedures; Radiation emergency scenario and the accidents in the accelerator facilities will also be covered under the course.
- In addition, the basics of laser concepts, classifications, the related hazard evaluation and control measures will also be taught in the course.

References:

1. Patterson, H. Wade, ed. Accelerator health physics. Elsevier, 2012.
2. d'Errico F. NCRP, Report no. 144—Radiation protection for particle accelerator facilities National Council on Radiation Protection and Measurements

3. Cossairt, J. D., & Quinn, M. (2019). Accelerator Radiation Physics for Personnel and Environmental Protection. CRC Press
4. Board, Atomic Energy Regulatory. "Safety Guidelines on Accelerators." No. AERB/SG/IS-5, Mumbai, India (2005).
5. Sliney, D. H., & Trokel, S. L. (2012). Medical Lasers and Their Safe Use. Springer-Verlag.

RE 605: Emergency Preparedness (15 Lecture Hrs)

Coordinators: Shri Bathula Sreekanth

(bathulas@barc.gov.in)

Course Details:

Brief Introduction to emergencies arising due to natural and man-made disasters
Radiation Emergency, Goals of Emergency Preparedness and Response, Hazard Categories, Radiological Impact Prediction and Assessment, Protection during Emergency and Existing Exposure Situations, Exposure Limits ,Philosophy of Implementing Protective Measures, Emergency Planning Zones, Generic Criterion for Intervention (GAL,GIL,OIL), Declaration and Termination of Emergency, INES.

Radioactive inventory and potential for release for NPP, Fission products, build-up of heavy elements, activation products of structural materials, aerosol behavior within the containment, classification of postulated NPP accidents, exposure modes and their significance
Principles of emergency planning for nuclear power plants
Classification of emergencies, Roles and Responsibilities (Local, State, National International), Exposure Limits of workers and public, Contribution to external and internal exposures in early, intermediate and late phase, countermeasures – sheltering, radio-protective prophyll axis, respiratory protection, body protection, personnel decontamination, evacuation, Emergency conditions in units other than NPPs

Emergency preparedness and Response
Authorities, Organization and Staffing, Coordination, Plans and Procedures, Logistical Support and Facilities, Training, Drills and Exercises, Quality Management Programme Emergency agencies and their composition, Identification, Declaration, Notification and Termination of Emergency, Providing Instructions, Warnings and Relevant Information to the Public, Managing the Medical Response , Communication, Managing Radioactive Waste, Mitigating Non-Radiological Consequences, Requesting, Providing and Receiving International Assistance , Analysing the Emergency and the Emergency Response, Equipment for handling emergencies, emergency control centre, assembly area, environmental monitoring during an emergency, duties and responsibilities of emergency groups, protective action, rehabilitation, decontamination of affected area, termination of emergency, evaluation of response and updation of action plan, lessons learnt from major nuclear accidents.
Dose assessment
Radiation doses from atmospheric releases under accident conditions, exposure from ground deposited activity, dose calculation from ingestion of contaminated food and water,
Physical Protection System, Safety and Security of Radioactive Sources, Nuclear Security Threats and techniques for security.

Course Outcomes:

- Risk Categorization: Understand the distinction between natural and man-made disasters and how to categorize radiological hazards based on their potential impact.

- Intervention Logic: Apply the philosophy of protective measures using Emergency Planning Zones and technical criteria like GAL, GIL, and OIL.
- Source Term Analysis: Evaluate the radioactive inventory of a Nuclear Power Plant (NPP), including fission products and aerosol behavior during a release.
- Accident Classification: Classify postulated nuclear accidents and determine the significance of various exposure modes for the public and environment.
- Protective Action Execution: Implement life-saving countermeasures, including sheltering, evacuation, and radio-protective prophylaxis.
- Jurisdictional Coordination: Differentiate the roles and responsibilities of local, national, and international agencies during a crisis.
- Dose Assessment: Quantify radiation doses resulting from atmospheric plumes, ground deposition, and contaminated food or water.
- Recovery Management: Oversee area decontamination, environmental monitoring, and the formal termination of an emergency state.
- Security Integration: Implement physical protection systems and techniques to mitigate modern nuclear security threats.

References:

1. Criteria for planning, preparedness and response for nuclear Or radiological emergency: aerb/nrf/sg/ep-5 (rev. 1)
2. Arrangements for Preparedness for a Nuclear or Radiological Emergency, IAEA Safety Guide,GSG 2.1
3. Preparedness and Response for a Nuclear or Radiological Emergency,IAEA, GSR Part 7.
4. STATE-OF-THE-ART REPORT ON NUCLEAR AEROSOLS, NEA/CSNI/R(2009)5

RE 606: Environmental Modelling (45 Lecture Hrs)

Coordinators: Dr. (Kum.) Roopashree Shrivastava (roopa@barc.gov.in)

Course Details:

Meteorology

The hydrostatic equation, Dry and moist adiabatic lapse rates Nature of solar radiation Thermal boundary layer, Temperature in the lower atmosphere Winds, Wind profile in the surface layer, Mean wind speed Atmospheric stability, Pasquill stability classes, Meteorological analysis, Meteorological instruments, General circulation of the atmosphere.

Atmospheric Dispersion Modelling

Atmospheric dispersion-Advection-Diffusion Equation (ADE), Analytical solution of ADE, Numerical Solution of ADE, Gaussian puff model, Gaussian plume model, particle trajectory model, Removal processes in atmospheric dispersion models-radioactive decay, dry-deposition, wet-deposition Radiological dose assessment using atmospheric dispersion models, plume gamma dose. Submersion and inhalation dose Introduction to meteorological modeling.

