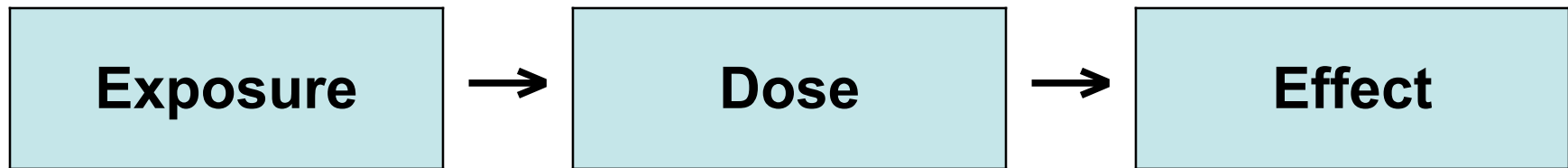


Radiological Risks Associated with the Use of Depleted Uranium Munitions

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Evaluating Radiological Risk



External

Internal

inhalation

ingestion

fragments

particle size

solubility

Early/deterministic

Late/stochastic

cancer

genetic effects

evaluated using
standard (ICRP) models

Background Radiation

| Source | Dose Rate (EDE, mrem/y) |
|---|----------------------------|
| Natural (world average) | 240 |
| Cosmic rays, cosmogenic (^{14}C) | 39 |
| Terrestrial external (^{238}U , ^{232}Th , ^{40}K) | 48 |
| Terrestrial internal (^{238}U , ^{232}Th , ^{40}K) | 29 |
| Radon (1.5 rem/y to bronchi) | 120 |
| Artificial (U.S. average) | 65 |
| Medical | 60 |
| Fallout | 0.6 |
| Other | 2 |

Substantial variations exist among/between populations

| Common Doses | EDE (mrem) |
|------------------------------------|-----------------------|
| Medical | |
| chest x-ray | 10 |
| lower GI tract x-ray; barium enema | 500 |
| whole-body CT scan | 1000 |
| Cross-country airplane flight | 5 |

| Dose Limits | (mrem/y) |
|--------------------|-----------------|
| Public | 100 |
| Occupational | 5000 |

Health Effects of Radiation

- Deterministic (early) effects
 - illness, death (observed >100, >200 rem acute)
sterility (>50 rem), teratogenic (>20 rem, 8-15 weeks)
- Stochastic (late) effects
 - cancer (observed >10-40 rem acute)
 - linear, no-threshold (LNT) dose-response
 - 1 death per 2000 rem delivered over extended time
 - 1 rem \approx 0.05% risk of death \approx 0.25% increased risk of cancer death
 - genetic (observed in animals, not humans)
 - 100 rem to double mutation rate
 - 1 rem \approx 0.01% risk \approx 1% increased risk/generation

External Exposure

- Dose rate in DU-armored tank fully loaded with DU ≈ 0.2 mrem/h (5x less than airline crew)
- Dose rate above soil uniformly contaminated with 1 g/m^2 (1 t/km^2) ≈ 1 mrem/y
 - DU rounds fired in Kosovo: $0.4\text{-}3 \text{ g/m}^2$
 - UNEP: $<1 \text{ g/m}^2$ except at impact points
- No significant risk, except for extended contact with bare DU (200 mrem/h to skin)
 - dose limit for public = 5000 mrem/y to skin
 - 30 mm round in pocket $\approx 0.1\%/y$ increase in skin cancer

Internal Exposure

- Inhalation
 - inside vehicles (when struck, clean-up, etc).
 - outside vehicles (passing cloud, resuspension)
- Ingestion
 - handling of DU fragments
 - contaminated water, food
- Wounds
 - fragments in soldiers inside struck vehicles

| Exposure Scenario | Amount (mg) |
|--|-------------------------|
| Inhalation | |
| Inside vehicle when struck | 25 – 250 |
| Inside contaminated vehicle | 1 – 20 h ⁻¹ |
| Downwind of impacts | |
| 100 m from 1 kg release | 0.01 – 0.7 |
| 1 km from 10 kg release | 0.03 – 0.3 |
| 10 km from 100 kg release | 0.01 – 0.6 |
| Resuspension of aerosols (1 g/m ²) | 1 – 80 |
| Ingestion inside contaminated vehicle | 0.5 – 5 h ⁻¹ |

50-y Dose Commitment (rem/g = mrem/mg)

