Dose Calculation for Externally Contaminated Livestock and Animal Triage

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Environmental and Radiological Health Sciences

Dose and Don’ts

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- Emergency response / consequence management
- Non-human biota
- Animal dosimetry
- Livestock triage

Radiological Emergency

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- Radiological emergency
  - release of radioactive material to environment
    - necessitating off-site emergency response
    - consequence management
- Priorities
  - emergency phase
    - concern for human wellbeing
    - “Snowball effect”?
      - pets, livestock, wildlife animals
      - public interest and perception
  - consequence management phase
    - also: human food chain, economic impact

Livestock and Food Supply

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- Shelter and / or evacuation
  - lack of human care for livestock
    - water, feed
- Concerns
  - dose to owner
  - external contamination
    - shelter
    - decontamination
  - internal contamination
    - consumption of animal products
  - handling and processing
    - function of dose to animal?

Handling and Processing

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- Salvageability
  - animal exposure
  - cost of decontamination
  - expected demand for animal (food) products
    - public perception
  - economic impact to owner
- Dose to animal
  - no visible acute radiation injuries
    - upper limit
    - rejection by public expected
      - → disposal
  - LD_{10}
    - comparison with animal data
    - large: $\mathcal{O}$(1 Sv), small: $\mathcal{O}$(2 Sv), poultry: $\mathcal{O}$(3 Sv)

Non-human Biota

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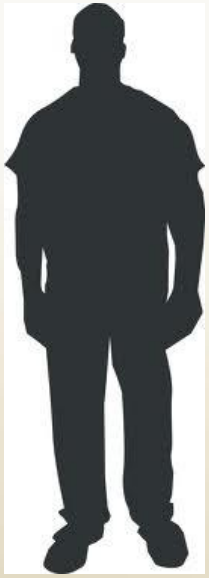

- Health Physics
  - employing dosimetry to:
    - prevent acute radiation injury
      - “deterministic effects”
    - limit probability of occurrence of late effects
      - “stochastic effects”
    - adverse effects to environment?
      - International Commission on Radiological Protection
        - prevention or reduction of frequency of deleterious effects
        - maintenance of biological diversity, conservation of species, health and status of natural habitats, communities, and ecosystems

Non-human Biota (II)

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- Reference Animals and Plants
  - set of 12 reference biota (9 animals, 3 plants)
    - development of system and science base
      - relate exposure to dose, dose to effect, effect to consequences
      - examination and interpretation by way of conceptual and numerical models
      - few biotic types before generalization
    - large mammal (deer), small mammal (rat), aquatic bird, amphibian, freshwater fish, marine fish, insect, crustaecean, annelid, large plants, grass, seaweed

Animal Dosimetry

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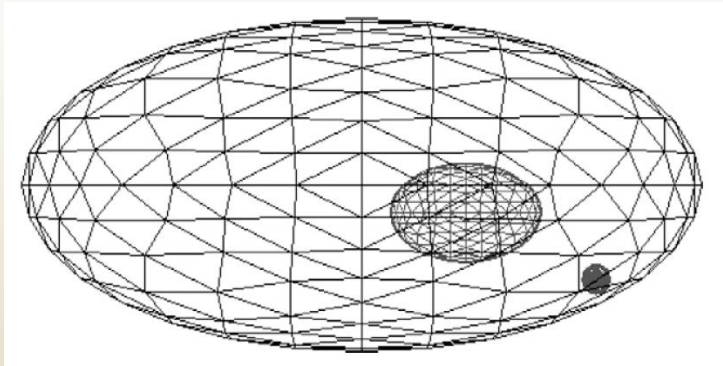

- Simple geometric shapes
  - spheres, ellipsoids
  - no assessment of individual organ / tissue doses
    - exceptions: liver, testes
- Computer models
  - exposure scenarios
    - ground deposition of radionuclides
    - “infinite homogeneous plane source”

$$D = \mathrm{D}\left(c_g(x, y, z)\right) = D\left(c_g\right)$$

Animal Dosimetry (II)

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- Absorbed dose

$$D = D(\vec{x}, V(\vec{x}'), A, E, \mu_{en}, B)$$

  - $\vec{x}$ … coordinates for radioactive source
  - $\vec{x}'$ … coordinates for absorber volume element dV
  - A … activity of the source
  - E … radiation energy
  - μ_{en} … energy absorption coefficient
  - B … buildup (function of depth in absorber)

Animal Dosimetry (III)

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- Analytic solutions
  - spheres

$$\dot{D} = \frac{3}{16\pi^2 R^3}\left(\frac{\mu_{en,m}}{\rho_m}\right) AE \int_0^R \int_0^{\pi} \int_0^{2\pi} \frac{B(\mu d_m)\, e^{-\mu d_m}\, r^2 \sin(\theta)}{r^2 + (h+R)^2 - 2r(h+R)\cos(\theta)}\, d\varphi\, d\theta\, dr$$

