Thyroid Dose
Acute Phase
Obtained from BNL
9/9/80

402924

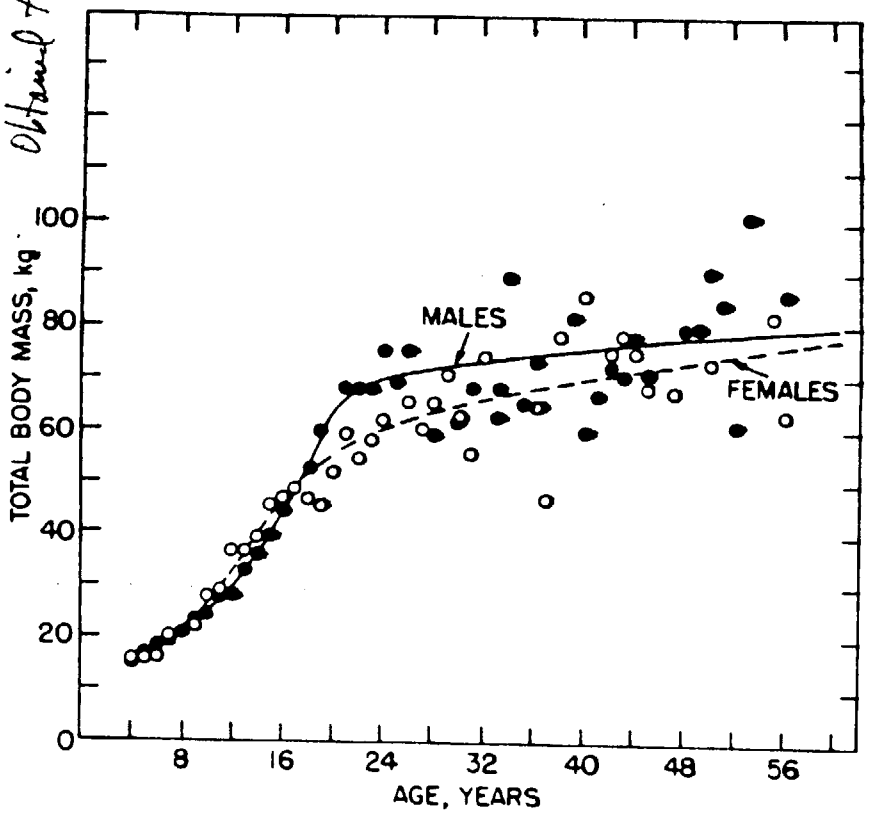



Fig. 1 Body Mass as a Function of Age for Residents of Rongelap Atoll

from 1979 Med Survey

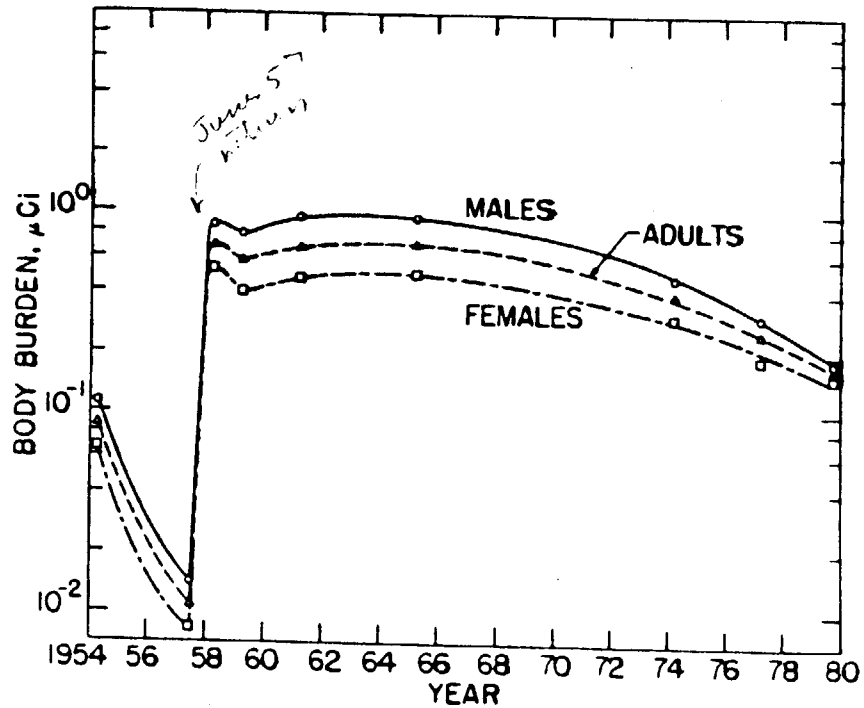



Fig. 2 Mean Adult $^{137}Cs$ Body Burden History at Rongelap Atoll

June 54 Urine

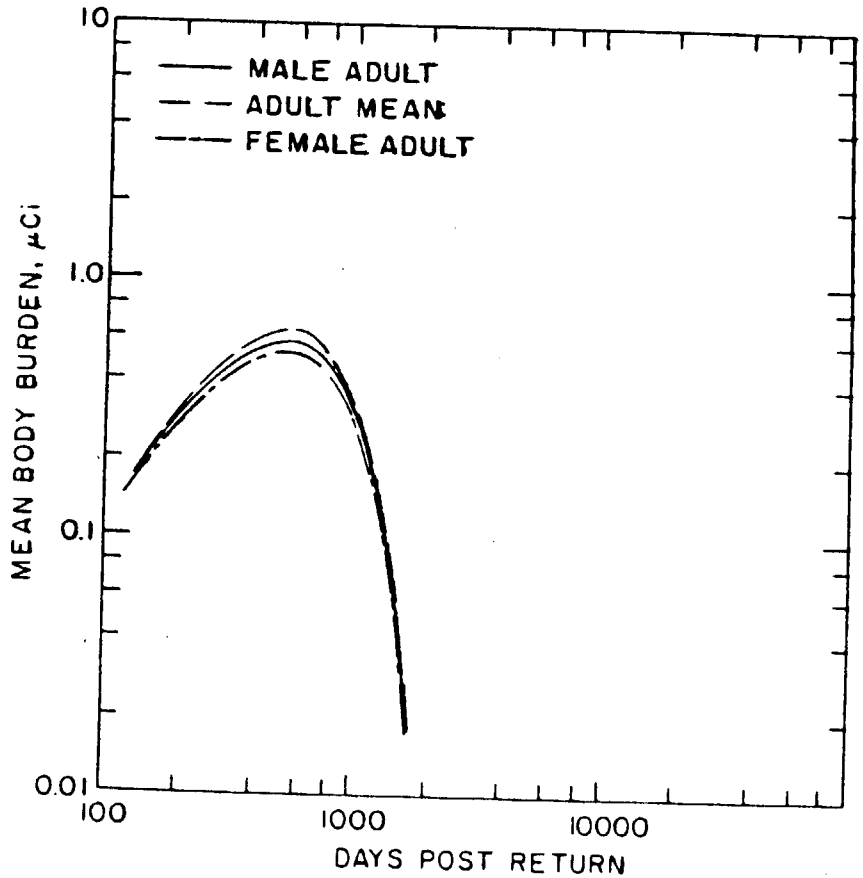



Fig. 3 Mean Adult $^{65}Zn$ Body Burden History at Rongelap Atoll

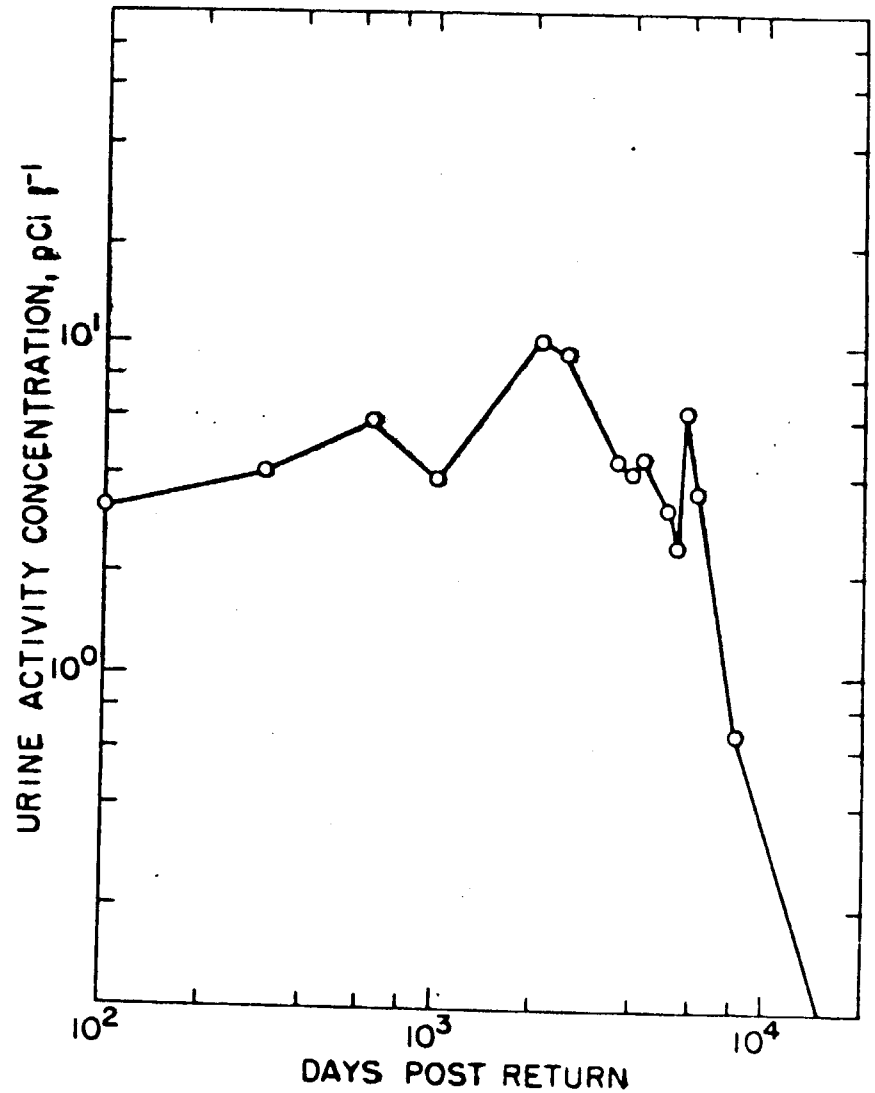



Fig. 4 Mean Adult $^{90}Sr$ Urine Activity Concentration History at Rongelap Atoll