Aquatic Dispersion Modelling

Types of aquatic environment–surface water such as rivers, estuaries, lakes, coastal sea, deep sea; and ground water. Fate of contaminants in the aquatic environment-Advection, Diffusion, Dispersion, Chemical and biological processes, Removal processes, Comparative importance of processes: Reynold's number, Peclet number, Damkholer number etc., Dilution factors.,
The subsurface environment- Unsaturated zone, Saturated zone, Aquifers: unconfined, leaky and confined, Water table; Confining beds, Types of rocks
Differential equations for groundwater flow field simulation, Differential equations of solute transport in groundwater, modeling in-situ progeny production during transport of long-lived radionuclides involving decay chains and its importance in radiological impact assessment, Concept of distribution coefficient and its importance with reference to solute transport in groundwater, Analytical solutions for solute transport equations in groundwater Numerical solutions for solute transport equations in groundwater Geophysical methods for subsurface characterization: Electrical resistivity imaging, Seismic refraction, Field and laboratory based estimation of groundwater flow parameters such as hydraulic conductivity, velocity, recharge, infiltration rate etc.: constant and falling head permeameter, pumping tests, slug tests, tracer tests, double ring infiltrometer. Field and laboratory-based estimation of dispersion parameters

Environmental Fluid Mechanics
Properties of Fluid
Compressibility, Viscosity, Surface tension Static equilibrium of fluid

Pressure variation, Measurement of pressure Equation of continuity, Bernoulli equation.

Pipe and channel flow
Laminar flow theory, Reynold number
Relation between flow rate and pressure gradient Flow in cannel and rivers
Equations of motion
Momentum equation Laminar and turbulent flow
Eddy viscosity, mixing length, boundary layer, thickness of boundary layer Navier Stokes equations.
Differential Equations of Heat Transfer
Conduction, convection and radiation heat transfer Classification of convecting heat transfer
Energy equation in heat transfer.
Differential Equations of Mass Transfer
The differential equation for mass transfer
Special forms of the differential mass-transfer equations
Simultaneous momentum, heat and mass transfer, Scaler transport equation. Darcy's Law and Continuity Relations
Darcy's law, Continuity relations for flow in porous media Steady and unsteady flow of air through porous media
Flow Equations for Unsaturated Zone, Flow Equations for Saturated Zone. Multi-phase Flow
Two phase flow, Suspended sediment transport in water
Settling of suspended matter, Interaction of suspended sediment and bottom sediment Migration of pollutants in soil.

Course Outcomes:
Basic understanding of

- Environmental systems such as air, surface water and groundwater
- Environmental fluid mechanics
- Meteorological and hydrogeological measurement techniques
- Concept building and application of mathematical techniques to model the fate of pollutants released in these environmental matrices

References:

1. Wang, H. F., Anderson, M. P. (1982). Introduction to Groundwater Modeling, Oxford, San Francisco.
2. Rastogi, A. K. (2007). Numerical groundwater hydrology, Penram International Publishing (India) Pvt. Ltd.
3. Charbeneau, Randall J. (2006). Groundwater Hydraulics and Pollutant Transport, Waveland Pr Inc.
4. Jacob Bear, Milovan S. Beljin, and Randall R. Ross (1992). Groundwater issue Fundamentals of Groundwater Modeling, EPA.
5. Kresic, N. (2007). Hydrogeology and Groundwater Modeling, Taylor & Francis, CRC Press, USA.
6. Todd, D. K. (2006). Groundwater Hydrology, Wiley.

7. Chapra, S. C. (1996). Surface Water Quality Modeling, McGraw-Hill Education, USA.
8. Burger, H. R., Sheehan, A. F., Jones, C. H. (2006). Applied Geophysics, W. W. Norton & Company, Inc., USA.
9. Holzbecher, E. (2007). Environmental Modeling using MATLAB, Springer, Berlin.
10. Streeter, V. L., Wylie, E. B., Bedford, K. W. (1998). Fluid Mechanics, McGraw-Hill Book Co., USA.
11. Stull R. B. (1988). An Introduction to Boundary Layer Meteorology, Kluwer Academic Publishers, London.
12. Jacobson M. J. (2005). Fundamentals of Atmospheric Modeling, Cambridge University Press, New York.
13. Seinfeld J. H. and Pandis S. N. (2016). Atmospheric Chemistry and Physics From Air Pollution to Climate Change, Wiley, New Jersey.

RE 607: Radiological Safety Analysis (15 Lecture Hrs)

Coordinators: Dr. S. Anand
(sanand@barc.gov.in)

Course Details:

Objective of Safety Analysis
Hazard identification, categorization and analysis. Risk analysis and risk management. Risk criteria.
Operational and Accident Safety
Safety during normal operation Anticipated operational occurrences
Classification of Accidents
Design basis accidents Beyond DBA, Severe accidents- LOCAs Reactivity induced accidents, Historical accidents in nuclear facilities.
Nuclear Reactor Safety
Inherent and engineered safety features of LWRs, PHWRs, GCRs, FBRs, Advanced reactors.
Elements of safety analysis
Selection of initiating events, categorization of initiating events Analysis assumptions, acceptance criteria, Consequence analysis, Computer methods for safety analysis.
General Radiological Safety Evaluation
Source characterization Inventory of radioactive sources, Source term, Public dose calculation Basic Safety design principles, On-site and off-site dose computations Regulatory requirements.
Deterministic and Probabilistic Safety Analysis
Deterministic safety calculations, Defence in depth
Elements of PSA
Applications of PSA-Introduction to PSA Level-I and Level-II Different modules of PSA level-III
Source term, atmospheric dispersion, Dosimetry, counter-measures, health effects and economic consequences Sensitivity and uncertainty analysis.
Criticality Safety Assessment
Hand Calculation Methods-surface density, solid angle and buckling/shape conversion. Monte Carlo methods. Sub-critical limits Criticality accidents.

