

Industrial Hygiene: Assessment and Control of the Occupational Environment

Main Topics

- Air Pollution Control
- Analytical Methods
- Ergonomics
- Gas and Vapour Sampling
- General Practice
- Heat and Cold Stress
- IH Management
- Industrial Ventilation
- Radiation
 - Ionizing
 - Non-Ionizing
- Noise Measurement and Control
- Particulate Sampling
- Personal Protective Equipment
- Regulations, Standards and Guidelines
- Toxicology

Radiation

Ionizing Radiation

- Any radiation that can ionize biological atoms
- Energy (Q) > 12.4 electron volts (eV)
 - (1 eV = 1.6×10^{-19} joule (J))
 - Nonionizing radiation - Q < 12.4 eV
 - Ultraviolet, Visible, Infrared, Microwave, Radiofrequency, Extremely low frequency

Ionizing radiation types

- Particles
 - alpha (α)
 - α - helium nucleus; 2 protons & 2 neutrons
 - beta
 - beta (β^-)
 - positron (β^+)
 - positive electron (e^+)
 - proton and neutron
- Photons
 - x and gamma (γ) rays are types of electromagnetic radiation (EMR)

Radiation Sources

- Radionuclides
 - Energetically unstable combinations of neutrons
 - Radioactive decay - unstable nuclide emits radiation to become stable
 - Types of radioactive decay
 - α , β^- , β^+ , γ
- X-Ray Machines
 - Two modes of production
 - Bremsstrahlung or braking radiation
 - Characteristic X-rays.
 - Byproduct sources - electron energy $>15,000$ V
- Others
 - Particle accelerators
 - Generate high-energy photon and particle beams.
 - Nuclear reactors
 - Chain reactions in fissionable materials
 - Uranium.
 - Neutron sources
 - Photoneutron sources
 - alpha neutron sources
 - fission and fusion

- Applications
 - Radionuclides
 - Medical diagnosis / therapy
 - Industrial radiography
 - Gages
 - Thickness
 - Density
 - Backscatter
 - Moisture
 - Chemical processes
 - Lab instruments
 - Static eliminators
 - Smoke detectors
 - X-ray
 - Medical diagnosis / therapy
 - Lab instruments
 - Industrial radiography
 - Sterilization
 - Byproduct emission from high voltage tubes (CRTs, klystrons)
 - Electron beam welding
 - Electron microscopes
 - Particle accelerators
 - Medical therapy

- Ion implantation
- Research
- Nuclear reactor
 - Power generation
 - Radionuclide production
 - Research
- Neutron sources
 - Activation analysis
 - Moisture gages

“Irradiation is a process in which food is passed through a chamber where it is exposed to gamma rays or X rays. These high-energy rays are strong enough to break chemical bonds, destroy cell walls and cell membranes, and break down deoxyribonucleic acid (DNA), the substance that carries genetic information in all cells. Irradiation kills most bacteria, molds, and insects that may contaminate food. Irradiation also delays the ripening of fruits and sprouting of vegetables, permitting produce to be stored for longer periods of time. Because irradiation involves minimal heating, it has very little effect on the taste, texture, and nutritive value of food.”

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Radiation Physics (basics)

- Radioactive decay
 - Unstable radionuclide becomes more stable by emitting radiation
 - Radioactive decay law
 - The activity of a radionuclide source as a function of time
 - $A_t = A_0 e^{- (0.693t/t^{1/2})}$
 - Where:
 - A_t = activity at time, t
 - A_0 = activity at time, t=0
 - t = time
 - $t^{1/2}$ = half-life of radionuclide
 - Half-life
 - Time it takes for a radionuclide with an activity A_0 to decrease to one-half that value

Interactions of radiation with matter

- Charged particles usually interact with orbital electrons causing ionization.
 - Electrons can interact with nucleus producing x rays.
 - X- and γ -rays have no finite range (photons)
 - Three interactions
 - Photoelectric
 - Compton
 - Pair production
 - Inverse square law
 - Intensity of x or γ -ray source varies with square of distance from the source.