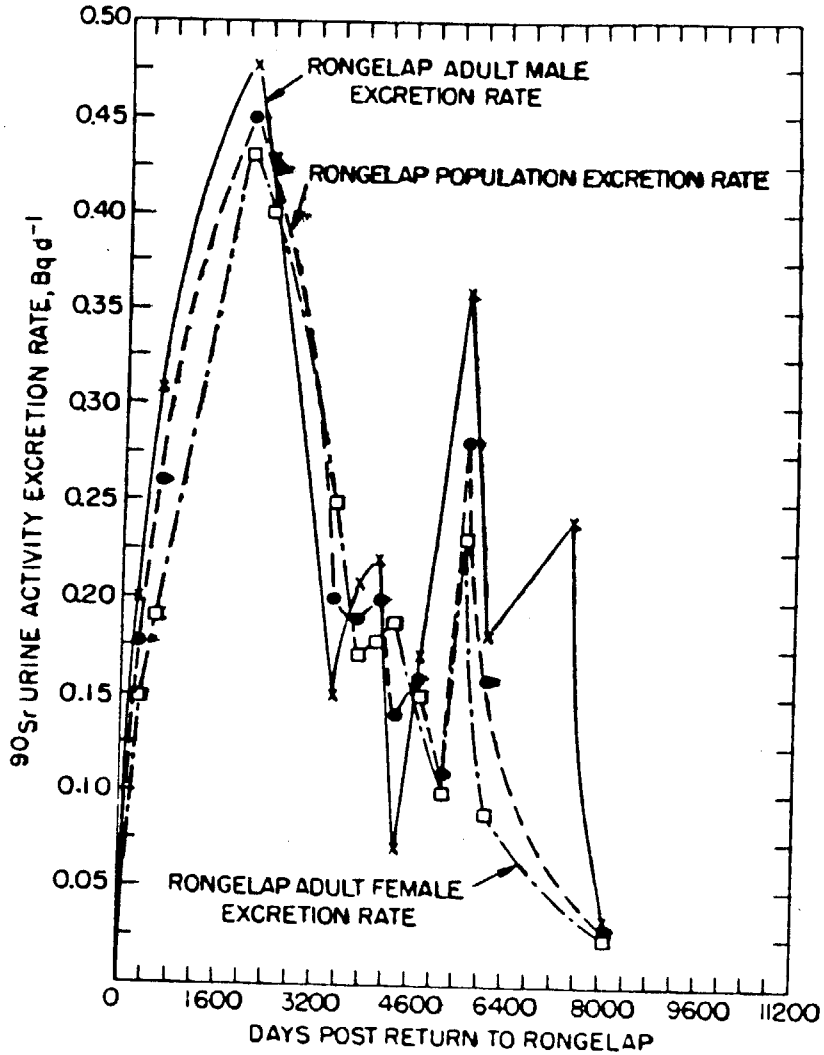



Fig. 5 Mean Adult $^{90}Sr$ Urine Activity Excretion Rate at Rongelap Atoll

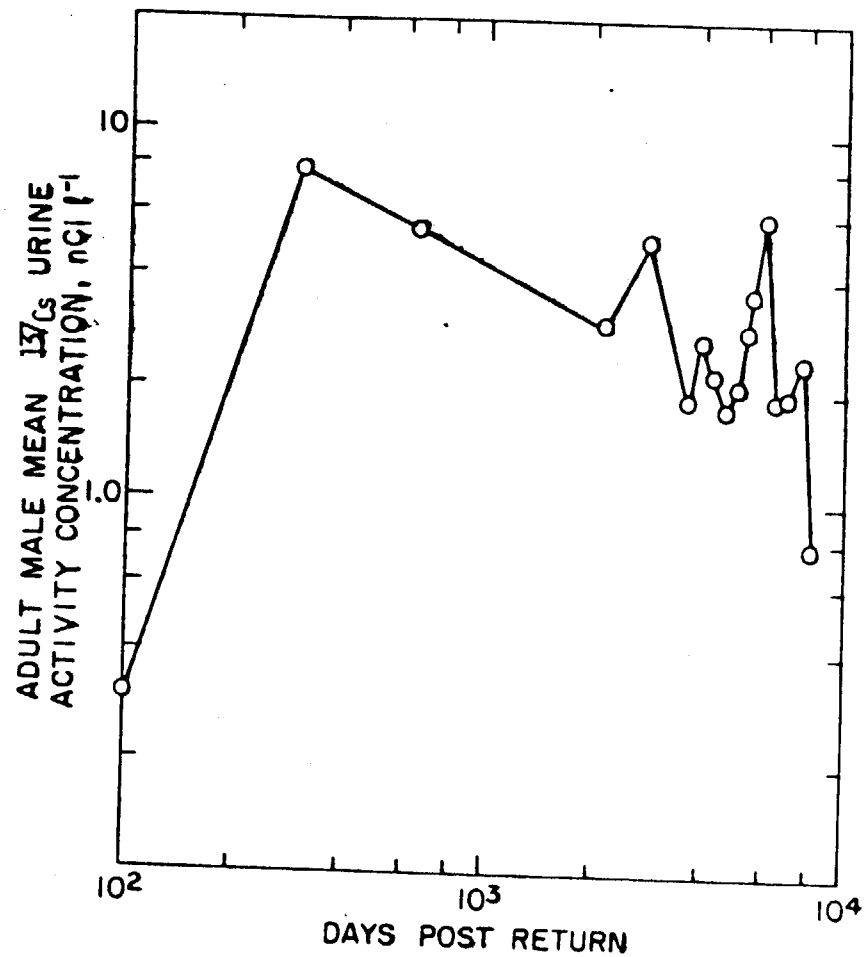



Fig. 6 Mean Adult Male $^{137}Cs$ Urine Activity Concentration History at Rongelap Atoll

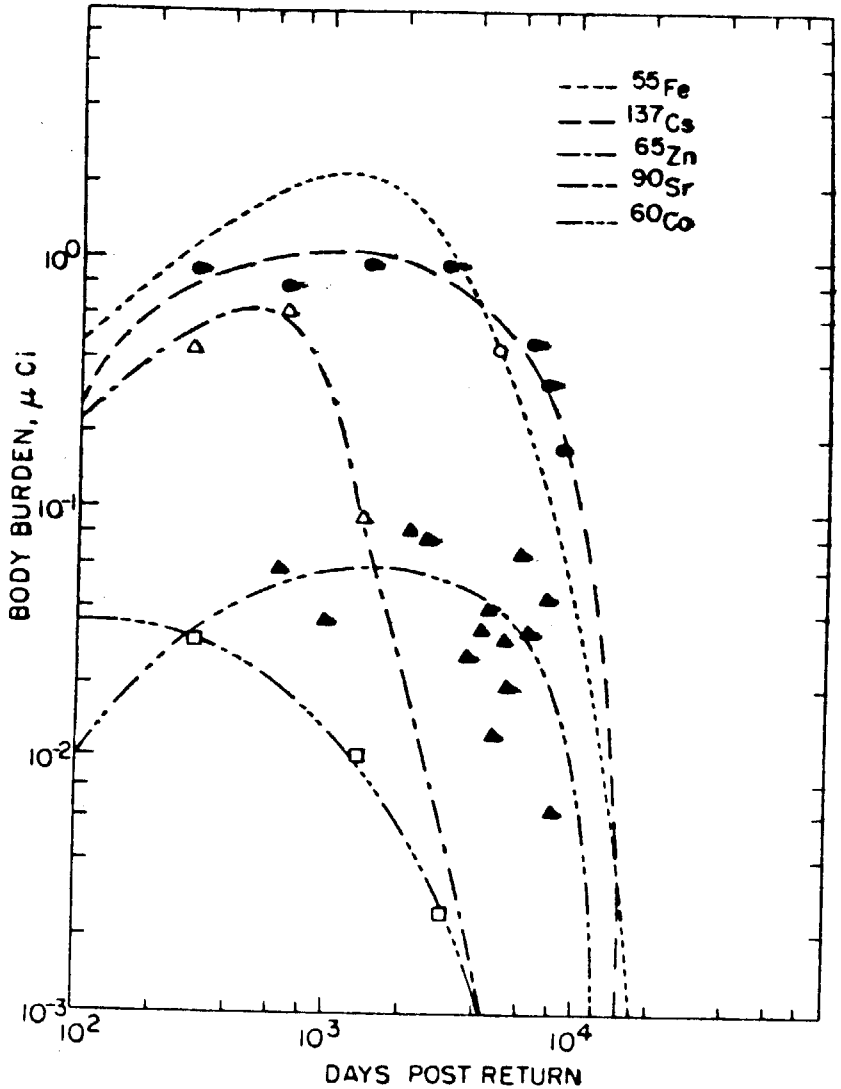



Fig. 7 Composite Nuclide Body Burden History for Adults at Rongelap Atoll

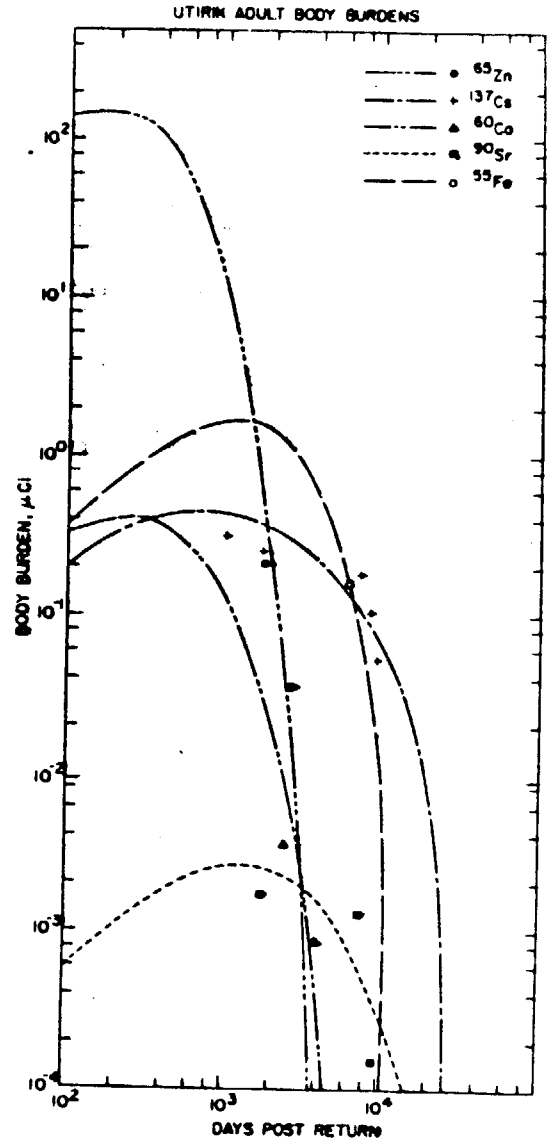



Fig. 8 Composite Nuclide Body Burden History for Adults at Utirik Atoll

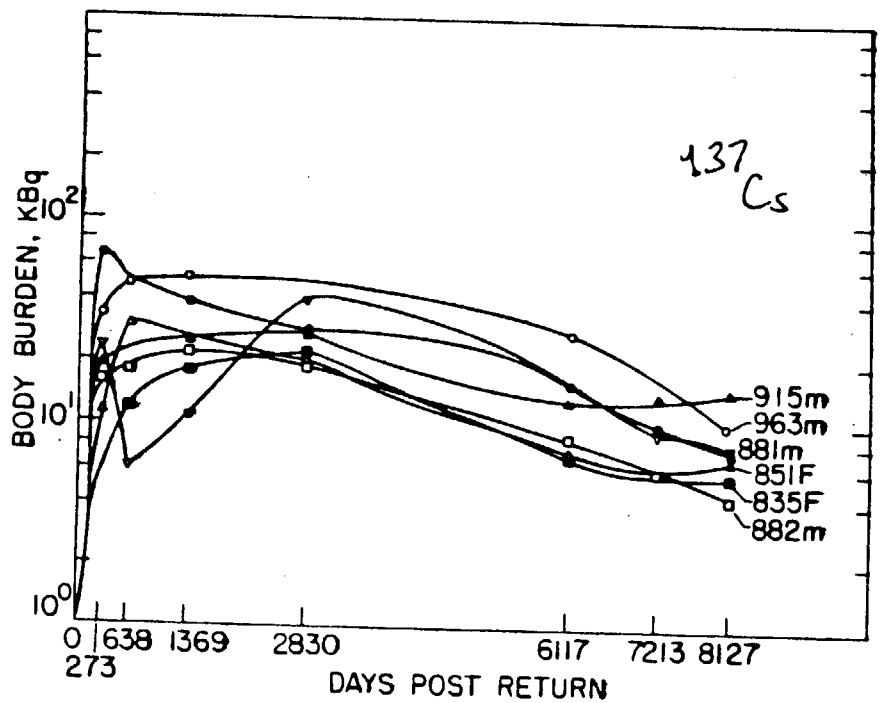



Fig. 9 Individual Male and Female Body Burden Histories Randomly Chosen from the Rongelap Atoll Population