Course Outcomes:

- The course aims to develop a comprehensive understanding of the methodologies and principles governing nuclear safety analysis.
- The curriculum builds the ability to identify, categorize, and analyze hazards, thereby enabling students to conduct both qualitative and quantitative risk assessments against established risk criteria.
- The course emphasizes on operational safety during normal and anticipated operational occurrences, while progressively introducing students to the full spectrum of accident regimes—from design basis events to severe, beyond-design-basis accidents. The course establishes a robust technical foundation in fundamental safety concepts such as defence-in-depth, redundancy, and diversity, which are essential for the design and evaluation of

nuclear systems.

- The course focuses on introduction to radiological safety evaluation, wherein students gain proficiency in source term characterization, radioactive inventory estimation and the computation of on-site and off-site public doses.
- The students are introduced to criticality safety, employing both traditional hand calculation methods and Monte Carlo techniques to verify sub-critical limits and understand the underlying mechanisms of criticality accidents.

References:

1. Martin J. E. (2006). Physics for Radiation Protection, Wiley, Heppenheim.
2. Knief R. A. (1985). Nuclear Criticality Safety: Theory and Practice, American Nuclear Society, Illinois.

RE 608: Industrial Hygiene and Safety (15 Lecture Hrs)

Coordinators: Smt. Garima Singh
(garima@barc.gov.in)

Course Details:

Principles of Industrial Hygiene
Definition - Anticipation and Recognition of Workplace Hazards, Environmental stresses; Chemical Agents, Physical Agents, Biological Agents, Ergonomic Factors, Evaluation of hazards, Occupational exposure limits; Control measures, Various physical and chemical agents in use in DAE, Case Studies, Notifiable diseases, Dangerous manufacturing processes/operations

Physical agents: Hazards and Control
Introduction - Electromagnetic Radiation, Non-Ionizing Radiation – UV and IR radiation, microwaves-sources, Health Hazards and Control Measures, Lasers: Hazards and Control Measures, Noise: Effects, Measurement and Control, Octave band analysis; Hearing conservation programme – Noise mapping – Audiometry, Vibration: hazards and control, Illumination: safety aspects, measurement, Extremes of temperature: Health Hazards, Heat Balance, Heat Stress Index, cold Stress, Control Measures, Threshold Limit Values for Physical Agents

Chemical agents: Hazards and Control
Introduction - Classification of Materials, MSDS information, Fire and Explosion Hazards Flammable Chemicals, Explosive Chemicals, Gases Under Pressure, Oxidising Agents, Water sensitive Chemicals, Health Hazards, Airborne Chemical Contaminants-routes of entry, types of exposures, Harmful Effects of Toxic Substances-Pneumoconiosis Dust Deposition in Respiratory System, Irritants, Simple Asphyxiants, Chemical Asphyxiants, Anaesthetics and Narcotics, Systemic Poisons, Cancer Causing Chemicals, Cryogenics: hazards, safe handling
Permissible Limits of Exposure: Factories Act, Threshold Limit Value, IDLH, LC50, LD50 Evaluation: Instrumental Methods, Air Sampling Methods, Control Measures: Engineering Control, Personal Control, Medical Control, Measuring instruments – Industrial hygiene surveys, General Safety Provisions -Layout, Access, Lighting, Ventilation, Safe Storage of Chemicals, Categories and Shelf pattern, housekeeping, Safe Handling of Chemicals, Safety with Glassware, Gas Cylinders, Autoclaves, Overnight Operations, Fire Safety, Personal Protective Equipment, Laboratory Waste Disposal, NFPA Symbol, Emergency Action Code for Transportation, TREM Card

Principles of Industrial Safety
Need for Safety, Terminology: Accident, Work Injury, Disabling Injury, Reportable Disabling Injury, Economic impact of accidents : costs of accidents, Injury causation model , Causes of Accidents - Immediate Causes, Unsafe Acts, Unsafe Conditions - Contributing Causes - Root Cause Analysis, Evaluation of safety performance, Computation of Accidents: FR, SR, Incidence Rate, Injury Index, IOD Form, Role of Safety Coordinators, Accident Prevention and Control Measures, Job Hazard Analysis, Safety inspections, Safety audit

Safety in the use of machines and hand tools
Statutory requirements, Common causes of machine accidents, Dangerous parts on machines
 Prevention methods – Principles of machinery guarding, various types of guards, advantages and disadvantages, design factors, work dress, use of personal protective equipment, safety in the use and storage of hand tools

Safe Operating Procedures
Permit To Work System, Locking and Tagging System, Safety Precautions regarding High Voltage Equipment, Monitoring of Healthiness of Electrical Installations and Equipment, Control of Hazards due to Static Electricity, General safety requirements under Indian Electricity Act and Indian Electricity Rules

Safety aspects in material handling and storage
Salient features of handling, Types of material handling, Equipment used for Material Handling

Manual Handling
Health Effects and Causation Factors, General Safety Practices, Proper Method of Lifting, Lifting of Specific Types of Articles, Accessories for Manual Handling

Mechanical Handling
Hazards, Mechanical Handling Equipment: Cranes, Hoists and Lifts, Lifting Tackles, Power Trucks and Lifting Machines, Safe Use and Maintenance - Competent Persons, Inspection and Testing, Handling of Dangerous Substances, Material Storage, Classification of Materials , Safety Requirement ,Storage of Specific Materials