  - prolate ellipsoid

$$\dot{D} = \frac{3}{16\pi^2 m_1 m_2{}^2}\left(\frac{\mu_{en,m}}{\rho_m}\right) AE \int_0^{\xi_{max}} \int_0^{\pi} \int_0^{2\pi} \frac{B(\mu d_m)\, e^{-\mu d_m}\, (m_1{}^2 - m_2{}^2)^{3/2}\left(\sinh^2(\xi) + \sin^2(\nu)\right)\sinh(\xi)\sin(\nu)}{(m_1{}^2 - m_2{}^2)\left(\sinh^2(\xi) + \cos^2(\nu)\right) + 2\sqrt{m_1{}^2 - m_2{}^2}\,(m_2 + h)\cosh(\xi)\cos(\nu) + (m_2 + h)^2}\, d\varphi\, d\nu\, d\xi$$

  - general ellipsoid

$$\dot{D} = \frac{3}{16\pi^2 abc}\left(\frac{\mu_{en,m}}{\rho_m}\right) AE \int_{-c^2}^{a^2} \int_{-b^2}^{-c^2} \int_{-a^2}^{-b^2} \frac{B(\mu d_m)\, e^{-\mu d_m}\, (\lambda - \xi)(\xi - \nu)(\lambda - \nu)}{8\sqrt{-(a^2+\lambda)(b^2+\lambda)(c^2+\lambda)(a^2+\xi)(b^2+\xi)(c^2+\xi)(a^2+\nu)(b^2+\nu)(c^2+\nu)}}\, d\nu\, d\xi\, d\lambda$$

  - point sources (on ground / animal hide)

Livestock Triage

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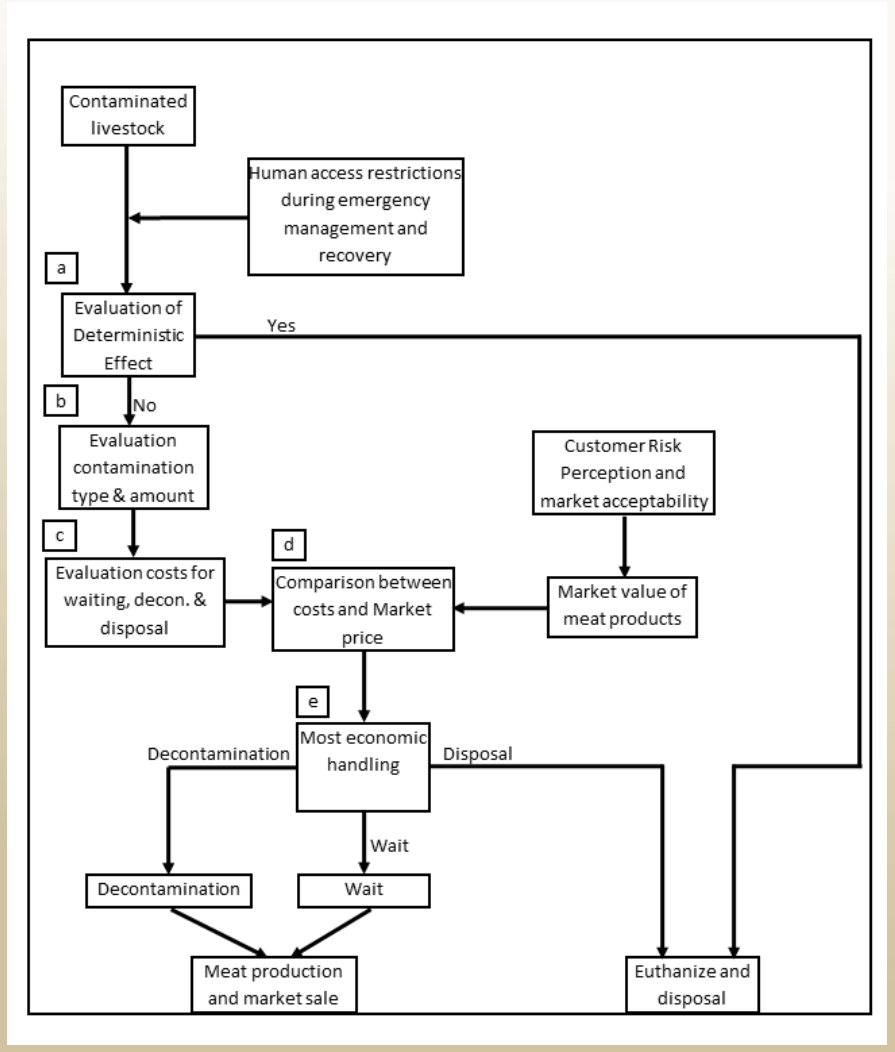
- Decision tree
  - (from McMillan et al.)



Conclusions

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- Animal triage consideration
  - animal exposure
    - analytical results for external exposure
  - cost of decontamination
    - effectiveness and efficacy
  - public perception
    - most difficult to quantify
      - stigmatization expected
        - labeling vs. unlabeled
      - alternative uses
        - animal products other than food
        - pet food
        - donations (zoos, etc.)
  - economic impact to owner