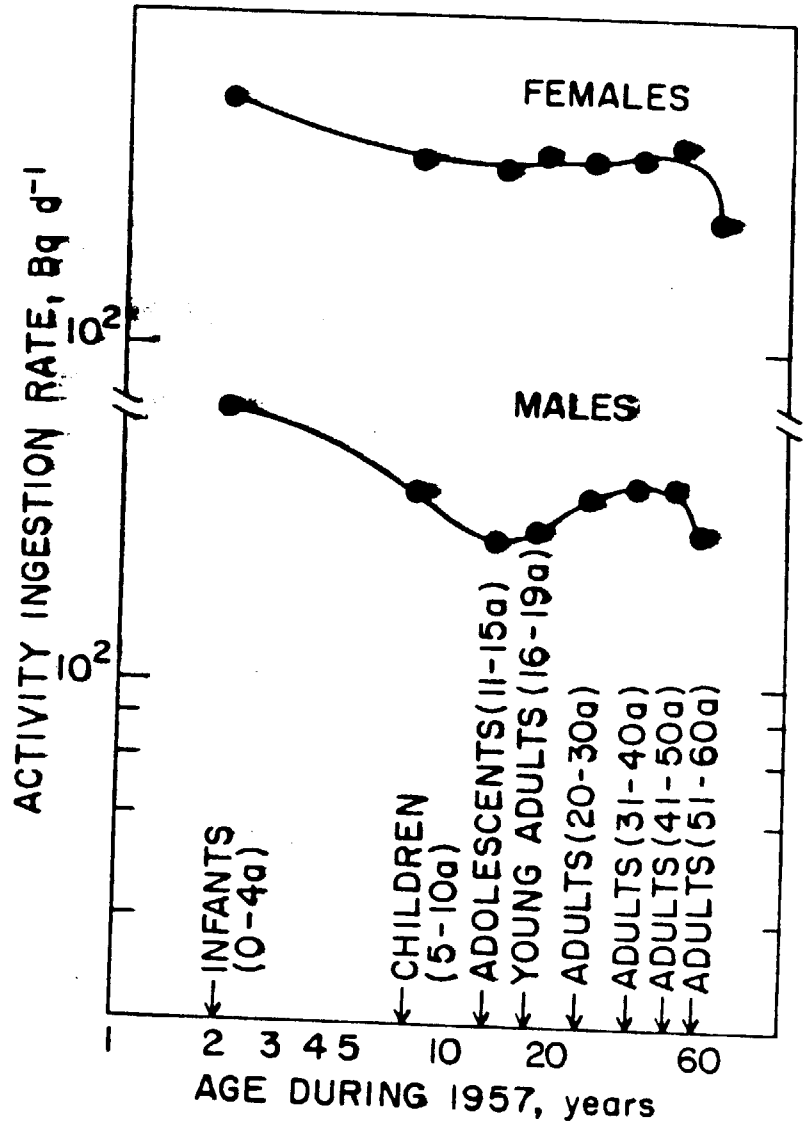



Fig. 10 Age and Sex Group Mean Values for $^{137}$Cs Activity Ingestion Rate Referenced to Mid-1957 for Rongelap Atoll

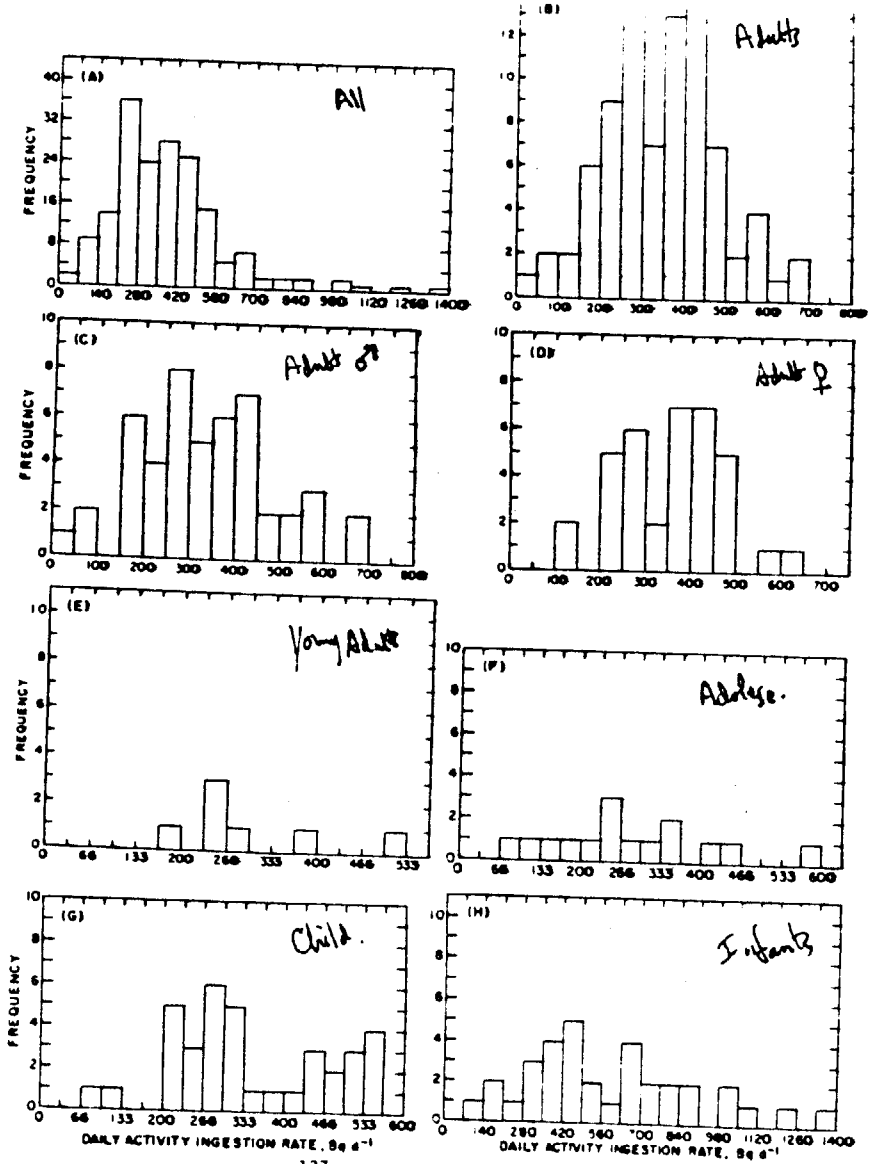



Fig. 11 $^{137}Cs$ Daily Activity Ingestion Rate for (A) All Residents (B) Adults (C) Adult Males (D) Adult Females (E) Young Adults (F) Adolescents (G) Children and (H) Infants on Rongelap Referenced to June 1957

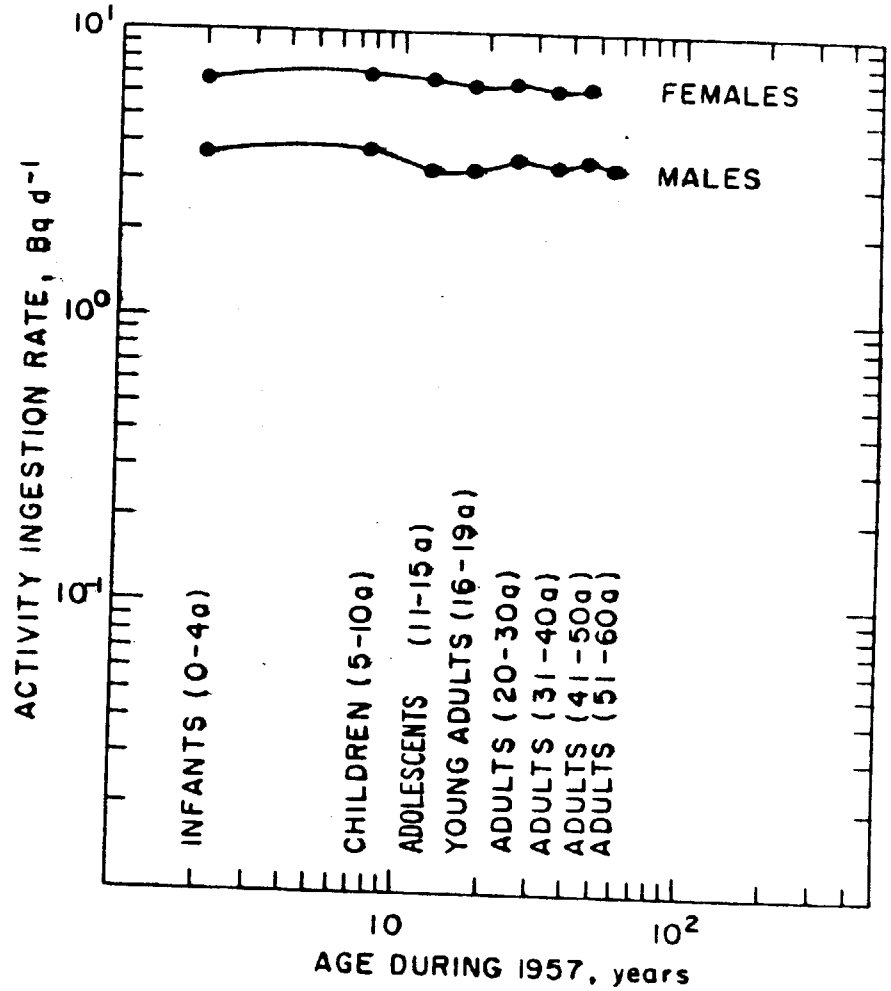



Fig. 12 Age and Sex Group Mean Values for $^{90}Sr$ Activity Ingestion Rate Referenced to Mid-1957 for Rongelap Atoll