Personal Protective Equipment -2 hrs
Need, Classification of Non-Respiratory Protective Equipment: Head Protection, Eye and Face Protection, Ear Protection, Arm and Hand Protection, Leg and Foot Protection ,Protective Clothing, Safety Belts, Respiratory Protective Equipment, Classification of Hazards, Classification of Respiratory Protective Equipment, Selection of Respiratory Protective Equipment, Protection Factors - Safety in the Use of Respirators, Testing and quality assurance, Training in Use, Care and Maintenance

Course outcome:

- Understanding of industrial hygiene. Ability to identify potential physical and chemical hazards in work environment and apply preventive measures.
- Basic understanding of the industrial safety
- Understanding of accident prevention - causes of accidents, safe handling of materials, and implementing safety management systems, including safety training, use of Personal Protective Equipment (PPE).
- Prepares students to contribute to a culture of safety with introduction to Key Safety regulations

References:

1. Introduction to Health and Safety at Work; 3rd Edition, Hughes, P. & Ferrett, E.(2007). Butterworth-Heinemann; Oxford.
2. Industrial Hygiene Simplified: A Guide to Anticipation, Recognition, Evaluation, and Control

of Workplace Hazards, Spellman, F. R. (2006). Government Institutes; Lanham, MD.
3. Guidelines for Hazard Evaluation Procedures, Third Ed., Center for Chemical Process Safety, ISBN: 978-0-471-97815-2, 2008.
4. IS 15656: Hazard Identification and Risk. Analysis- Indian Standard/Code of Practice/IS 15656:2006. ICS 13.100.

RE 609: Research Methodology & Publication Ethics

Course Details:

Research Methodology
Objectives and types of research: Motivation and objectives - Research methods vs. Methodology. Types of research – Descriptive vs. Analytical; Applied vs. Fundamental; Quantitative vs. Qualitative; Conceptual vs. Empirical.
Research Formulation – Defining and formulating the research problem - Selecting the problem - Necessity of defining the problem - Importance of literature review in defining a problem - Literature review – Primary and secondary sources - reviews, treatise, monographs-patents - web as a source - searching the web - Critical literature review - Identifying gap areas from literature review - Development of working hypothesis.
Research design and methods - Research design – Basic Principles - Need of research design - Features of good design – Important concepts relating to research design - Observation and Facts, Laws and Theories, Prediction and explanation, Induction, Deduction, Development of Models. Developing a research plan - Exploration, Description, Diagnosis. Experimentation: Proper approach - Importance of recording observation, maintaining the records, sample history, transparency in data recording. Determining experimental and sample designs.

Data Analysis: Data Preparation – Univariate analysis (frequency tables, bar charts, pie charts, percentages), Bivariate analysis – Cross tabulations and Chi-square test including testing hypothesis of association.

Value of Statistics; Errors and Statistics - Limitation of analytical methods; Accuracy; Precision; Classification of errors; Minimisation of errors; Significant figures and computations; Standard Deviation; Normal Distribution; Comparison of results - students's t test; F-test; Chi Square test; propagation of errors.

Research Publication and Ethics
Application of results and ethics - Environmental impacts - Ethical issues - ethical committees - Commercialisation - Copy right - Royalty - Intellectual property rights and patent law – Trade Related aspects of Intellectual Property Rights - Reproduction of published material - Plagiarism - Citation and acknowledgement - Reproducibility and accountability.
Reporting and thesis writing – Structure and components of scientific reports - Types of report - Technical reports and thesis - Significance - Different steps in the preparation – Layout, structure and Language of typical reports - Illustrations and tables - Bibliography, referencing and footnotes - Oral presentation - Planning - Preparation - Practice - Making presentation - Use of visual aids - Importance of effective communication -Computers in Chemistry, Usage of packages such as, Excel, AIM2000, ChemCraft, etc. Manuscript drafting based on 'Experimental data and Literature Survey'.

Course outcome:
A mandatory course for all Ph.D. students for pre-registration as per directive of University

Grants Commission in its 543rd meeting held on August 9, 2019. The course encompasses motivation and objectives of research; Research methods vs. Methodology; Types of research: Descriptive vs. Analytical, Applied vs. Fundamental, Quantitative vs. Qualitative, Conceptual vs. Empirical; Stages of research; Research philosophy; Theory development; Research process etc,.

References:

1. Garg, B.L., Karadia, R., Agarwal, F. and Agarwal, U.K., 2002. An introduction to Research Methodology, RBSA Publishers.
2. Kothari, C.R., 2000, Research Methodology: Methods and Techniques. New Age International.
3. Sinha, S.C. and Dhiman, A.K., 2002. Research Methodology, Ess Publications (2 volumes)
4. R. Paneer Selvam - Research Methodology Prentice Hall India Learning Private Limited; Second edition (2013)
5. Anthony, M., Graziano, A.M. and Raulin, M.L., 2009. Research Methods: A Process of Inquiry, Allyn and Bacon.
6. Day, R.A., 1992.How to Write and Publish a Scientific Paper, Cambridge University Press.
7. Whitesides, G. M., Whitesides' Group: Writing a Paper, Adv. Mater. 16 (2004) 1375.
8. Vogel's Text Book of Quantitative Inorganic Analysis, ELBS.

