

*Gutta Serpente Crux*



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# Uranium Medical Research Centre



Washington, New York, Toronto, London

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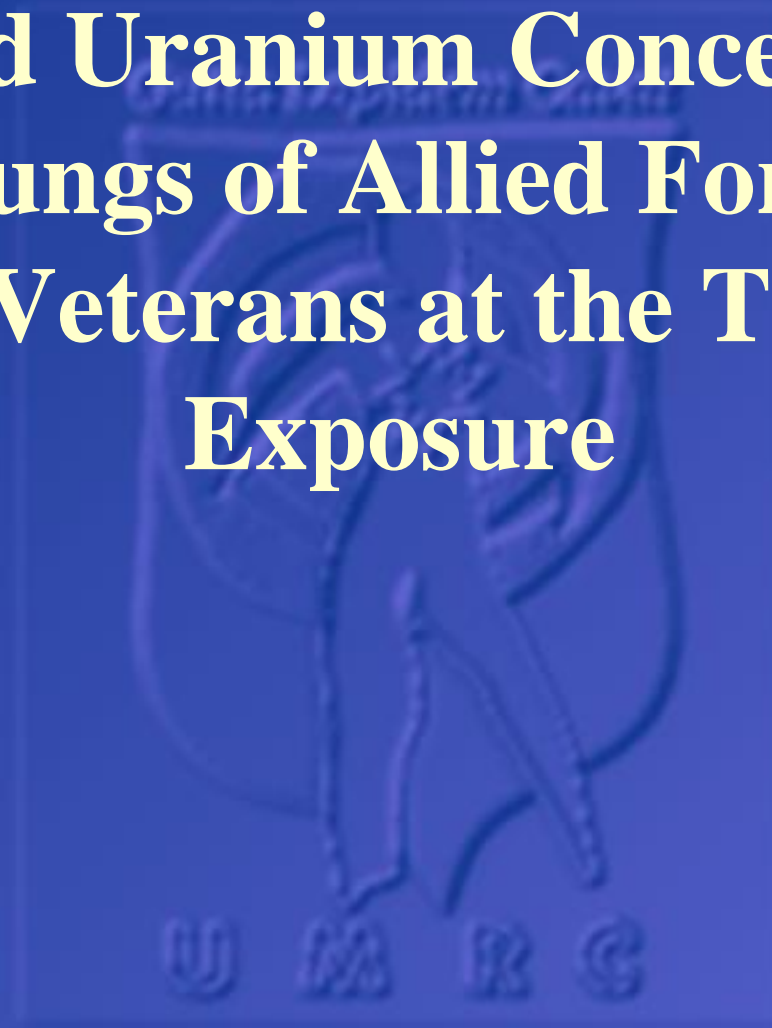
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**Depleted Uranium Concentration  
in the Lungs of Allied Forces Gulf  
War Veterans at the Time of  
Exposure**



# Objective of the Study

The purpose of this study is to report an estimate of the amount of DU in the respiratory system at the time of exposure from the quantitative current rate of daily excretion.

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# Patients and Methods

Mass spectrometry (TIMS) analysis of 24-hour urinary excretion of the isotopes of DU in five positive ( $^{238}\text{U}/^{235}\text{U} > 191.00$ ) and six negative ( $^{238}\text{U}/^{235}\text{U} < 138.25$ ) veterans were utilized in the mathematical estimation of the pulmonary body burden at the time of exposure.





# Table 1: Gravimetric Data

Patient	mg U / 24hrs	mg DU / 24hr
G.B.	$1.02 \times 10^{-5}$	$8.87 \times 10^{-8}$
P.C.	$1.21 \times 10^{-5}$	0.00
M.K.	$3.59 \times 10^{-8}$	$3.27 \times 10^{-10}$
C.P.L.	$5.45 \times 10^{-7}$	$6.00 \times 10^{-10}$
G.L.	$1.42 \times 10^{-7}$	$1.56 \times 10^{-10}$
P.R.	$7.60 \times 10^{-6}$	$1.83 \times 10^{-8}$
R.G.D.	$1.29 \times 10^{-6}$	$1.10 \times 10^{-7}$
K.I.M.	$1.41 \times 10^{-5}$	$4.18 \times 10^{-6}$
S.R.	$2.68 \times 10^{-4}$	$1.50 \times 10^{-4}$
F.S.	$1.08 \times 10^{-5}$	$4.67 \times 10^{-6}$
A.W.	$1.14 \times 10^{-5}$	$4.92 \times 10^{-6}$
Average	$3.06 \times 10^{-5}$	$1.49 \times 10^{-5}$
SD	$7.90 \times 10^{-5}$	$4.48 \times 10^{-5}$
SE	$2.38 \times 10^{-5}$	$1.35 \times 10^{-5}$