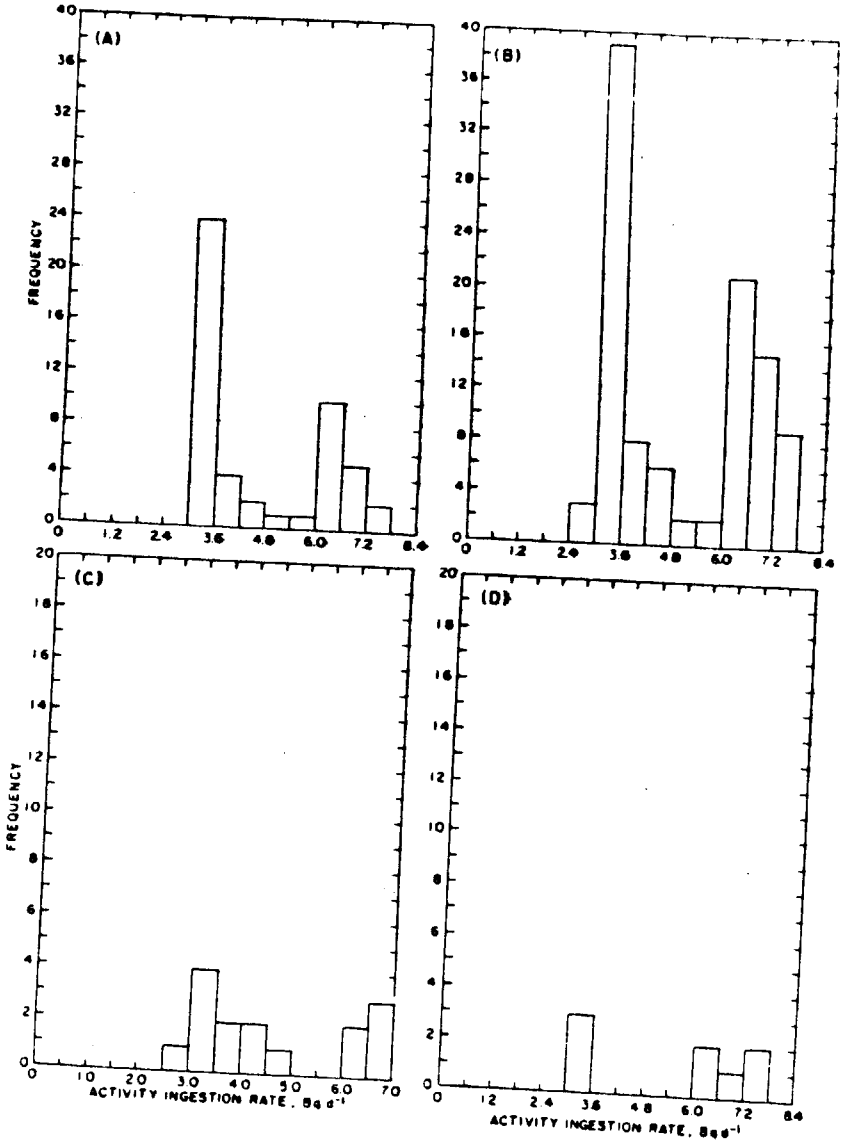



Fig. 13a $^{90}Sr$ Daily Activity Ingestion Rate for (A Adults (B) All Residents (C) Infants and (D) Adolescents on Rongelap

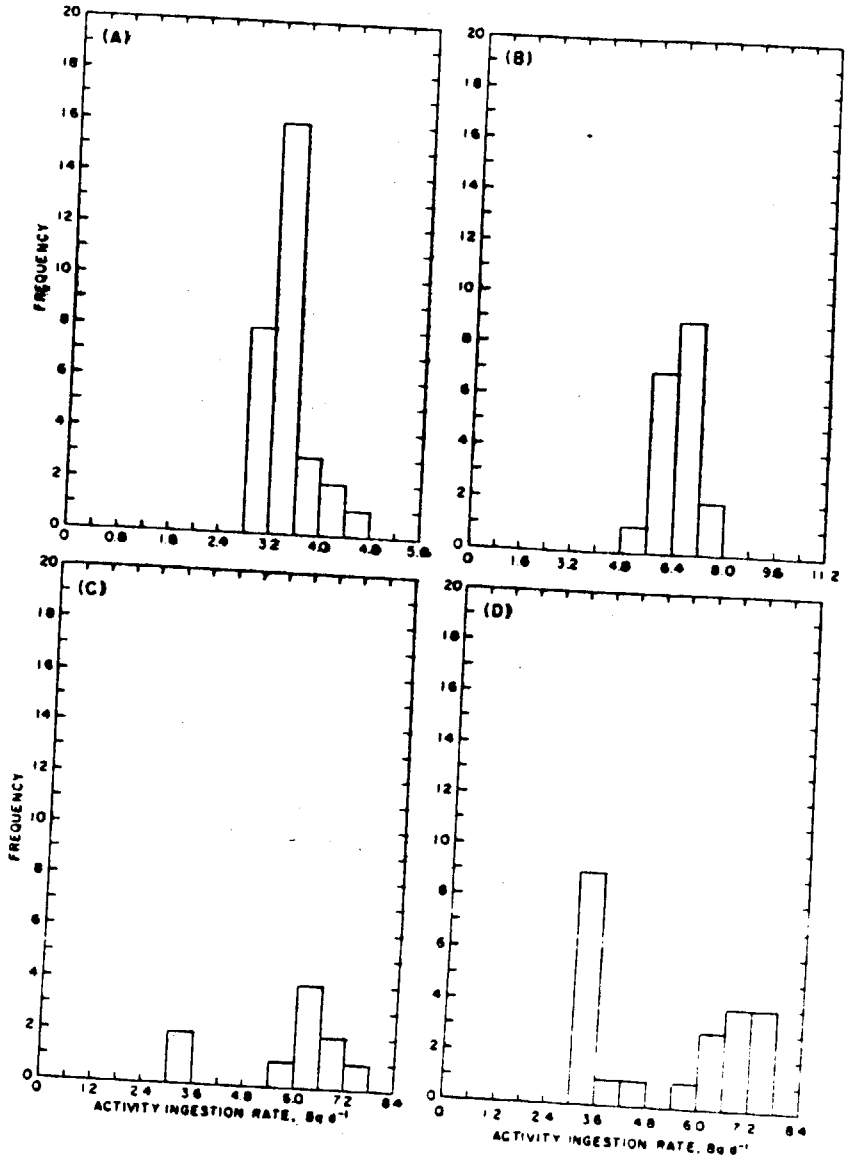



Fig. 13b $^{90}Sr$ Daily Activity Ingestion Rate for (A) Adult Males (B) Adult Females (C) Young Adults and (D) Children on Rongelap

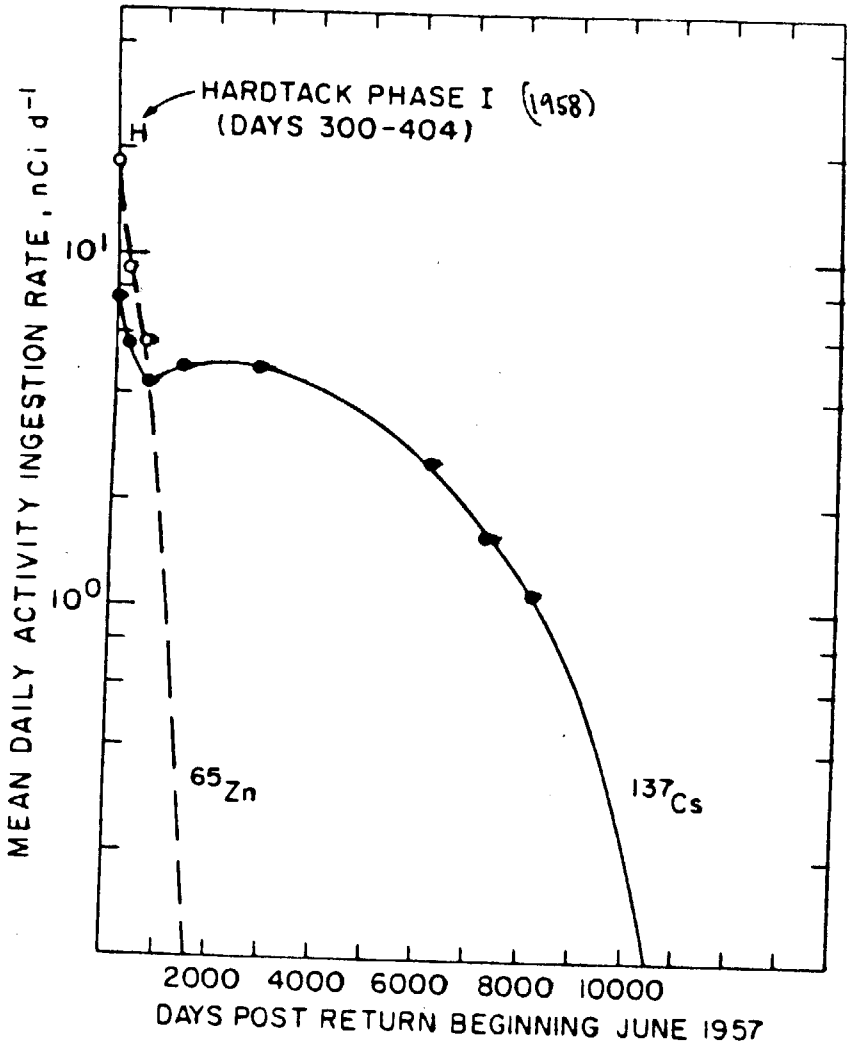



Fig. 14 Adult Mean Daily Activity Ingestion Rate for $^{137}Cs$ and $^{65}Zn$ at Rongelap Referenced to Mid-1957

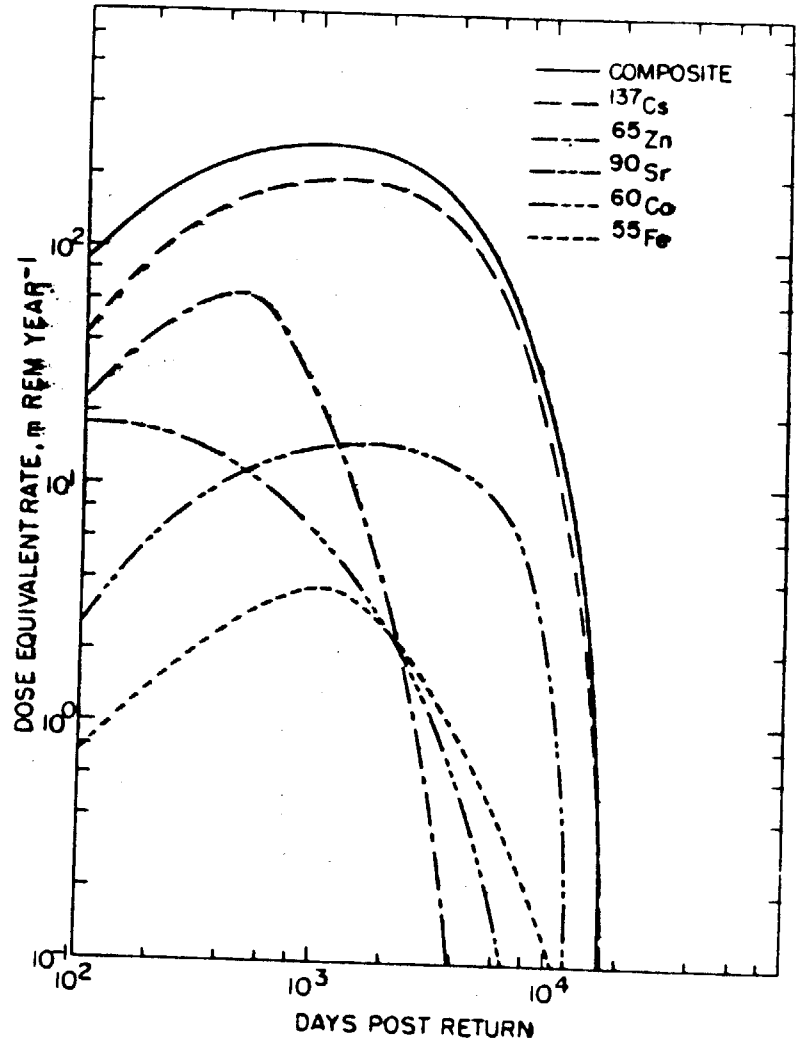



Fig. 15 Adult Mean Total Body Dose Equivalent Rate at Rongelap Atoll Post Mid-1957

