Presentation 10 - Al Marshall

Preliminary Assessment of DU Munitions Health Effects.

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Presented to RAC Gulf War Veteran's Illness
Washington DC
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Who am I? Why am I studying DU?

- Sandia National Laboratories
  - DOE Lab (Nuclear Weapons, Energy)
  - National Security Studies department
- National Security Studies Dept.
  - Explore Terrorist Threats (DU?)
  - Objective studies of Sandia activities (U use)
  - DU issues of interest to department
- My Background
  - Physics, Nuclear Engineering
  - Physics orientation, not medical details

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Objective: Explore DU exposure issues.

Examine:

- DU issues
- DU dispersal mechanisms
- Possible exposure mechanisms
- DU biokinetics
- Radiological health effects
- Heavy metal (chemical) health effects
- Report findings

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Used Gulf War as DU case study.

DoD defined 3 exposure levels:

- Level I exposures: "Friendly fire" veterans
  - Accidentally targeted by US tanks
  - Highest exposures Highest exposures
  - Study completed

- Level II: Post-battle teams – No study planned
- Level III: Incidental Exposures – No study planned
- Civilian exposures – Study planned

Work in Progress

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Preview of Preliminary Findings.

- Inhaled DU mass exceeds DoD estimates
- Fragment dose contribution significant
- DU radiological effect insignificant
- DU in Kidney high for max case, chemical heavy metal: consequences uncertain
- Other DU heavy metal effects possible, significance uncertain

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Presentation Outline

1. DU Characteristics and Use
2. Intake and Biokinetics
3. Radiological Effects
4. Heavy Metal Effects
5. Summary and Conclusions

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1. DU Characteristics and Use

- Uranium:
  - Naturally occurring heavy metal, high density
  - Chemically toxic, slightly radioactive
  - Principal use: nuclear weapons, power reactors
- Natural isotopes:

Uranium Isotope	Z Protons	N Neutrons	A $Z+N$	half-life $T_{1/2}$ (yrs)	Support Chain Reaction?
U-234	92	142	234	2.5×10^5	No
U-235	92	143	235	7.0×10^8	Yes
U-238	92	147	238	4.5×10^9	No

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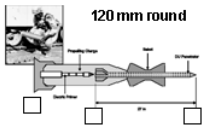
DU use as armor penetrator.

- U enriched in U-235: reactors, nuclear weapons
- Leftover is DU, mostly U-238
- Ideal for armor penetration
  - Penetration depth ~density
  - Self sharpening
  - Inexpensive
  - Pyrophoric

impact generates particles, explo



1991 Gulf War
- 900,000 DU rounds
- 315 tons DU

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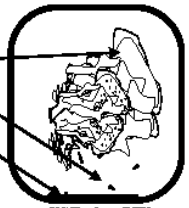
2. Intake and Biokinetics

Level I veteran exposure mechanisms.

- 1 or 2 120 mm rounds hit vehicle
- DU particulate, explosion

(1) Occupants inhale DU particles
(2) Occupants hit by DU fragments
(3) Occupants ingest DU powder



US Tank or BFV
Crew Compartment

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(1) Look at inhalation exposure.

- Inhaled mass determines dose
- Estimated inhaled mass for nominal case

	This Study	DoD	Royal Society	Fetter and von Hippel
Mass (mg)	150	27	250	25
Approach	Both tank and BFV cases	Single tank test, air monitor data questioned	Crude modeling, Tank only	7 yr lag data taking Old model, old data
Reported validated by urine data?	Yes ?	Yes Old data	Yes Broadly consistent ?	Yes Old model, old data

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Estimated inhaled mass for maximum case.

	This Study	DoD	Royal Society	Fetter and von Hippel
Mass (mg)	**1850**	**237**	**5000**	**250**
Approach	Tank and BFV	Multiplier on nominal data -includes ingestion	Crude model Tank only	As for nominal
Reported consistent with urine data?	Yes	Not compared	Not compared	Yes Old data, model

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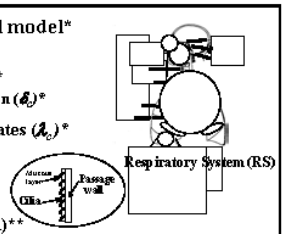
Inhalation biokinetics: DU in RS.