# Table 2: Isotope Ratios

Patient	$^{238}\text{U} / ^{235}\text{U}$	% DU
G.B.	138.76	0.87
P.C.	137.67	0.00
M.K.	138.80	0.91
C.P.L.	137.84	0.11
G.L.	138.10	0.11
P.R.	138.32	0.24
R.G.D.	146.96	8.52
K.I.M.	175.58	29.64
S.R.	231.34	55.86
F.S.	200.77	43.28
A.W.	200.34	43.08
Average	162.23	16.60
SD	34.03	21.84
SE	10.26	6.59



# Table 3: Ratio of Uranium Isotopes

	$^{238}\text{U}$	$^{235}\text{U}$	$^{238}\text{U} / ^{235}\text{U}$	$^{235}\text{U} / ^{238}\text{U}$
Natural Uranium	99.2739	0.7200	137.88	0.0073
Depleted Uranium	99.7945	0.2026	492.60	0.0020
Urine	99.1778	0.6542	162.23	0.0062

# Mathematical Analysis

## Half-life Equation

$$dN/dt = -\lambda * N$$

N - current concentration of depleted uranium  
when sample was taken

(dN/dt) - derivative of current concentration of  
uranium with respect to time

$\lambda$  - decay constant

# Mathematical Analysis

## Decay Equation

$$N = N_0 * e^{-\lambda t}$$

$N$  - current concentration of depleted uranium  
when sample was taken

$N_0$  - initial concentration of depleted uranium

$\lambda$  - decay constant

# Mathematical Analysis

Equation relating initial DU concentration to the rate of excretion

$$N_0 = (dN/dt) * e^{\lambda t} / \lambda$$

- $N_0$  - initial concentration of depleted uranium
- $(dN/dt)$  - derivative of current concentration of uranium with respect to time
- $\lambda$  - decay constant



# Minimum Value of the Biological Half-life of Ceramic DU

A minimum value for the biological half-life of ceramic DU oxide in the lungs was derived from the Batelle report of minimum dissolution time in simulated interstitial lung fluid corresponding to 3.85 years

# Table 4

Patient	$^{238}\text{U} / ^{235}\text{U}$	% DU	mg U / 24hrs	mg DU / 24hr	DU at $T_0$
G.B.	138.76	0.87	$1.02 \times 10^{-5}$	$8.87 \times 10^{-8}$	$9.09 \times 10^{-4}$
P.C.	137.67	0.00	$1.21 \times 10^{-5}$	0.00	0.00
M.K.	138.80	0.91	$3.59 \times 10^{-8}$	$3.27 \times 10^{-10}$	$3.35 \times 10^{-6}$
C.P.L.	137.84	0.11	$5.45 \times 10^{-7}$	$6.00 \times 10^{-10}$	$6.15 \times 10^{-6}$
G.L.	138.10	0.11	$1.42 \times 10^{-7}$	$1.56 \times 10^{-10}$	$1.60 \times 10^{-6}$
P.R.	138.32	0.24	$7.60 \times 10^{-6}$	$1.83 \times 10^{-8}$	$1.87 \times 10^{-4}$
R.G.D.	146.96	8.52	$1.29 \times 10^{-6}$	$1.10 \times 10^{-7}$	$1.13 \times 10^{-3}$
K.I.M.	175.58	29.64	$1.41 \times 10^{-5}$	$4.18 \times 10^{-6}$	$4.29 \times 10^{-2}$
S.R.	231.34	55.86	$2.68 \times 10^{-4}$	$1.50 \times 10^{-4}$	1.54
F.S.	200.77	43.28	$1.08 \times 10^{-5}$	$4.67 \times 10^{-6}$	$4.78 \times 10^{-2}$
A.W.	200.34	43.08	$1.14 \times 10^{-5}$	$4.92 \times 10^{-6}$	$5.05 \times 10^{-2}$
Average	162.23	16.60	$3.06 \times 10^{-5}$	$1.49 \times 10^{-5}$	$1.53 \times 10^{-1}$
SD	34.03	21.84	$7.90 \times 10^{-5}$	$4.48 \times 10^{-5}$	$4.59 \times 10^{-1}$
SE	10.26	6.59	$2.38 \times 10^{-5}$	$1.35 \times 10^{-5}$	$1.38 \times 10^{-1}$