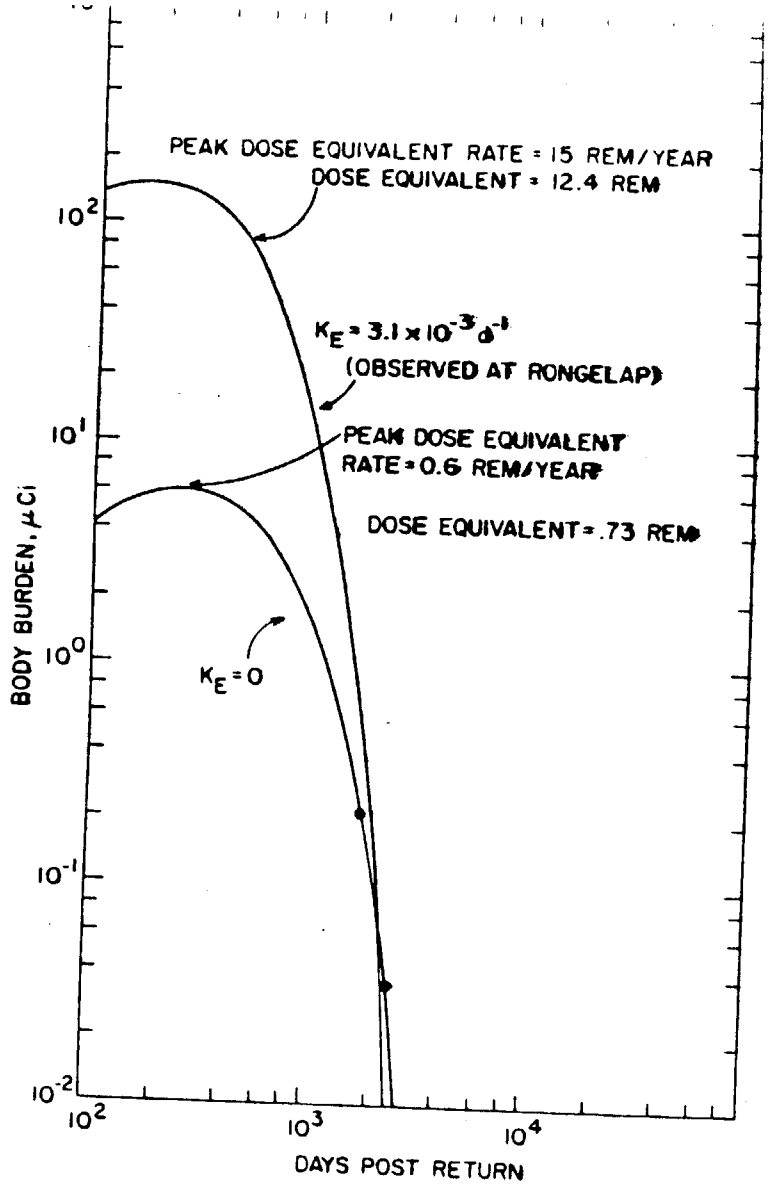



Fig. 16 Mean Adult $^{65}Zn$ Body Burden, Peak Dose Equivalent Rate and Dose Equivalent for Utirik Atoll

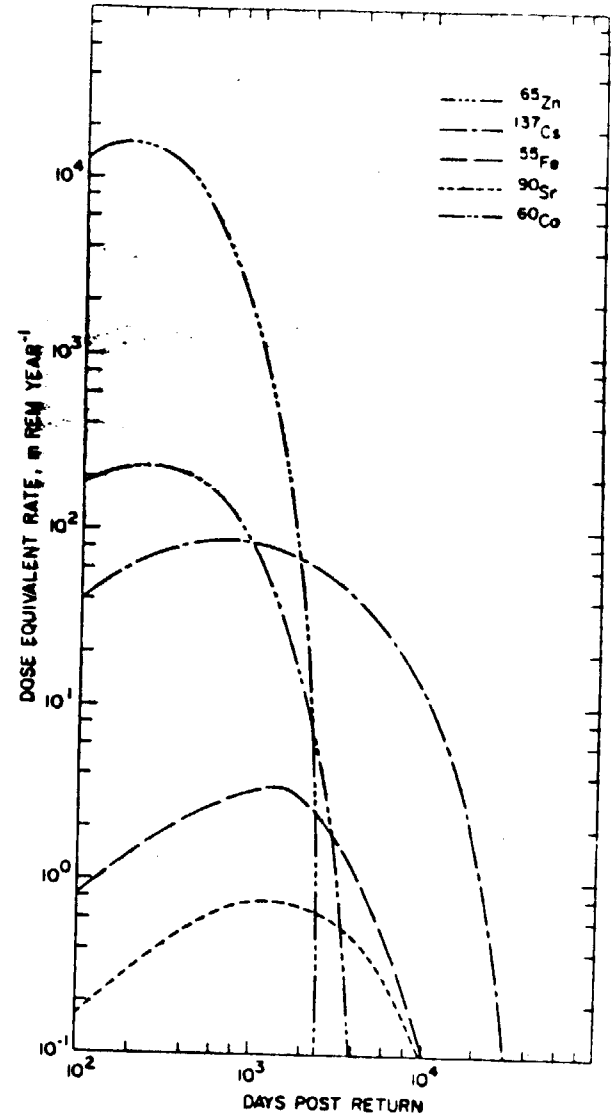



Fig. 17 Adult Mean Total Body Dose Equivalent Rate at Utirik Atoll Post Mid-1954

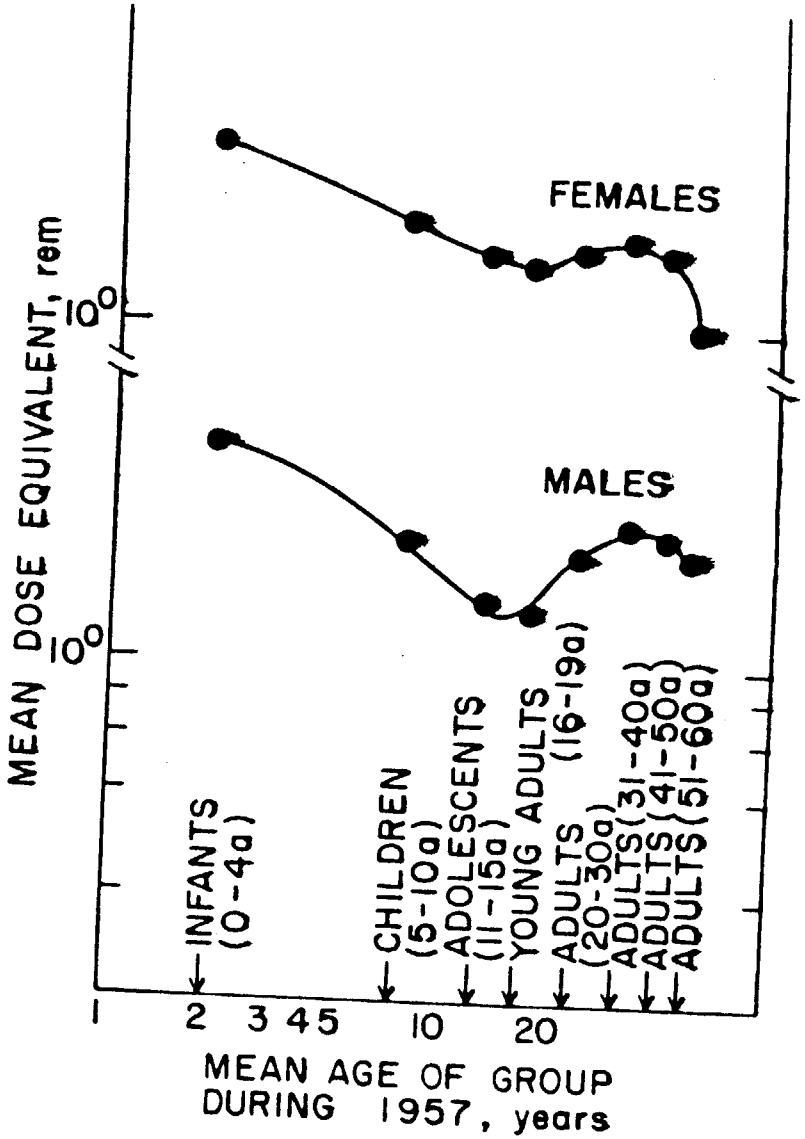



Fig. 18 $^{137}Cs$ Mean Dose Equivalent for Various Mid-1957 Age Groups for the Interval 1957 to 1980 at Rongelap Atoll