- Recent international model*
  - –Particle deposition
    - •Particle size (d)**
    - •Deposition fraction (δ_D)*
  - –Particle transport rates (λ_{tr})*
    - •Ciliary action
    - •Lymph nodes
  - –Blood dissolution
    - •Rapid fraction (f_r)**
    - •Rapid, slow rates (λ_{rr})**
- Data from
  - *International Commission on Radiological Protection (ICRP)
  - **Impact particulate research



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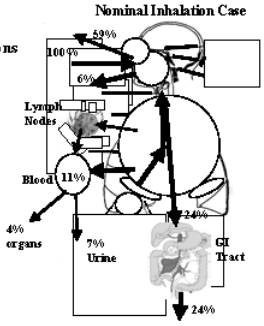
Basic distribution of inhaled DU.

- Basic equations solved
  - Coupled differential equations
  - Compute time-dependent
    - Transport
    - Blood absorption
  - Each compartment
  - Rapid and slow blood
- Equations couple to
  - Other organ models
  - Urine elimination



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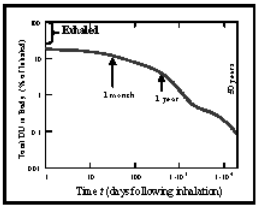
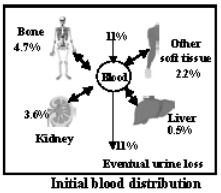
Blood distributes DU to organs

- Coupled to RS equations
- Total in body
  - ~60% exhaled, % remaining:
    - 10% at 2 months
    - 4% at 1 yr
    - < 0.01% at 50 yrs





Initial blood distribution to organs for DU

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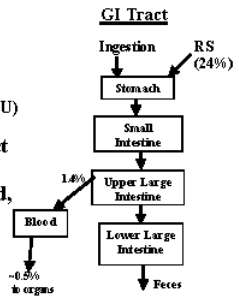
(2) Level I Ingested DU insignificant.

- Used ICRP model
- DU to GI tract from:
  - Ingestion (hand-to-mouth contact)
  - Respiratory System (RS inhaled DU)
- Passes rapidly through GI tract
- Small (1.4%) absorbed by blood, passed to organs
- Effect small for level I ignored here



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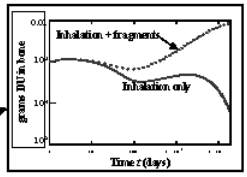
(3) Embedded fragments effect.

- Embedded fragment dissolution
  - Inferred dissolution rate from DU in urine (McDiarmid study)
  - Nominal case: Used average DU in urine
  - Maximum case: Used 2 x max DU in urine
  - Assume constant rate
  - Developed simple model
- Effect is significant

DU mass in bone nominal case



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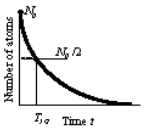
3. Radiological Effects

Background: Radioactive decay

- Radioactive decay: emission of particles from nucleus
  - Disintegration (Decay)
    α, β, and γ
  - New element formed
- Activity: dis./sec
  - –Curies (Ci) = 3.7 x 10^{10} dis./sec
  - –Activity/g for U is very small
- Half life:
  - –Time for no. atoms to decay by 1/2
  - –Activity ~ $1/T_{1/2}$
  - –Long half-life = low activity



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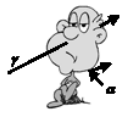
Types of radiation and exposures.

- Alpha (α) radiation
  - –External: no skin penetration, no health risk
  - –Internal: damage soft tissue, health risk
- Beta (β) radiation
  - –External: some penetration, skin burns
  - –Internal: damage soft tissue, health risk
- Gamma (γ) radiation
  - –External and internal:
    highly penetrating, health risk



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Dose determines health effects.

