

# Advanced Radiation Biology & Radiological Risk Course

For DEP/Bureau of Radiation Protection

## Scope

Department of Environmental Protection, Bureau of Radiation Protection requires a provider to conduct an *Advanced Radiation Biology and Radiological Risk* class. This 5-day advanced course covers both low-level and high-level radiation effects on the human body. The latest theories and risk-assessment models of the biological effects of ionizing radiation are discussed in depth. Topics covered must include:

- interaction of charged particles
- review of basic biology
- radiation cellular effects and cellular response to radiation damage
- system biological considerations
- high and low-level radiation effects
- radiation cataractogenesis
- radiation effects on skin - cancer and threshold effects (tissue reactions)
- case studies of radiation accidents/incidents and resultant injuries
- radiation-induced heritable ill-health (genetic effects)
- radiation effects on the embryo/fetus
- non-cancer effects such as the cardiovascular syndrome
- radiation risk and risk terminology
- human study groups (cohorts) who were exposed to various types of radiation

Concepts such as non-targeted (bystander) effects, genomic instability, epigenetics, use of biomarkers in radiation therapy; apoptosis; delayed stress response protections; hyperradiosensitivity and increased radiation resistance (HRS/IRR); immediate operating protections; integrated defenses; adaptive response; development of radiation effectiveness factors (REFs) for radiation injury compensation programs and evaluation of exposed individuals; and endogenous vs. radiogenic cancers will be discussed.

Theories of radiation carcinogenesis and dose models will be presented, including absolute risk, relative risk, excess relative risk, and deterministic vs. probabilistic risk-assessment modeling.

The main points in reports BEIR and UNSCEAR will be covered, including a detailed discussion of BEIR VII and the BEIR IV and VI reports on radon. Other pertinent literature on radiation effects (e.g. EPA Blue Book) will be discussed.

Human experience with dose reconstruction and radiation effects will be summarized, including discussion of at least 12 different cohorts which have been followed.

Increased use of radiation in diagnostic medical procedures will be discussed and comparisons made between charged particle and photon irradiation modalities for cancer patients.

Problem solving and case studies on dose/risk assessment and risk communication will be interspersed among the lectures.

Class will be conducted in the 4<sup>th</sup> floor training room of the Rachel Carson Office Building, 400 Market Street, Harrisburg, PA 17105. The class date will be determined upon mutual agreement between the awarded vendor and Bureau of Radiation Protection within not more than sixty (60) days of the date of the fully executed purchase order.

## Suggested Course Outline

### **Interaction of Radiation with Matter**

- Ionization and the W value
- Directly and Indirectly Ionizing Radiations
- Range of Charged Particles
- Density Thickness
- Specific Ionization
- Stopping Power
- High Atomic Number, High Energy (HZE) Charged Particles
- RBE vs. LET
- Photon Interactions
- Neutron Interactions

*EXAMPLE EXERCISE - Calculation of the RBE For Radiation Cataractogenesis in Mice Following Exposure to Fast Neutrons*

### **Review of Basic Biology**

- Cell Structure
- Chromosomes and Genes
- DNA (bases, sugar-phosphate matrix, H-bonding, telomeres)
- Cell cycle and mitosis
- Body Systems (Blood, GI, Respiratory, etc.)

### **Radiation Cellular Effects**

- Direct vs. Indirect Effects

- Radiolysis of water
- Production of reactive oxygen species (ROS)
- Radiation Damage to DNA
- Chromosome Aberrations
- Oxygen Effect
- Cell Cycle Radiosensitivity
- Target Theory and G Values

*EXAMPLE EXERCISE - Calculation of Radiation-Induced DNA Single-Strand and Double-Strand Breaks Using G Values*

- Law of Bergonie and Tribondeau
- Radiosensitivity of Various Cell Types

**Cellular Response to Radiation Damage**

- Non-targeted (e.g. bystander) effects
- Genomic Instability
- Epigenetics
- Repair mechanisms and scavenging of toxins
- Mitotic Delay
- Hyper-radiosensitivity & increased radioresistance (HRS/IRR)
- Apoptosis
- Biomarkers

**System Biological Considerations**

- Propagation of Perturbations in the System
- Immediate Operating Protections
- Delayed Stress Response Protections
- Adaptive Response
- Integrated Defenses Against Cancer
- Endogenous vs. Radiogenic Cancer

**High-Level Radiation Effects**

- Acute vs. Chronic Exposure
- Definition of High Dose and High Dose-Rates
- Deterministic Effects
- Acute Radiation Syndrome
- Detailed discussion of acute exposure damage to hematopoietic, GI and CV systems as a function of dose
- LD50/60 for humans and animals
- Non-cancer effects such as cardiovascular & circulatory
- Cataracts (NCRP Scientific Committee 1-23 & NCRP Commentary 26)
- Impaired Fertility and Sterility

- Cutaneous Radiation Syndrome (CRS)
- Highlights of ICRP Report 118 on Tissue Reactions
- Non-Specific Life Shortening
- Summary of Dose Thresholds for Various Types of Radiation Injury
- Case Studies of Radiation Accidents/Incidents (e.g. orphaned sources, spills, fires, criticalities) and Associated Injuries

### **Low-Level Radiation Effects**

- Stochastic Effects
- Theory of Radiation Carcinogenesis
- Latency Periods for Leukemia and Solid Cancers
- Radiation-Induced Heritable Ill-Health
- Studies on Non-Humans (Drosophila and mice)
- Extrapolation to Humans

*EXAMPLE EXERCISE - Estimate the radiogenic genetic risk from CT pelvic scans*

### **Radiation Effects on the Embryo/Fetus**

- Embryonic Development
- Major Organogenesis
- Teratogenic Effects
- Mental Retardation and Developmental Anomalies
- Medical Implications