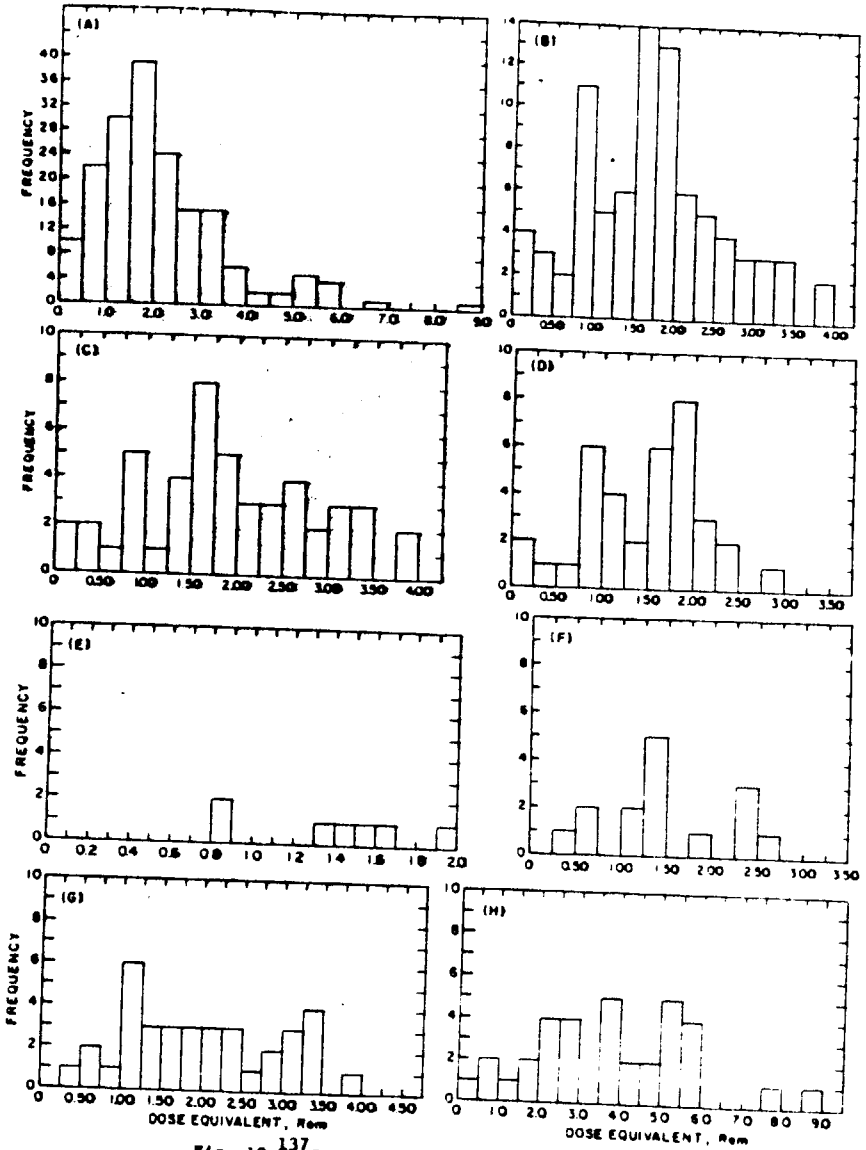



Fig. 19 $^{137}Cs$ Dose Equivalent to (A) All Residents (B) Adults (C) Adult Males (D) Adult Females (E) Young Adults (F) Adolescents (G) Children and (H) Infants on Rongelap.

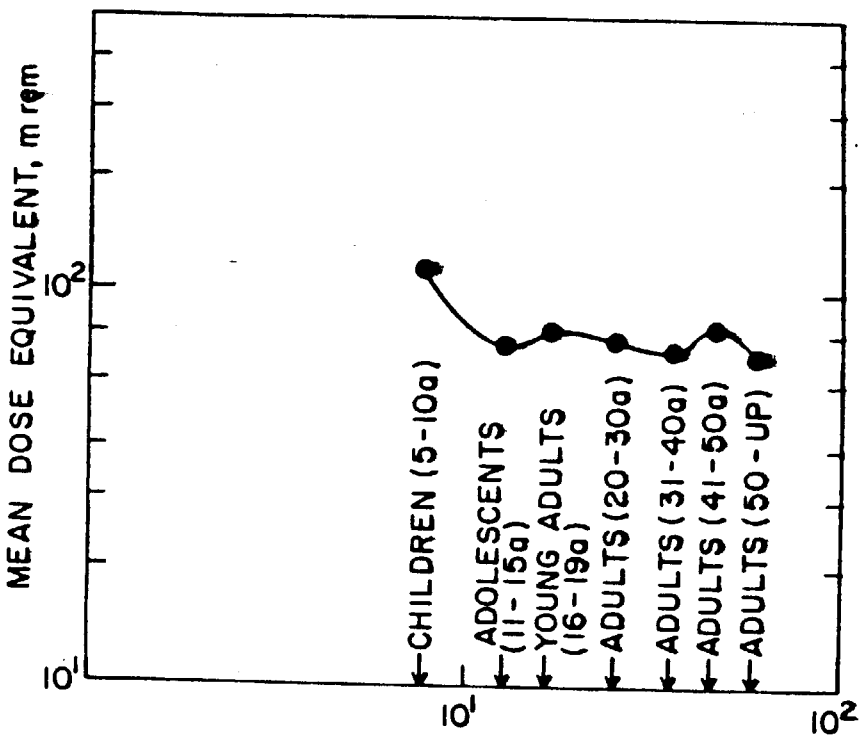



Fig. 20 $^{65}$Zn Mean Dose Equivalent for Various Mid-1957 Age Groups for the Interval 1957 to 1980 at Rongelap Atoll

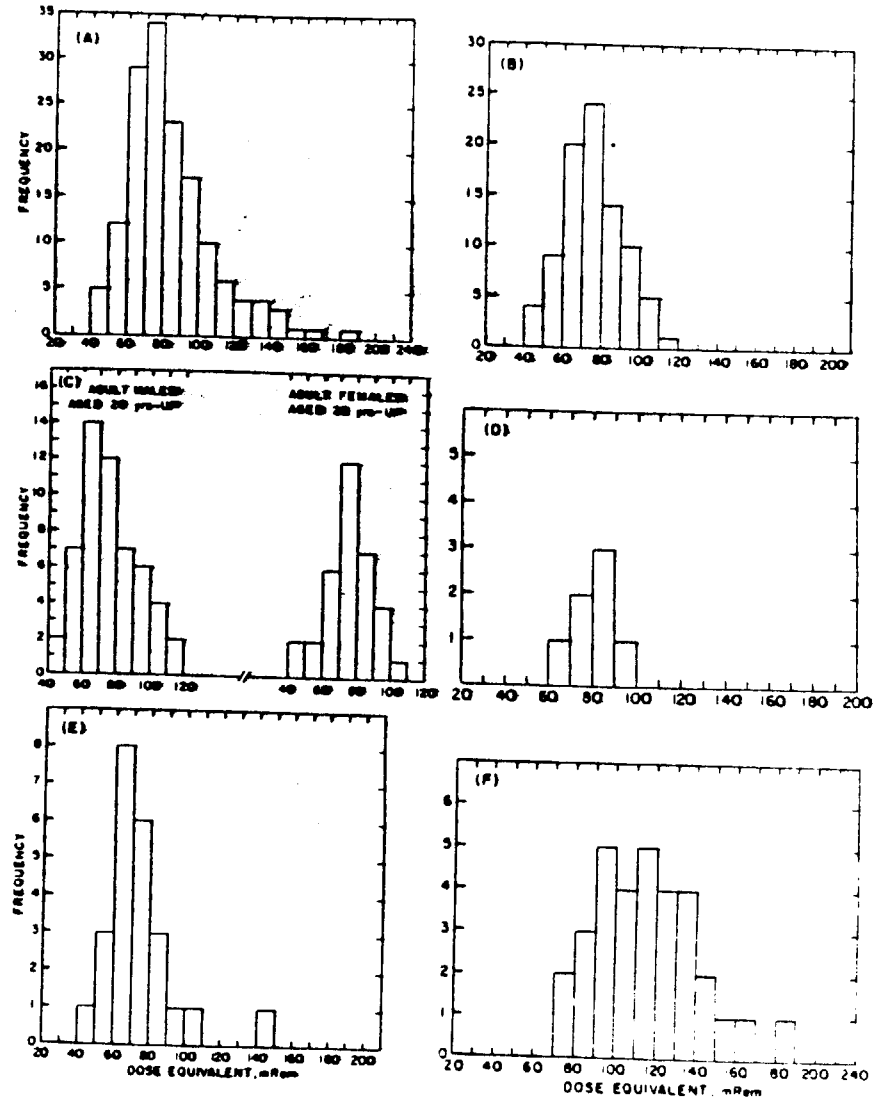



Fig. 21 $^{65}$Zn Dose Equivalent to (A) All Residents (B) Adults (C) Adult Males and Females (D) Adolescents (E) Children and (F) Infants on Rongelap Atoll.

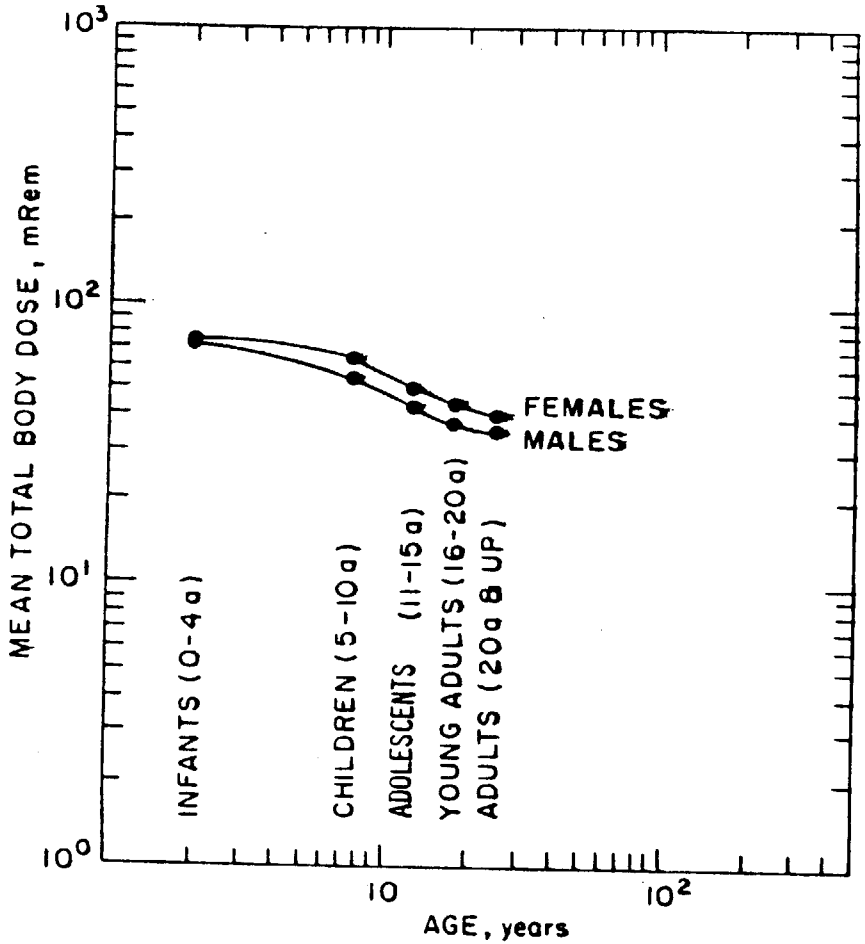



Fig. 22 Age and Sex Group Mean Values for $^{90}Sr$ Dose Equivalent for the Interval 1957 to 1980 at Rongelap Atoll