ELECTIVE COURSES

RE 701: Nuclear and Analytical Techniques (30 Lecture Hrs)

Coordinators: Dr. Aditi C. Patra
(aditic@barc.gov.in)

Course Details:

X-rays, production of X-rays K-capture, Interaction of x-rays with matter X-ray
Fluorescence, Auger effect, Auger electron spectroscopy Absorption edge, Characteristic binding energies Variation of X-ray absorption with wavelength
Energy Dispersive XRF, Wavelength Dispersive XRF, XRD, PIXE Sensitivity, detection limit

Atomic Spectroscopy
Basic principles of atomic spectroscopy
Effect of temperature on atomic distribution, Boltzmann distribution Atomization sources,
Absorption and emission spectra
Flame atomic absorption, Graphite furnace AAS, hydride generation AAS, Background correction, Zeeman effect
Inductively coupled plasma emission spectroscopy

Chromatographic Techniques
Basic principles of chromatography, optimization of chromatographic parameters,
Gas chromatography, Liquid chromatography, Ion chromatography, Hyphenated techniques.

Mass Spectrometry, Isotope Ratio Mass Spectrometry
Basic principle, Ionization techniques, Fragmentation. Mass detectors-magnetic sector, ion trap, quadrupole, time of flight, Resolution, Mass spectra, Atomic and molecular MS, Applications.

Activation Analysis
Types of Activation Processes, Neutron activation analysis, Charged particle activation analysis, Prompt gamma activation analysis, Instrumental neutron activation analysis, Interferences in Activation Analysis, Interference reactions. Gamma spectrometry: -Ray spectrum,-ray spectral interferences Sensitivity, detection limit Advantages and disadvantages

Radiochemical Analysis
Radiochemical Separation techniques, Ion exchange, Solvent extraction, Tracer and carriers Chemical yield, Radiochemical neutron activation analysis, Isotope dilution techniques.

Electro Analytical Techniques
Basic principles of electrochemistry Redox reaction, Nernst equation Half wave potential
Polarography, Voltammetry Stripping voltammetry Applications.

Ray Fluorescence
ESCA, Metrology: Calibration of method, accuracy and precision of results, selectivity, sensitivity, detection limit, limit of determination, specificity, linearity, analytical error, accreditation systems, QA/QC parameters in environmental studies, use of CRMs (Certified reference materials), inter-laboratory comparison exercise,

participation in National and International round Robin tests. Representativeness of sampling site, proper storage of samples with suitable preservative, selection of appropriate analytical technique, sample blank, efficiency of methodology, determination of uncertainty in process, etc.

Course outcome:

- Basic understanding of Nuclear Analytical Techniques and operating principles.
- Basis of selection of a NAT, advantages and disadvantages, complementary techniques
- Sampling strategy, sample collection and storage
- Metrology in NAT, uncertainty and QAQC in environmental studies

References:

1. Principles of Instrumental Analysis. Douglas A. Skoog | F. James Holler | Stanley R. Crouch. ISBN: 9789353506193.
2. Nuclear Techniques in Analytical Chemistry. International Series of Monographs on Analytical Chemistry. A. J. Moses. Pergamon Press. eBook ISBN: 9781483157047.
3. Concepts, Instrumentation and Techniques in Atomic Absorption Spectrophotometry. Richard D. Beaty and Jack D. Kerber.
4. Radiation Detection and Measurement. Glenn F. Knoll. ISBN: 9789354644238.
5. Gamma- and X-Ray Spectrometry with Semiconductor Detectors. K. Debertin and R. G. Helmer. ISBN-10 : 0444871071.

RE 702: Application of Radioisotopes And Radiation Technology (30 Lecture Hrs)

Coordinators: Dr. K. Tirumalesh (tirumal@barc.gov.in)

Course details:

A. Radiotracer Applications in Industry

Concept of radiotracer, selection of radiotracer, estimation of amount of radiotracer, preparation of radiotracer, methods of injection of radiotracer, detection and measurement of radiation, data treatment, radiological safety considerations. Basic concept of RTD, calculation of moments, RTD analysis procedure, ideal and non-ideal reactors, flow abnormalities, modelling, case study, mixing time measurements. Flow measurement using radiotracer (background, pulse velocity method, dilution method, case study), general concept of leak detection, leak detection in processing plants and heat exchangers (leak detection by flow rate measurement, leak detection by residence time distribution (RTD) measurement, leak detection by direct tracer technique), leak detection in underground pipelines (detection from the surface, radiotracer - pig detection method), case study. Principle of sediment transport study, transport parameters, case study, effluent dispersion studies. Methodology of radiotracer applications in oil field, principle of TLA, ion beam irradiation, case study

B. Isotope Hydrology

Introduction of environmental isotopes and basic principles of isotope techniques, stable isotopes: ^{18}O, ^{2}H and ^{13}C measurements, tritium and carbon-14 measurements. Applications in groundwater recharge studies, applications in surface water- groundwater or aquifer-aquifer interaction, applications in groundwater contamination studies, applications in submarine groundwater discharge studies, applications of radiotracer techniques in hydrology

C. Sealed Source Applications

Types of sealed radioisotope sources, machine based radiation sources, radiation detectors and nucleonic instrumentation, measurement techniques, gamma ray absorption techniques, thickness measurement, density measurement, level measurement, voidage measurement, gamma radiometry, case studies. Principle of Industrial Radiography (IR) using Gamma rays and X-rays, source projectors, x-ray equipment, image recording media, principle of radiographic exposures, spatial and contrast sensitivity, exposure charts, defects and class of defects, interpretation of radiographs, introduction to codes and standards. Introduction to electronic radiation-based imaging, film scanning and conversion to digital data, detectors and nucleonic instrumentation, digital industrial radiography (DIR), computed radiography (CR), basic principles of CR and dir, spatial resolution and contrast sensitivity, signal to noise ratio, radiographic parameters, codes and standards. Principles of computation imaging and tomography, computed tomography methods for non-destructive evaluation of industrial specimen, sealed radioisotope source based gamma tomography, 2D fine-resolution detector arrays for planar and volumetric tomography, data pre-processing and image reconstruction techniques, image analysis and interpretation, codes and standards, case studies

