Biological and Man-Made Extreme Environments

"Field" by Richard Box

Power lines light up fluorescent tubes

Centers for Disease Control (CDC)

- Responsible for maintaining public records of infectious diseases
  - identify, track, and provide information for treatment
- also tracks potential biological and chemical warfare agents

Natural Biological Diseases

- Plague
- Yellow Fever
- Influenza
- Meningitis
- Encephalitis

Plague

- 2003, New Mexico man and woman diagnosed with plague
- April 30th, 2004 Two cats found in Santa Fe with plague

Yellow Fever Epidemics in Galveston

- Periodic epidemics during summers to the first frost
- 20 lives / day, 10% of the population
- Houston militia sent out to stop trains from Galveston--enforced quarantine.
- influenced the decision to locate the medical school in Galveston, 1891

Biological Effects of Atmospheric Ions?

- Biometeorology: effects of environmental factors on living organisms
- Ions
  - Folk lore of effects of changing weather patterns
  - Weather causes atoms (oxygen, water) to gain or lose electrons
  - Real effects??

Natural Effects of Ions?

- Positive ions
  - Associated with hot, dry winds
    - Santa Ana (CA), Chinook (Canada)
  - 30% of humans are sensitive
  - Migraines, limb swelling, asthma, arrhythmias, GI hyperactivity
- Negative ions
  - Associated with lightning, waterfalls
  - Neutralize effects of positive ions

Seratonin Irritation Syndrome

- Ions travel in respiratory tract
- Cause release of seratonin
  - Cause production of NE and EPI
  - Increase secretion of ACTH and prolactin
- Decreased visual rn time, increased fatigue
- Depression, irritatibility
- Neg ions result in smaller increases in body temp, HR, RPE and increased "work output" in a hot environment

Man-Made Extreme Environments

Biological Weapons

- Used in warfare since the 6th century
  - Assyrians poisoned enemy wells
  - Native Americans first exposed to European diseases
    - Mayans, Pueblo, Inuits
  - ricin (a toxic product from castor beans) used in an assassination in London in1978

Potential Biological Warfare Agents Table 19.1

- Category A, easily disseminated, high mortality
  - **anthrax, botulism toxin, plague**
- Category B, not easily disseminated, moderate or low mortality
  - **Q fever, ricin toxin, staphylococcus**
- Category C, emerging pathogens
  - **hanta virus, yellow fever, tuberculosis**

Chemical Weapons

- Arrived with the industrial revolution
- Used extensively in WW1
  - chlorine, phosgene, mustard gas
- Sarin used in Tokyo subway 1998 kills 12 people
- Mustard and nerve gases used in Iraq in 1988

Regulations against biological and chemical weapons

- 1972 Biological Weapons Convention
  - prohibit development, production, stockpiling
  - US destroyed microbes for anthrax, tularemia, viruses for Q fever, encephalitis, and staphylococcus and botulism toxins
  - not all countries signed
  - not all countries who signed have complied

Radiation: friend or foe?

- Albuquerque Atomic Energy Museum
  - Central across from Old Town
- Exhibits of the development of the first Atomic bombs
- Exhibits of the medical uses of radiation

Natural Radiation Exposures

(25% of total)

- Radioactive potassium in foods
- radioactive radon in air
- normal background cosmic radiation
  - increases 100 fold during jet travel

Radiation from human activities (75% of total)

- Work in mines (uranium mines in Galisteo)
- x-rays, medical, security
- radioactive meds, cardiac imaging
- atomic weapons testing fallout

Astronauts and Radiation exposure

- Radiation exposures outside Earth's atmosphere are much larger
  - cosmic rays not filtered by the Earth's atmosphere
  - x-rays and gamma rays from the Sun
  - high atomic number energetic particles (HZE) derived from the sun or stars
    - biological effects are unknown
  - products from interaction with shielding

Physiological Effects that might alter radiation damage

- Impaired immune function
- impaired repair processes?
- Unknown effects of HZE
- 3-year trip to Mars, estimated 3% of cells would sustain lethal damage
- long-term effects?

Career Radiation Limits (Sv)

Age at entry	Male	Female
25	1.5	1.0
35	2.5	1.75
45	3.25	2.5
55	4.0	3.0

HZE exposure of 4 Sv is estimated to double the risk of cancer (1 SV = 100 REM)

Thermonuclear Weapons

- Greatest threat from terrorism
  - initial blast
  - long-term effects, medical and environmental

Hiroshima/ Nagasaki

- 103,000 to 200,000 civilians died initially

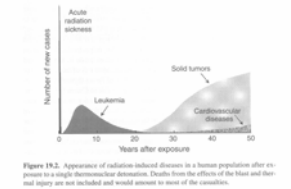


Figure 19.2. Appearance of radiation-induced diseases in a human population after exposure to a single thermonuclear detonation. Deaths from the effects of the blast and thermal injury are not included and would amount to most of the casualties.