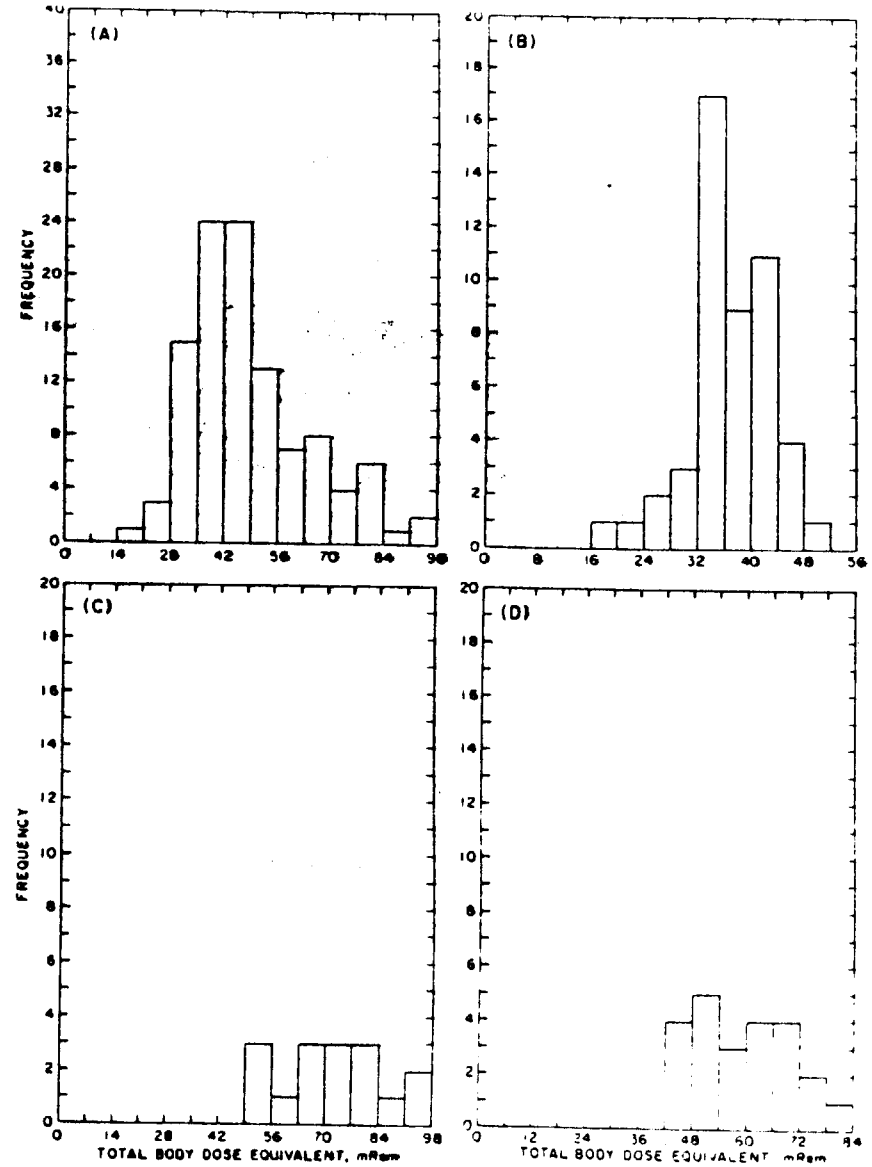



Fig. 23a $^{90}Sr$ Dose Equivalent for (A) All Residents (B) Adults (C) Infants and (D) Children on Rongelap

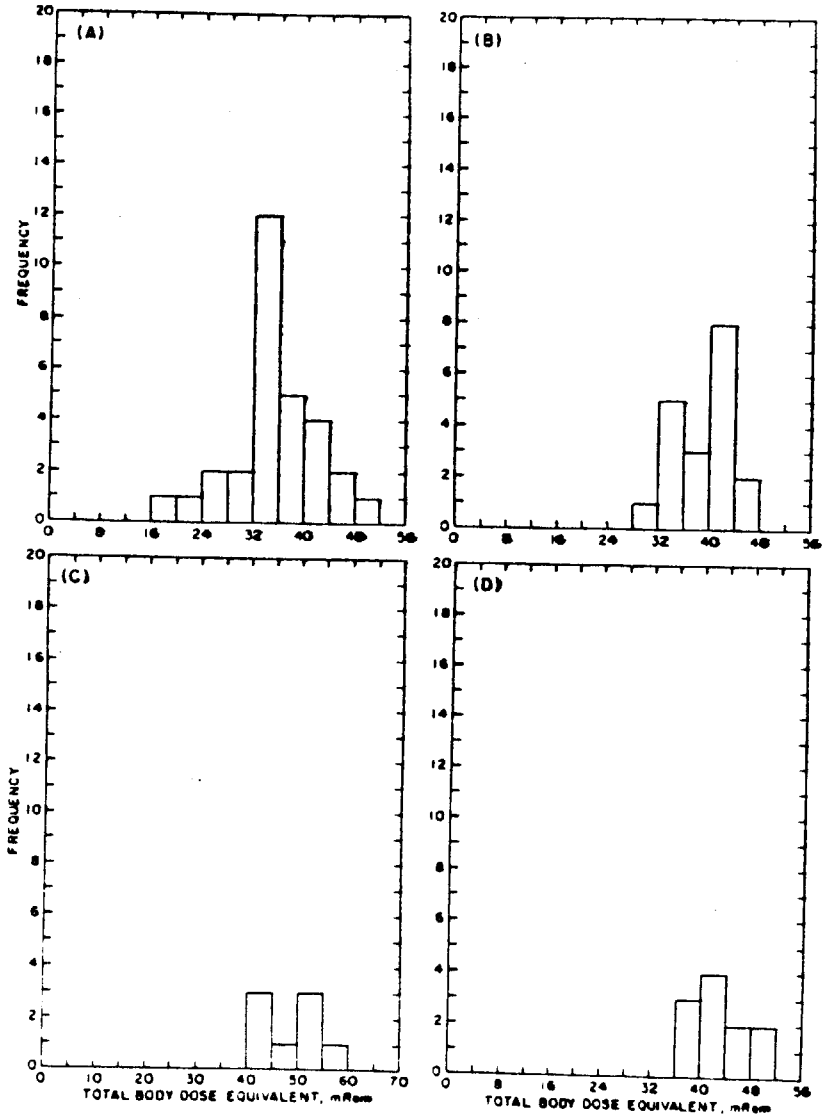



Fig. 23b $^{90}$Dose Equivalent for
(A) Adult Males (B) Adult Females
(C) Adolescents and (D) Young Adults
on Rongelap