D. Radiation Technology

Radiation processing plants (gamma irradiators and electron beam accelerators), depth dose profiles, G-value and dosimetry. Chemistry of polymerization; copolymerization kinetics and copolymer structures, chemical modification of polymers; crosslinking, degradation, grafting, imprinted polymers and functionalization. Basic radiation chemistry and physics of polymers; time scale of energy deposition, interaction of radiation with monomers and polymers, energy transfer and radiolysis, overall effect of radiation on properties of polymers and factors that can affect the overall radiochemical yield of a process, theory of swelling in cross-linked polymers, charlesby-pinner and cross-linking density analysis of irradiated polymers. polymer structure and cross-linking density correlations, mechanical, thermal and spectroscopic evaluation of radiation processed polymers, role of EPR and NMR in quantifying radical yield and radiolytic transformations, radiation grafting, types of radiation grafting, kinetics and characterization of grafting yield. Sterility assurance level (SAL), effects of sterilization, radiation chemistry of flue-gas treatment and sludge hygienization

E. Radiopharmaceuticals

Nuclear medicine and its importance in human healthcare, radiopharmaceuticals, general structure of a radiopharmaceutical, classification of radiopharmaceuticals, carrier moieties for radiopharmaceuticals, characteristics of diagnostic and therapeutic radiopharmaceuticals, methods of radio labelling. Concept of tomography, SPECT and PET, hybrid imaging, Basis of designing radiopharmaceuticals, quality control of radiopharmaceuticals- physicochemical and biological quality control tests, concept of thernostics and personalized medicine. Some important organ-specific diagnostic (SPECT & PET) radiopharmaceuticals (myocardial imaging, brain imaging, renal imaging, tumor and inflammation imaging, receptor-specific imaging etc.), Radioimmunoscintigraphy (RIS).Concepts of brachytherapy, teletherapy and radionuclide therapy, therapeutic radiopharmaceuticals for some specific applications (metastatic bone pain palliation (MBPP), radiation synovectomy (rsv), peptide receptor radionuclide therapy (PRRT), radioimmunotherapy (RIT))

F. Radioisotopes Applications in Food and Agriculture (4 Lectures)

History of plant breeding, objectives of plant breeding, characteristics improved by plant breeding, breeding methods. Nature and classification of mutations (spontaneous and induced mutations, micro and macro mutations), mutagenic agents, observing mutagen effects in m1 generation (plant injury, lethality, sterility, chimeras), observing mutagen effects in M2 generation (estimation of mutagenic efficiency and effectiveness, spectrum of chlorophyll and viable mutations), mutations in traits with continuous variation. mutation breeding in cereals, pulses and oilseeds. Cultivar development- testing, release and notification, maintenance breeding, classes of seed, participatory plant breeding, plant breeder's rights and regulations for plant variety protection and farmers rights, achievements made at BARC. Food irradiation (Basic principles and Radiation sources), applications of food irradiation, benefits and limitations, wholesomeness of irradiated foods, regulatory approvals and current national and international status.

Course outcome:

- This course will help to understand the fundamental concepts of radioisotopes, radiotracers

and their multidisciplinary applications in industry, healthcare and agriculture.

- Acquire knowledge on sealed source applications for non-destructive testing and measurements in various industries.
- Additionaly, radioisotope applications in healthcare and unique applications of radioisotope for food preservation and agricultural improvement including mutation breeding.

References:

1. IAEA. (2004). Radiotracer Applications in Industry — A Guidebook (Training Course Series No. 38). Vienna.
2. IAEA. (2015). Radiation Technology for Food Preservation. Vienna.
3. Pant, H. J. (2022). Applications of the radiotracers in the industry: A review. Applied Radiation and Isotopes, 182, 110076.
4. ICRU. (2002). Nucleonic Gauging and Industrial Applications. ICRU Reports.3. Sanwick, A. M., & Chaple, I. F. (2025). Radiocobalt theranostic applications: current landscape, challenges, and future directions. Frontiers in Nuclear Medicine, 5.
5. Xu, S., Liu, G., Wei, Q., Liu, H., Wu, J., Liu, Y., & He, Z-X. (2025). Recent advances in radionuclide medical imaging techniques. Frontiers in Medicine, 12, 1662020.
9. Cherry, S. R., Sorenson, J. A., & Phelps, M. E. (2012). Physics in Nuclear Medicine (4th ed.). Elsevier Saunders.
6. DeVol, T. A., & Wernick, M. N. (2004). Emission Tomography: Fundamentals of PET and SPECT. Academic Press.
7. 16. Farkas, J. (1985). Food Irradiation. Elsevier Science Publishers.
8. Prajapati, H., Agrawal, A., & Gupta, A. K. (2020). A review on importance of radioisotopes & radiotracer techniques in agriculture. Research & Reviews: Journal of Agricultural Science and Technology, 9(1), 1-9.
9. Charlesby, A. (1960). Atomic Radiation and Polymers. International Series of Monographs on Radiation Effects in Materials, Vol. 1. Pergamon Press, Oxford. ISBN: 9781483197760
10. Ivanov, V.S. (1992). Radiation Chemistry of Polymers. New Concepts in Polymer Science. VSP, Utrecht. ISBN: 9789067641371
11. Makuuchi, K., and Cheng, S. (2011). Radiation Processing of Polymer Materials and Its Industrial Applications. Wiley. ISBN: 9780470587690
12. Clough, R.L., and Shalaby, S.W. (Eds.). (1991). Radiation Effects on Polymers. American Chemical Society, Washington, DC. ISBN: 9780841221659
13. Clark, I.D., Fritz, P. (1997). Environmental Isotopes in Hydrogeology. Lewis Publishers, New York.
14. Herczeg, A., Edmunds, W. M. (2000). Inorganic ions as tracers. In: Cook P, Herczeg A (Eds.), Environmental Tracers in Subsurface Hydrology. Kluwer Academic Publishers, Boston, 31–77.
15. IAEA (1983). Guidebook on nuclear techniques in hydrology, Technical reports series no.91, Vienna, 1983, p.223.
16. W. G. Mook, "Environmental Isotopes in the Hydrological Cycle," Principles and Applications, IHP-V, Technical Documents in Hydrology 1, Vol.1-6.