Regulations against Nuclear Testing

- 1963 Test ban treaty between the US and Soviet Union
- Now over 40 nations have nuclear bomb capability

Units of Measure for Radiation

- Roentgen (R)
  - amt of radiation required to ionize a specific volume of air under standard conditions
- Rad (radiation absorbed dose)
  - energy deposited in tissue (100 ergs/gm)
- Gray (Gy) is the international unit
  - equals 100 Rads

Dose Equivalence

- Different types of radiation (gamma, x-ray, cosmic) produce different amts of biological effect
- Dose equivalence
  - exposure dose x biological effect factor for the type of radiation

Units for dose equivalence

- REM (roentgen equivalent in man)
- SI units, 1 Sievert (Sv) = 100 REM
  - 10 Sv = 1000 REM is lethal
  - 1 mSV = 100 mrem, average bkg radiation per year
    - 0.1 to 0.5 mSv = 10 to 50 mrem = chest x-ray
    - 5 mSv = 500 mrem = yearly allowable radiation exposure for most IRBs

Types of Radiation

- Ionizing radiation: tissue absorbs radiation energy, exciting an electron which is ejected from the atom
- 2 types
  - electromagnetic
  - particle

Electromagnetic Radiation

- X-rays
  - produced when electrons strike a target and release energy
- Gamma rays
  - produced by the decay of radioactive isotopes
  - *Electromagnetic radiation lacks charge and mass*

Particle Radiation

- electrons, protons, and alpha particles
  - are accelerated in an electrical field, have charge and mass
  - lose energy rapidly when they enter tissue
  - cause a region of local ionization
- alpha particles
  - are helium nuclei (2 protons and 2 neutrons) usually too large to enter tissues
- neutrons
  - emitted as fission products or produced in colliders

Biological effect: RBE

- Vary with the type of radiation
- Radiation effect is normalized by being expressed in terms of relative biologic effectiveness (RBE)
  - RBE for x-rays and gamma rays is 1
  - RBE for neutrons is 10-20, much more potent
- RBE varies with type of radiation, dose, and type of tissue

Radiation and Mortality

data from Hiroshima, Pacific Islanders, Chernobyl

- < 2 Gy (200 Rad), little if any therapy
- 3.25 Gy, LD50/60
  - 50% of population is dead in 60 days
  - young and old are more sensitive
  - non-pregnant women are more radiation tolerant than men

Exposure effects

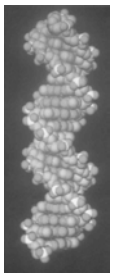
- 2-8 Gy, death from hematopoietic syndrome in 3-6 wks (bone cells)
- 5-10 Gy, gastrointestinal syndrome in 3-10 days (GI epithelial cells)
- 100 Gy, cerebrovascular syndrome within 2 days (brain and heart cells)

Free Radicals

- FR = reactive and unstable molecules that contain an unpaired electron
- radiation can produce FR by interacting with oxygen, carbon, or water inside the cells
- FR oxidize nucleic acids in the cell and cause break in DNA

DNA damage and cancer

- If both stands of DNA are broken it causes cell death
- If one strand is broken
  - it can be repaired by the cell
  - it can cause mutations when the cell divides, may be years later
  - it can cause cell death when the cell divides



Long-Term Fall-out

- Stochastic effect (long-term) of radiation
  - induction of cancer years after the original exposure
  - 8 types of radiation-induced cancer
    - leukemia, meningioma, thyroid, breast, lung, stomach, colon, skin
- Deterministic effects
  - Short term effects

Effects of nuclear testing

- Release of I-131 from American nuclear tests has caused 49,000 cases of thyroid cancer in the US
- Release of all substances from all tests has led to 430,000 deaths by 2000.
- Effect on human germ cell mutation rate?

Controversy over Food Irradiation

- Irradiation kills lethal microbes and other pathogens
- Eating of irradiated food is safe?

Radiation treatment for cancer

- Effective as a cancer treatment when it causes greater harm to cancer cells than tumor cells
- Cancer cells may be more susceptible since they are more active and undergoing more divisions
- Locally heat cells to increase effect
- Radiowaves to heat “tagged” cells

Radiation sensitivity vs. resistance

- Natural resistance to radiation damage
  - hypoxia
  - tumor protection genes (oncogenes)
  - response of various growth factors and cytokines (tumor necrosis factor, IL-1)
    - may increase or decrease susceptibility to radiation damage

Exercise and Survival in a world of natural and man-made terrorism

- Exercise improves immune function; does it protect against radiation damage?
- Exercise produces FR yet it also builds tolerance against FR
  - what is the net effect of exercise on FR damage?