

# Advanced Radiation Biology and Radiological Risk

March 20-24, 2023 ♦ Live Instruction Online



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 include:

- interaction of charged particles, photons and neutrons with matter
- high-LET vs low-LET radiation and RBE
- review of basic biology including cell structure and DNA
- radiation cellular effects and cellular response to radiation damage
- system biological considerations
- high and low-level radiation effects
- partial vs. whole body exposures
- 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
- delayed Effects of Acute Radiation Exposure (DEARE)
- radiation risk and risk terminology (e.g. DDREF)
- major reports/conferences on radiation risk (e.g. BEIR, ICRP, NCRP, EPA Blue Book, HPS/ANS conferences, HPS position papers, etc.)
- radon
- human study groups (cohorts) who were exposed to various types of radiation
- radiation injury claims, compensation, and IREP Program
- estimation of radiation risk (absolute vs. relative risk, annual vs. lifetime risk)
- stochastic effects and tissue reactions
- sources of radiation exposure

Concepts such as non-targeted (bystander) effects, genomic instability, epigenetics, use of biomarkers in radiation therapy; apoptosis; delayed stress response protections; hyper-radiosensitivity 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, odds ratio, attributable 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, ICRP and BEIR 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

## Course Instructor

DR. RODICAN P. REED has over 40 years of experience in health physics. From 1992 to 2007, he was a Senior Health Physicist at the U.S. Nuclear Regulatory Commission (NRC) Technical Training Center. At NRC, he provided health physics training to NRC inspectors, Agreement State inspectors, and other Federal agencies. He was responsible for the uranium fuel cycle technology training curriculum, including uranium mining and milling, health physics, nuclear criticality safety, fire protection, integrated safety analyses (ISAs), and uranium enrichment technologies. He trained fuel facility inspectors and license reviewers as part of the inspector qualification program. He briefed NRC Commissioners, the Office of the Inspector General (OIG), the Atomic Safety and Licensing Board Panel (ASLBP), and the news media, in radiation protection and uranium fuel cycle technology. He developed post-graduate training in radiation protection for the International Atomic Energy Agency (IAEA). He trained NRC and Agreement State health physics inspectors in the new 10 CFR Part 20 and also developed and presented training on health physics for the proposed high-level radwaste geologic repository at Yucca Mountain.

Dr. Reed is certified by the American Board of Health Physics (ABHP) and is a member of the American Academy of Health Physics (AAHP). He is also a Board Member of the American Board of Health Physics. He is Past Chair of the Part I Panel of Examiners for the American Board of Health Physics (ABHP). He currently serves as an Associate Editor of the Health Physics Journal, having also served in this capacity from 1986-1990. He is also Chair of the ANSI/HPS N13.45-2012 working group on Incineration of low-level radioactive waste. Dr. Reed has also served as a technical reviewer for the journal Radiation Protection Management.

He is a past member of the History Committee of the Health Physics Society (HPS), the HPS Continuing Education Committee, and the Professional Development Committee of the AAHP. He has published papers in health physics, made numerous technical presentations, served on industry and governmental committees and workgroups, and prepared input to environmental impact statements. He has a B.S. in Physics, M.S. in Nuclear Engineering, and Ph.D. in Health Physics, all from Georgia Tech.

# 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

*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

*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
- 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
- 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
- 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
  - Lifetime vs. Annual Risk
- 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"
- EXERCISE- Calculation of Lung Dose and Risk From Exposure to EPA's Indoor Radon Guideline*

## Human Experience

- Sources of Exposure (NCRP Report No. 160)
- 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
- EXERCISE – Estimation of Risk from Drinking Water Contaminated with Tritium (EPA FGR No. 13)*
- 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

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