### **Radiation Risk**

- Concepts of Absolute vs. Relative Risk

*EXAMPLE EXERCISE - Estimate relative risk and excess relative risk for leukemia in the environs of a nuclear facility*

- Mortality vs. Morbidity (Total Detriment)
- Radiation Tissue Weighting Factors

*EXAMPLE EXERCISE - Calculation of the Relative Risk of Leukemia in Survivors of Hiroshima and Nagasaki*

- Dose-Response Models (linear, quadratic, linear-quadratic, and linear-quadratic-exponential)

- Summary of NCRP Commentary 27 on LNT Model

A. Lifetime vs. Annual Risk

*EXAMPLE EXERCISE - Estimation of lifetime and annual risk from radiation exposure*

- Deterministic vs. Probabilistic Risk-Assessment Modeling
- Summary of Latest UNSCEAR Reports on Risk
- Evolution of BEIR Reports (BEIR III, V and VII)
- Detailed discussion of BEIR VII and updates (e.g. Ozasa et. al.)
- EPA Blue Book

- Risk From Radon (BEIR IV and VI Reports)
- Highlights of 2014 ICRP Conference on Radon
- NCRP SC 1-21 “Health Effects of Low Doses of Radiation: Integrating Radiation Biology and Epidemiology”
- Summary of 2018 AAHP Special Session on Low Dose
- Summary of 2018 Pasco, WA Conference on Low Dose
- NCRP Report No. 181 entitled “Evaluation of the Relative Effectiveness of Low-Energy Photons and Electrons in Inducing Cancer in Humans”

*EXAMPLE EXERCISE- Calculation of Lung Dose and Risk From Exposure to EPA’s Indoor Radon Guideline*

### **Human Experience**

- Sources of Exposure (NCRP Report No. 160)

*EXAMPLE EXERCISE – Dose and Risk Communication to the Public From I-131 Fallout in Drinking Water*

- Exposure and Risk from Medical Diagnostic Procedures
- NASA Twin Study - Telomeres & Radiation
- National Cancer Institute (NCI) Dose Reconstruction for Medical X-Ray Technologists
- Radiation Treatment For Ankylosing Spondylitis
- Radium Dial Painters
- Uranium Miners
- Children Treated for Tinea Capitis and Enlarged Thymus
- Tuberculosis Patients and Breast Cancer
- Hiroshima and Nagasaki Survivors (Lifespan Study)
- Hanford Downwinders
- Chernobyl

*EXAMPLE EXERCISE – Estimation of Risk from Drinking Water Contaminated with Tritium (EPA FGR No. 13)*

*EXAMPLE EXERCISE – Estimation of Risk from KR-85 Submersion in Air (EPA FGR No. 13)*

- Russian Nuclear Workers (Mayak) and Extended Techa River Cohort
- Charged Particle vs. Photon Irradiation For Cancer Therapy
- Cancer Patients and Radiation-Induced Secondary Tumors
- Medical Misadministrations
- Interactive Radioepidemiological Program (IREP)
- Changes in Radiation Weighting Factor
- Radiation Effectiveness Factor (REF)
- USNRC-Sponsored Study of Cancer Risk in Populations Surrounding Nuclear Facilities
- Fukushima Daiichi Japanese Nuclear Power Plant Accident

## Course Materials

In addition to copies of the visual aids used by the instructor, the awarded vendor shall provide each attendee with a complete course notebook for further depth of study. The awarded vendor will retain the rights to all course materials. Duplication in any form is not permitted without the prior written consent of the awarded vendor. DEP Bureau of Radiation Protection may request a copy of the course notebook prior to award.

## Instructor Resume

A resume for the instructor performing the class shall be submitted with the bid. DEP reserves the right to approve of the instructor's credentials.

## Agency Contacts

Questions regarding the bidding or contract execution procedures should be directed to Janet Noll; telephone (717) 772-5747, email: [janoll@pa.gov](mailto:janoll@pa.gov). Email communication is preferred.

Questions regarding the course details should be directed to Robert Lewis (program office contact); telephone (717) 783-9485, email: [rolewis@pa.gov](mailto:rolewis@pa.gov). Email communication is preferred.

## Contract Award/Term and Payment

A purchase order (a.k.a. contract) will be awarded to the vendor who submits a response in accordance with the specifications set forth in this document. The contract will be awarded to the responsive and responsible bidder based upon the lowest total price.

The contract term shall commence upon execution of the purchase order/contract and terminate upon successful completion of the course which will be approved by DEP Bureau of Radiation Protection (a.k.a. "program") and no later than June 30, 2020. The course schedule will be set forth by the program.

Payment of a submitted invoice shall be made on a reimbursement basis at completion of all classes for actual services performed.

## Estimated Quantities

The contract quantities contained herein are estimated only and may increase or decrease dependent upon the needs of DEP. The contractor shall be paid according to the payment terms outlined herein. Any overage must be explained in detail, submitted to the DEP in writing, and approval must be granted by the program office contact.

## Bid Submission

All Bids must be submitted electronically through the Department of General Services' (DGS) eMarketplace website. The eMarketplace website is located at <http://www.emarketplace.state.pa.us>. DEP is not responsible for the maintenance of the eMarketplace website.

DGS's Supplier Service Center ([Supplier Service Center](#)) is available to assist vendors with registration, bidding, and account management. For questions regarding registration help, send an email to [RA-PSC\\_Supplier\\_Requests@pa.gov](mailto:RA-PSC_Supplier_Requests@pa.gov) or call (877) 435-7363, choose option 1. For questions regarding bidding help, send an email to [srmhelp@pa.gov](mailto:srmhelp@pa.gov) or call (877) 435-7363, choose option 2.