# Table 5: DU Positive Patients

Patient	$^{238}\text{U} / ^{235}\text{U}$	% DU	mg U / 24hrs	mg DU / 24hr	DU at $T_0$
R.G.D.	146.96	8.52	$1.29 \times 10^{-6}$	$1.10 \times 10^{-7}$	$1.13 \times 10^{-3}$
K.I.M.	175.58	29.64	$1.41 \times 10^{-5}$	$4.18 \times 10^{-6}$	$4.29 \times 10^{-2}$
S.R.	231.34	55.86	$2.68 \times 10^{-4}$	$1.50 \times 10^{-4}$	1.54
F.S.	200.77	43.28	$1.08 \times 10^{-5}$	$4.67 \times 10^{-6}$	$4.78 \times 10^{-2}$
A.W.	200.34	43.08	$1.14 \times 10^{-5}$	$4.92 \times 10^{-6}$	$5.05 \times 10^{-2}$
Average	191.00	36.08	$6.12 \times 10^{-5}$	$3.27 \times 10^{-5}$	$3.36 \times 10^{-1}$
SD	31.57	17.98	$1.16 \times 10^{-4}$	$6.55 \times 10^{-5}$	$6.71 \times 10^{-1}$
SE	14.12	8.04	$5.19 \times 10^{-5}$	$1.97 \times 10^{-5}$	$3.00 \times 10^{-1}$

# Table 6: DU Negative Patients

Patient	$^{238}\text{U} / ^{235}\text{U}$	% DU	mg U / 24hrs	mg DU / 24hr	DU at $T_0$
G.B.	138.76	0.87	$1.02 \times 10^{-5}$	$8.87 \times 10^{-8}$	$9.09 \times 10^{-4}$
P.C.	137.67	0.00	$1.21 \times 10^{-5}$	0.00	0.00
M.K.	138.80	0.91	$3.59 \times 10^{-8}$	$3.27 \times 10^{-10}$	$3.35 \times 10^{-6}$
C.P.L.	137.84	0.11	$5.45 \times 10^{-7}$	$6.00 \times 10^{-10}$	$6.15 \times 10^{-6}$
G.L.	138.10	0.11	$1.42 \times 10^{-7}$	$1.56 \times 10^{-10}$	$1.60 \times 10^{-6}$
P.R.	138.32	0.24	$7.60 \times 10^{-6}$	$1.83 \times 10^{-8}$	$1.87 \times 10^{-4}$
Average	138.25	0.37	$5.11 \times 10^{-6}$	$1.80 \times 10^{-8}$	$1.85 \times 10^{-4}$
SD	0.47	0.41	$5.53 \times 10^{-6}$	$3.54 \times 10^{-8}$	$3.63 \times 10^{-4}$
SE	0.19	0.17	$2.26 \times 10^{-6}$	$1.45 \times 10^{-8}$	$1.48 \times 10^{-4}$

# Results

- Average total uranium concentration:  
 $3.06 \times 10^{-5}$  mg/24hr.
- Average total DU concentration:  
 $1.49 \times 10^{-5}$  mg/24hr.
- Fraction of DU: 16.60%
- Lung DU burden at  $t_0$ : 0.153 mg

# Conclusion

The presented results demonstrate significant difference of the lung burden of DU between positive and negative patients at the time of exposure.