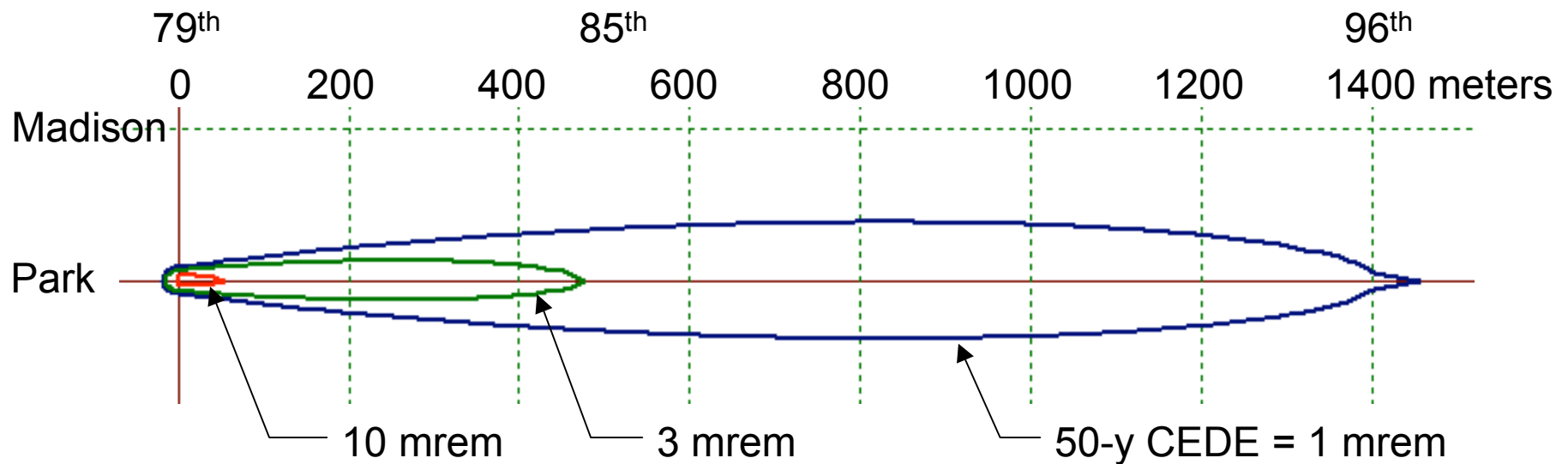
| | Inhalation | Ingestion |
|---------------|-------------------|------------------|
| EDE | 4 – 60 | 0.01 – 0.06 |
| Lung | 20 – 500 | |
| Bone surfaces | | 0.09 – 0.9 |

*depends on size and solubility of particles; fine, insoluble aerosols give highest inhalation dose

| Exposure Scenario | EDE (mrem) |
|---|-------------------|
| Inhalation | |
| Inside vehicle when struck | 200 – 6000 |
| Inside contaminated vehicle (1-10 h) | 5 – 4000 |
| Downwind of impacts | |
| 100 m from 1 kg release | 0.06 – 40 |
| 1 km from 10 kg release | 0.2 – 20 |
| 10 km from 100 kg release | 0.06 – 30 |
| Resuspension of aerosols @ 1 g/m ² | 3 – 2000 |
| Ingestion inside contaminated vehicle | 0.005 – 3 |
| Shrapnel (not including dose to muscle) | 30 – 3000 |

Release of 10 kg DU aerosol:

- hard-target impact of ~10 large- or ~200 small-caliber rounds—a major engagement
- typical weather conditions, aerosol size/chemistry



- Dose at given point could be 10 times higher or lower, depending on weather, particle size, chemical form
- Compare to ~5 mrem for cross-country round-trip flight

Summary

- Radiation doses and corresponding health risks are insignificant, except *possibly* people who:
 - are in vehicles when struck (inhalation, shrapnel)
 - enter struck vehicles for long periods (10+ h)
 - inhabit highly contaminated, very dusty areas
 - keep fragments next to skin for 1+ y
- In worst-case exposures of these types, risk of cancer death from exposure $\approx 0.1-0.5\%$

Collective Dose

- Collective dose to civilian population, assuming 30 tons of DU aerosol dispersed over area with average population density of 50/km² (Iraq):

| | |
|------------------|------------------------|
| external | 3 – 20 |
| inhalation | 40 – 10,000 |
| resuspension | 6 – 10,000 |
| <u>ingestion</u> | <u>1 – 1,000</u> |
| total | 50 – 20,000 person-rem |

- <10 cancer deaths (assuming 1 per 2000 rem)

Criticisms of Standard Model

- LNT assumption underestimates risk
 - large underestimate highly unlikely based on studies of low-dose exposures in humans
 - more evidence that LNT overestimates risk
- Radioactive contaminants in DU increase risk
 - maximum concentrations: 30 ppm ^{236}U , 0.04 ppb ^{239}Pu , 5 ppb ^{237}Np , 16 ppb ^{99}Tc
 - contaminants increases dose by $\sim 0.5\%$ (^{236}U) and $\sim 0.1\%$ (Pu, Np, Tc) compared to DU produced from virgin natural uranium

Criticisms of Standard Model

- Risk to children much larger
 - exposures about same (e.g., children playing in or around vehicles, with fragments)
 - doses about same for given exposure
 - risk coefficients are population-weighted
- Lung cancer risk far greater due to “hot particles”
 - no evidence in human, animal studies that risk hot particle dose $>$ risk of equal uniform dose
 - some in-vitro studies indicate modestly higher risks ($\sim 3x$) for hot particles at low doses

Criticisms of Standard Model

- Ceramic particles have longer half-life in lung
 - model includes possible very slow lung clearance
- High urine U output implies larger amount inhaled
 - high output only in veterans with shrapnel; those without had output consistent with assumptions
- Gulf War Syndrome, illness in Iraq, Kosovo
 - epidemiology must account for confounding factors (smoking, stress, nerve agents, public health, etc...)
 - epidemiological studies show no correlation between NU exposure and any cancer or kidney disease among workers, no increased incidence of disease at much higher average exposures than plausible in soldiers