$$(X_1) (d_1)^2 = (X_2) (d_2)^2$$

- (X_1) = exposure rate at point 1
- (d_1) = distance from source to 1
- (X_2) = exposure rate at point 2
- (d_2) = distance from source to 2

Radiation Terminology

- Activity
 - Strength of a radionuclide source
 - Number of atoms decaying per unit time
 - Units
 - Traditional - curie (Ci)
 - 1 curie (Ci) = 3.7×10^{10} d/s
 - Systeme Internationale (SI) becquerel (Bq)
 - 1 becquerel (Bq) = (1 d/s)
 - (1 pCi/L = 37.5 Bq/m³)

Radiation Effects and Hazards

- Mechanism of action
 - Direct effect
 - Interaction with DNA, RNA
 - Indirect effect
 - Interaction with water producing free radicals
 - Law of Bergonie and Tribondeau
 - the shorter the cell's division time, the more sensitive it is to radiation damage
- Acute effects
 - High doses, short time of exposure, death can result.

- Acute Radiation Syndrome (ARS) - >50-100 rad to a major portion of the body
- Illness modes
 - Bone marrow or hematopoietic, gastrointestinal and CNS
- Minimum lethal dose – 100 to 200 rad
 - LD50/60 – 400 to 500 rad;
 - Few survive doses above 600 rad

Approx. Dose (REMS)	Effect	Survival...
0-100		
100-200		
200-600		
600-1,500		
1,500		

(1R (Roentgen) = 1 rad = 1 rem for most x- and γ -rays, due to “Quality Factor”)

- Chronic effects - Result from high, acute doses or long-term low doses.
 - Somatic effects
 - Cancer
 - Leukemia
 - Cataracts
 - Sterility
 - Teratogenic
 - Genetic effects
 - No dose threshold
 - Incidence of effects related to dose rate
- Radiation Hazards
 - Internal exposure
 - Primarily ingestion or inhalation
 - Seldom skin absorption
 - Degree of hazard
 - $\alpha \gg \beta > \gamma$
 - External exposure
 - Source outside of body can irradiate internal body tissues
 - Degree of hazard
 - Neutrons $\gg \gamma > \beta$
 - α not hazardous outside of the body

- Accumulated exposure, per year
 - Whole body – 5 rem/yr
 - Skin, extremities, 50 rem/yr
 - Fetal dose (entire pregnancy), 0.5 rem

- Other sources
 - Natural, 100 mrem/yr
 - Medical, 100 mrem/yr
 - Consumer products, 4 mrem/yr
 - Air flight, 1.3 mrem/trip
 - Global fallout, 4.4 mrem/yr

- ALARA principle: Doses are kept As Low As Reasonably Achievable
 - Limits based on cancer and genetic risk
 - assume linear, non-threshold hypothesis, i.e., risk regardless of how low the dose.

Control Measures

- Internal hazards
 - Bioassays
 - Monitor workers for radioactive material by sampling body tissues / fluids

- External hazards
 - Time, distance, shielding

- Time – dose increases linearly with time
- Distance
 - α - absorbed readily in air
 - β - several meters in air
 - x and γ rays
 - No finite range, follow inverse square law
- Shielding - Radiation absorbed by matter.
 - α – absorbed by sheet of paper
 - β – (low atomic number (<13) materials to minimize Bremsstrahlung x rays
 - x and y rays – High density, high atomic number elements are best shielding materials. Steel and concrete are used for large shields.
- Shielding equation for x, γ rays:
 - $I_t = I_0 e^{-\mu x}$
 - I_t = exposure rate transmitted through shield
 - I_0 = exposure rate incident on the shield
 - μ = absorption coefficient for that material and photon energy
 - x = shield thickness