RE 703: Radioactive Waste Management (30 Lecture Hrs)

Coordinators: Shri K. C. Pancholi
(keyur@barc.gov.in)

Course Details:

Radioactive Waste Generation
Classification, segregation and management of radioactive liquid waste Treatment &management of low level liquid waste (LLW) Management of organic liquid waste Decontamination &recycling of radioactive materials Philosophy & discharges of radioactive liquid waste Regulatory aspects in radioactive waste management Sources & management of gaseous waste. Management of airborne iodine waste & emergency air cleaning in nuclear plants Minimization of radioactive solid waste
Management of radiation sources: Treatment & management of LW, recovery of valuables from radioactive waste Treatment &management of High-Level Liquid Waste (HLW)
Remote handling aspects/ Maintenance/Upgradation of verification plants. Near Surface Disposal Facility(NSDF), Selection criteria, Safety & surveillance aspects of NSDF

Course outcome:

The course will enlighten radioactive waste management aspects in the nuclear fuel cycle. It is important and inevitable to safely segregate and manage the radioactive waste from the generation. The course will help to understand various aspects of radioactive waste generation, minimization, segregation and general aspects of disposal and plan safe management of radioactive waste.

References:

1. Benedict M., Pigford T.H. and Lewi H. Nuclear Chemical Engineering, McGraw Hill. 2nd ed. (1981)
2. Uranium Extraction Technology, Tech. Rep. Series, IAEA, Vienna 1993
3. Laser Isotope Separation, Ed. J.A Paisner, SPIE vol.1895 (1993)
4. International Atomic Energy Agency, Radioactive Waste Management: An IAEA Source Book, IAEA, Vienna (1992)

RE 704: Medical Physics (30 Lecture Hrs)

Coordinators: Dr. S. D. Sharma
(sdsharma@barc.gov.in)

Course Details:

Classification of radiation effects

Somatic, genetic, deterministic, stochastic, late effects and early effects.

Deterministic effects

Acute radiation injury-radiation sickness, different phases and types of acute radiation syndrome, Haematopoetic syndrome, blood picture changes, gastrointestinal syndrome, CNS syndrome, interaction of different systems in the induction of lethality, LD_{50} (60).

Physics of Radiation Therapy

Basis of radiotherapy, Radiotherapy equipment (telecobalt, medical accelerators, radiotherapy simulator) and accessories, Beam dosimetry protocols (IAEA TRS 398, AAPM TG 51), Quantities and concepts used for high energy photon and electron beam dosimetry (PDD, TMR, PSF, OAR, ROF). Dosimetry formalisms for bracgy therapy sources (Sievert Integral, AAPM TG 43), Advanced radiotherapy techniques (IMRT/IGRT, VMAT, SRS/SRT), Concept of treatment planning, Rationale for 3-D treatment planning (Forward and inverse planning), Computers in treatment planning, QA methodologies for radiotherapy equipment.

Physics of Diagnostic X-rays

Physical principles of X-ray diagnosis, operating control selection criteria. Concept of modular transfer function and its application, Dark room, film processing conditions, image intensifiers, Television monitoring and reduction of patient dose, QA in diagnostic radiology. Other imaging modalities like CT and MRI.

Physics of Nuclear Medicine

Radioisotopes used in medical applications, physical characteristics, criteria for choice of radio isotopes for diagnostic and therapeutic procedures, Radionuclide generators with special reference to ^{99}Mo-^{99m}Tc-generator, Other types of generators, Medical cyclotron. Diagnostic nuclear medicine procedures, Radioisotopes used, In-vivo non-imaging and imaging procedures, Thyroid function test, Renogram, Therapeutic nuclear medicine procedures, Radioisotopes used and their characteristics. Safe disposal methods, Spatial reference to waste arising from generators, delay tank in isolation ward and medical cyclotron facilities. In-vivo Imaging instruments: Rectilinear scanners, Gamma camera, SPECT and PET imaging devices. Collimators - Multi hole focusing collimator, Multi hole parallel collimator, Flat field collimator, Slit collimator, Characteristics of different collimator, Resolution and Sensitivity. Q.A. in nuclear medicine, Calibration of monitoring instruments, Radiation emergencies in nuclear medicine and preparedness.

Cell Biology, basic anatomy and physiology

Structure and functions of a living cell, cell division -mitosis, meiosis and differentiation, protein biosynthesis. Organization of the human body-cells, tissues, organs and systems, Important systems - hematopoietic, digestive, respiratory, nervous, endocrine, urinary,

reproductive, circulatory and skeletal, functioning of the human body-metabolism and its regulationbyendocrinesystem,transpiration,eliminationofwastes(lung,kidneyandskin),protectionagainst external agents (immune system), communication-nervous and skeletal systems, reproductive function of ovaries and testis, prenatal development.