- Absorbed dose: Radiation energy absorbed
  - SI unit: Gray (Gy)
  - Older unit: rad (1 Gy = 100 rad)
- Dose equivalent: Dose x (W_r)
  - For radiation biological effect
  - SI unit: Sievert (Sv)
  - Older unit: (rem) 1 Sv = 100 rem
- Effective Dose: Dose x (W_r) x (W_t)
  - For organ sensitivity
  - W_t = 0.12 lung, bone marrow
  - W_t = 0.01 skin, bone surface
  - SI unit: Sievert (Sv)

Radiation	W_r
γ, β	1
α (internal)	20

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Level I Maximum individual dose.

- Lung dominates dose
- Max dose individual (Inhalation + fragments)
  - – 1st yr: = 190 mSv/yr
  - – 50 yr committed dose = 290 mSv
- Comparison
  - – Background: ~ 3 mSv/yr
  - – Worker limit: 50 mSv/yr
  - – Pack-a-day smoker: ~ 60 mSv/yr
  - – Worker 35 yr committed dose = 350 mSv/yr
- Fragment dose effect significant
  - – Organs 20 to 30 x inhaled dose
  - – Local effect?

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Level I Max Individual Radiological Effect.

- Linear No-threshold (LNT) model used
- Lifetime risk of radiation-induced fatal cancer:

  ~1 chance out of 70
- General population lifetime fatal cancer risk:

  ~1 chance out of 7
- Risk of radiation-induced birth defect:

  << 1 chance out of 10,000 (overestimate)
- General population risk of birth defect:

  ~1 chance out of 30

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Level I Collective Radiological Effects.

- Level I collective risk, assuming total for:
  - 60 individuals with fragments
  - 100 individuals inhalation-only
- Lifetime collective risks, radiation-induced fatal cancers:

  ~ 1 chance out of 5 any cancer in Any Level I Veteran
  (vs. ~24 fatal cancers for 160 individuals of general public)

  ~ 1 chance out of 50 leukemia
  ~ 1 chance out of 100 bone tumor
  ~ 1 chance out of 3000 lymph cancer
  Any Level I Veteran

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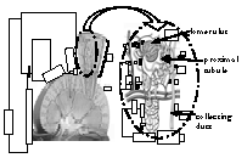
4. Heavy Metal Effects

Kidney is the target organ for DU.

- Heavy metal damage to kidney well established
  - Damage to proximal tubes
  - Depressed glomerluar function



Criterion (DOE*)	Kidney Burden μg DU / g kidney
No effect (chronic)	< 0.1
No effect* (acute)	< 1
Permitted*	< 3
LD/50*	55

2/3 kidney damage –without apparent symptoms

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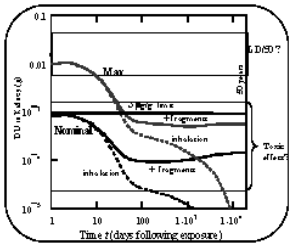
High DU mass in kidney predicted.

- Maximum case
  - No effects observed in vets
  - < 2 weeks: predict measurable effects
  - –> > 2 g inhaled unlikely
  - –> 3 μg/g, < LD/50
- Kidney resilient, but
  - Total recovery unlikely
  - Acidosis Alkalosis?
    - Disorientation
    - Fatigue
    - Spasms
    - Nervousness



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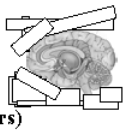
Comments.

- **Predicted risks are overestimates**
- **Lymph node W_t challenged**
  - Even if off by factor of 100, still small
- **Standard LNT challenged**
  - Too high? Too low?
  - Significant effect not likely
- **Other possible heavy metal effects**
  - Neurotoxic, hormonal, reproductive, cancer
  - Insufficient data to predict
  - Effect uncertain
- **U workers findings: (120,000 workers)**
  - Fatalities < avg. all cancers, kidney damage
  - Healthy worker effect?



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5. Summary and Conclusions

- **Inhaled mass higher than DoD estimates**
- **Significant Fragment contribution to dose**
- **Radiological effect appears insignificant**
- **Max case Kidney DU heavy metal effect uncertain**
- **Other DU chemical effects possible**

All results are preliminary

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