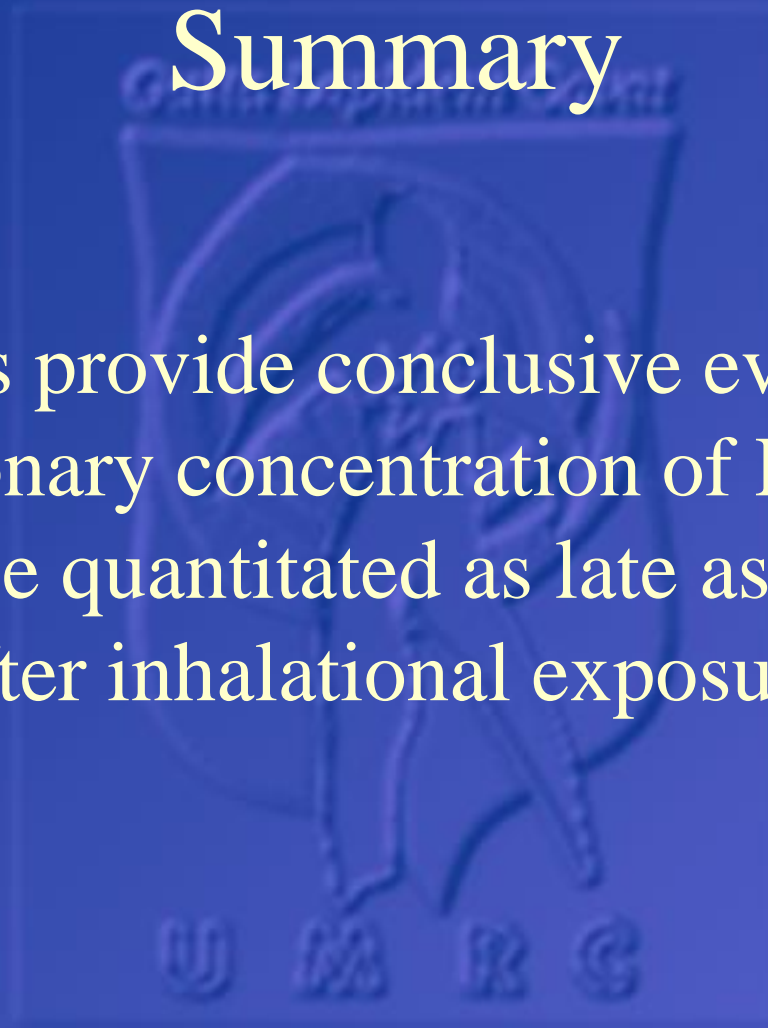
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# Summary

Our work provides a model for estimating the minimum pulmonary concentration of DU at time zero by utilizing gravimetric and mass spectrometric data of the DU isotopes in 24-hour urinary samples and theoretical model of DU dissolution time in simulated interstitial lung fluid.

# Summary

The results provide conclusive evidence that the pulmonary concentration of DU at time zero can be quantitated as late as nine years after inhalational exposure.

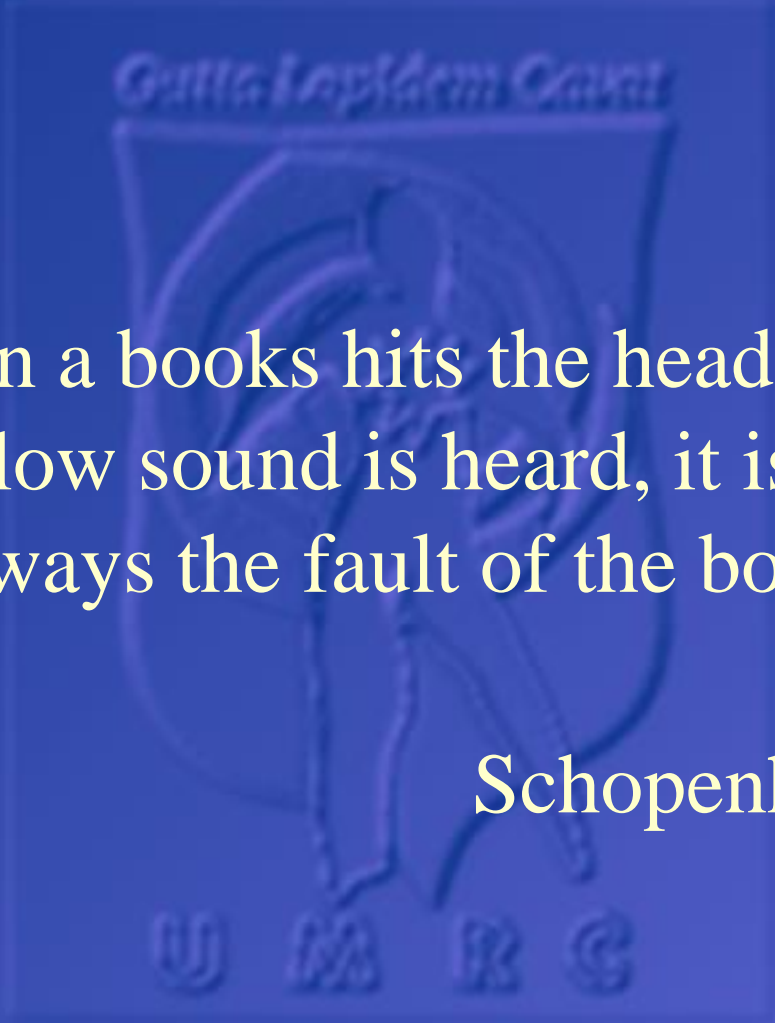






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When a books hits the head and a  
hollow sound is heard, it is not  
always the fault of the book.

Schopenhauer

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