Cellular Radiobiology

Mechanism of induction of damage-direct and indirect effects, cellular target for the action of radiation, molecular level damage-strand breaks, base damage, cross linking, chromosomal aberrations-its application in biodosimetry. Law of Bergonnie and Tribondeau, Target theory and its modifications, linear quadratic model, factors modifying cell survival- dose, dose rate, dose fractionation, LET-RBE, chemical protectors, sensitizers, Radiobiological basis of radiotherapy of cancer.

Prenatal (in utero) radiation effects, Damage to individual organs-bone marrow, skin, reproductive system, eye lens, lung, kidney and the endocrine system, Manifestation of late damage. Medical management of radiation injury.

Stochastic Effects of Radiation

Mechanism of induction of radiation carcinogenesis-somatic mutation theory, Carcinogenesis-Latent period, organ sensitivity, dependence on sex, age, genetic pre disposition, dose and dose rate effect(DDREF), radiation weighting factors, detriment and tissue weighting factors.

Hereditary Effects

Basic genetic sand mechanism of induction of heritable effects, types of inherited genetic disorders. Doubling dose, relative mutation risks, PRCF and MC factors human hereditary risk evaluation.

Course outcome:

- Knowledge of the technology and working principles of various beam therapy equipment such as Telecobalt machine, Medical electron linear accelerators (LINAC), and medical proton accelerator.
- Knowledge of the technology and use of brachytherapy equipment, sources and techniques as well as dosimetry and treatment planning in brachytherapy
- Knowledge in medical radiation dosimetry, quality assurance of various radiotherapy equipment and use of computers in radiation treatment planning including optimization and associated radiation safety.
- Knowledge of different radiotherapy techniques such as stereotactic radiosurgery/ stereotactic radiotherapy (SRS/SRT), stereotactic body radiotherapy (SBRT), intensity modulated radiotherapy (IMRT), image guided radiotherapy (IGRT), volumetric modulated radiotherapy (VMAT) and associated quality assurance.
- Understanding the process of X-ray based imaging using both conventional and advanced imaging systems such as digital X-ray imaging systems (radiography and mammography), dental imaging systems and computed tomography (CT) scanners
- Knowledge of working principles and use of open isotope-based imaging systems such as Gamma Camera, Single Photon Emission Computed Tomography (SPECT), Positron Emission Tomography (PET)
- Understanding of the technology and use of medical cyclotron and internal dosimetry techniques

References:

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RE 705: Radiological Safety In Front End And Back End Of Nuclear Fuel Cycle (30 Lecture Hrs)

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Course Details:

Uranium Mining and Milling Facilities
Nuclear fuels, prospecting for uranium deposits, physical and chemical properties of uranium Ore, world uranium resources, minerals of uranium, mining of uranium, control of radon in mines, ventilation of uranium mines, processing of uranium ores (acid and alkali leaching), insitu leaching chemistry of uranium, Radiological hazards in uranium mines or processing, Monitoring of hazards, personal monitoring, work place and environmental monitoring, internal and external exposures assessment, Radon Dosimetry, waste generation its treatment and management, tailings pond(design, operation and closure), chemistry of tailings, treatment of effluents, environmental impact assessment, regulatory aspect of uranium milling and processing.

Thorium Processing Facilities
World Thorium Resources, deposits of thorium, physical and chemical properties of Monazite, separation of thorium minerals from rare earth minerals, Processing of monazite, Chemistry of thorium, Radiological hazards in thorium processing, Monitoring of hazards, personal monitoring, work place and environmental monitoring, internal and external exposures, waste generation, its treatment and management, Evaluation of external and internal doses, role of thorium in nuclear fuel cycle.
Non-radiological hazard in mining and processing of uranium and thorium.

Fuel Fabrication Facilities
Purification of MDU, processing of naturally and low enriched uranium, fuel fabrication, Radiological hazards in nuclear fuel assembly, handling of Th-based nuclear fuels, treatment and management of wastes

Fuel Reprocessing Facility
Design requirement for transport of reactor fuel for reprocessing, Safe transport, receipt and storage of spent fuel, Design aspects of the spent fuel storage pond, Principles of reprocessing, Safety systems in a typical reprocessing plant and their design criteria, Process description and stage -wise hazards control measures, External and Internal exposure control, Area radiation monitoring systems & CRPC, Special work permits, Criticality safety and detection systems, Radiation protection programme of the RHC Unit of a reprocessing plant, environmental releases, technical specifications, Occupational and public dose control measures, Management of the wastes generated in a reprocessing plant.

Waste Management Facility
Radioactive waste generation, Responsibility of radioactive waste management, radiation protection goals, protection of human health and environment, radioactive waste releases from NPPs, Radiation Protection Policy for the disposal of radwaste,

Engineered barriers, Natural barriers, Derived limits based on critical pathways, Safety and environmental impact Assessment of waste disposal facilities, Effluent release criteria and environmental monitoring.

Course outcome:

The course will enable students to

- Identify and assess radiological hazards across front-end nuclear fuel cycle facilities including uranium and thorium mining, milling, and fuel fabrication, and implement appropriate monitoring, dosimetry, and exposure control measures.
- Describe radiological safety systems in spent fuel reprocessing facilities including criticality safety, area radiation monitoring, radiation hazard control measures at various stages of spent fuel reprocessing, radioactive waste management of back-end nuclear fuel cycle and occupational & public dose management strategies.
- Explain radiological safety aspects of designed engineered safety systems, and derived limits based on critical pathways, environmental impact assessment, and effluent release criteria for waste disposal facilities.

References:

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