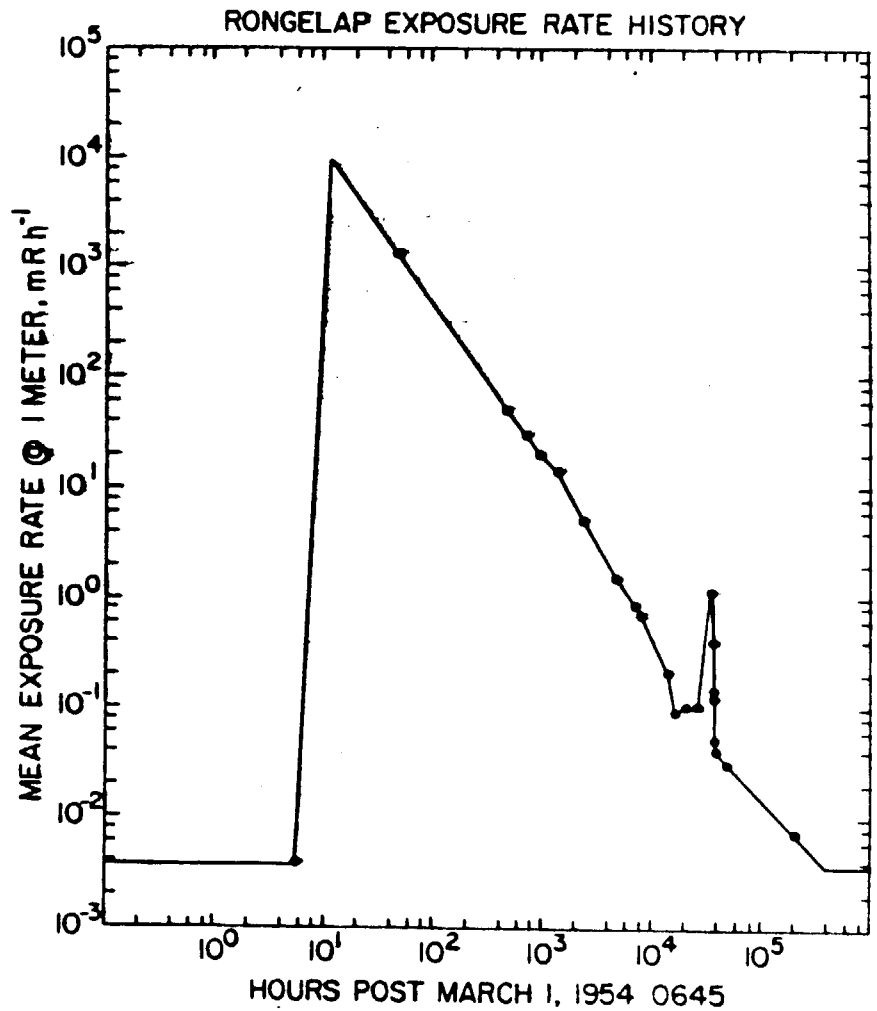



Fig. 24 Rongelap External
Exposure Rate History
Post Bravo

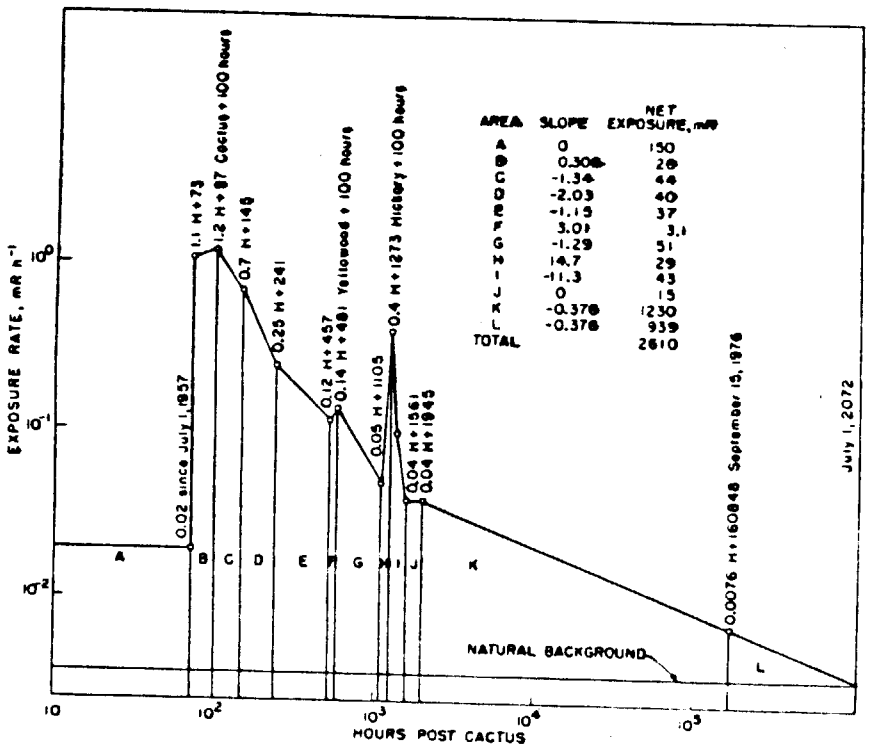



Fig. 25 Rongelap External Exposure Rate History Post Cactus

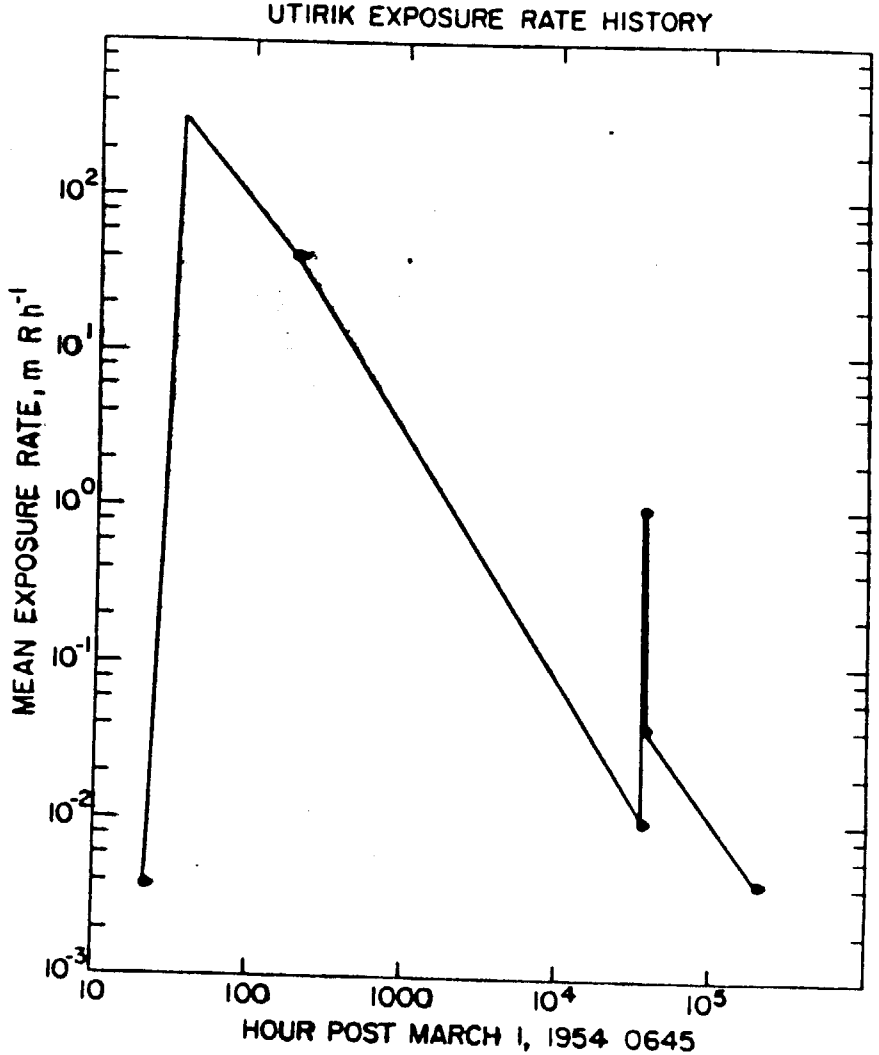



Fig. 26 Utirik External Exposure Rate History Post Bravo

Table I

Rongelap Body Burdens

| | Adult Males | | Adult Females | | Adults | | |
|---|---|---|---|---|---|---|---|
| | Body Burden μCi | Number of Persons | Body Burden μCi | Number of Persons | Body Burden μCi | Number of Persons | Days Post Return Days |
| $^{60}Co$ | $2.9\times10^{-5}$ | NA | $1.7\times10^{-5}$ | NA | $2.3\times10^{-5}$ | NA | 1 |
| | $1.0\times10^{-2}$ | 37 | $7.8\times10^{-3}$ | 37 | $9.0\times10^{-3}$ | 74 | 1370 |
| | $2.5\times10^{-3}$ | 45 | $2.0\times10^{-3}$ | 45 | $2.2\times10^{-3}$ | 90 | 2831 |
| $^{65}Zn$ | $4.3\times10^{-2}$ | NA | $3.8\times10^{-2}$ | NA | $4.1\times10^{-2}$ | NA | 1 |
| | $4.3\times10^{-1}$ | 30 | $3.8\times10^{-1}$ | 12 | $4.1\times10^{-1}$ | 42 | 304 |
| | $6.2\times10^{-1}$ | 32 | $5.0\times10^{-1}$ | 27 | $5.6\times10^{-1}$ | 59 | 639 |
| | $9.5\times10^{-2}$ | 38 | $8.5\times10^{-2}$ | 23 | $9.0\times10^{-2}$ | 61 | 1370 |
| $^{55}Fe$ | $4.3\times10^{-1}$ | 28 | $4.0\times10^{-1}$ | 32 | $4.1\times10^{-1}$ | 60 | 4626 |
| $^{90}Sr$ | $1.9\times10^{-4}$ | NA | $1.4\times10^{-4}$ | NA | $1.7\times10^{-4}$ | NA | 1 |
| | $3.7\times10^{-3}$ | 11 | $2.8\times10^{-3}$ | 4 | $3.4\times10^{-3}$ | 15 | 304 |
| | $5.7\times10^{-3}$ | 24 | $3.5\times10^{-3}$ | 16 | $4.8\times10^{-3}$ | 40 | 639 |
| | $3.7\times10^{-3}$ | 9 | $1.6\times10^{-3}$ | 4 | $3.0\times10^{-3}$ | 13 | 1370 |
| | $8.8\times10^{-3}$ | 12 | $7.9\times10^{-3}$ | 13 | $8.4\times10^{-3}$ | 25 | 2100 |
| | $7.9\times10^{-3}$ | 11 | $7.4\times10^{-3}$ | 7 | $7.7\times10^{-3}$ | 18 | 2466 |
| | $2.8\times10^{-3}$ | 12 | $4.6\times10^{-3}$ | 12 | $3.7\times10^{-3}$ | 24 | 3561 |
| | $3.9\times10^{-3}$ | 11 | $3.1\times10^{-3}$ | 11 | $3.5\times10^{-3}$ | 22 | 3927 |
| | $4.1\times10^{-3}$ | 11 | $3.3\times10^{-3}$ | 13 | $3.6\times10^{-3}$ | 24 | 4292 |
| | $1.3\times10^{-3}$ | 8 | $3.3\times10^{-3}$ | 11 | $2.5\times10^{-3}$ | 19 | 4657 |
| | $3.1\times10^{-3}$ | 8 | $2.8\times10^{-3}$ | 7 | $3.0\times10^{-3}$ | 15 | 5022 |
| | $2.0\times10^{-3}$ | 5 | $1.4\times10^{-3}$ | 7 | $1.6\times10^{-3}$ | 12 | 5388 |
| | $6.6\times10^{-3}$ | 4 | $4.2\times10^{-3}$ | 7 | $4.3\times10^{-3}$ | 13 | 5753 |
| | $3.3\times10^{-3}$ | 10 | $1.7\times10^{-3}$ | 4 | $2.8\times10^{-3}$ | 14 | 6118 |
| | $4.4\times10^{-3}$ | 23 | NA | 0 | NA | NA | 7579 |
| | $6.3\times10^{-4}$ | 24 | $4.6\times10^{-4}$ | 19 | $5.5\times10^{-4}$ | 43 | 8097 |
| $^{137}Cs$ | $1.4\times10^{-2}$ | NA | $8.4\times10^{-3}$ | NA | $1.1\times10^{-2}$ | NA | 1 |
| | $8.7\times10^{-1}$ | NA | $5.2\times10^{-1}$ | NA | $6.8\times10^{-1}$ | NA | 304 |
| | $7.9\times10^{-1}$ | 47 | $4.1\times10^{-1}$ | 49 | $5.7\times10^{-1}$ | 96 | 639 |
| | $9.5\times10^{-1}$ | 37 | $4.7\times10^{-1}$ | 37 | $6.7\times10^{-1}$ | 74 | 1370 |
| | $9.4\times10^{-1}$ | 44 | $4.9\times10^{-1}$ | 45 | $6.8\times10^{-1}$ | 89 | 2831 |
| | $4.8\times10^{-1}$ | 22 | $3.0\times10^{-1}$ | 24 | $3.9\times10^{-1}$ | 46 | 6118 |
| | $3.0\times10^{-1}$ | 30 | $1.9\times10^{-1}$ | 21 | $2.5\times10^{-1}$ | 51 | 7213 |
| | $1.8\times10^{-1}$ | 19 | $1.5\times10^{-1}$ | 18 | $1.7\times10^{-1}$ | 37 | 8097 |

NA = Not available

Table 2

Utirik Body Burdens

| | Adult Males | | Adult Females | | Adults | | |
|---|---|---|---|---|---|---|---|
| | Body Burden µCi | Number of Persons | Body Burden µCi | Number of Persons | Body Burden µCi | Number of Persons | Days Post Return Days |
| $^{60}Co$ | | | | | | | |
| D | $4.0 \times 10^{-3}$ | | $3.1 \times 10^{-3}$ | | $3.5 \times 10^{-3}$ | | 2464 |
| D | $9.7 \times 10^{-4}$ | | $7.6 \times 10^{-4}$ | | $8.7 \times 10^{-4}$ | | 3924 |
| $^{65}Zn$ | $3.5 \times 10^{-1}$* | 2 | - | | - | | |
| | $2.7 \times 10^{-1}$ | 14 | $1.6 \times 10^{-1}$ | 15 | $2.1 \times 10^{-1}$ | 29 | 1734 |
| D | $3.7 \times 10^{-2}$ | | $3.3 \times 10^{-2}$ | | $3.5 \times 10^{-2}$ | | 2464 |
| $^{55}Fe$ | | | | | | | |
| D | $1.7 \times 10^{-1}$ | | $1.6 \times 10^{-1}$ | | $1.6 \times 10^{-1}$ | | 6114 |
| $^{90}Sr$ | | | | | | | |
| | $1.4 \times 10^{-3}$ | 5 | $2.4 \times 10^{-3}$ | 2 | $1.7 \times 10^{-3}$ | 7 | 1734 |
| | $1.2 \times 10^{-3}$ | 5 | $1.3 \times 10^{-3}$ | 6 | $1.3 \times 10^{-3}$ | 11 | 7213 |
| | NA | 12 | NA | 12 | NA | 24 | 8669 |
| | $1.5 \times 10^{-4}$ | 14 | $1.5 \times 10^{-4}$ | 17 | $1.5 \times 10^{-4}$ | 31 | 9225 |
| $^{137}Cs$ | | | | | | | |
| | $4.1 \times 10^{-1}$ | NA | $2.7 \times 10^{-1}$ | NA | $3.3 \times 10^{-1}$ | NA | 1004 |
| | $2.9 \times 10^{-1}$ | 15 | $2.0 \times 10^{-1}$ | 15 | $2.5 \times 10^{-1}$ | 30 | 1734 |
| | $2.6 \times 10^{-1}$ | 9 | $1.3 \times 10^{-1}$ | 13 | $1.8 \times 10^{-1}$ | 22 | 7213 |
| | $1.2 \times 10^{-1}$ | 27 | $7.8 \times 10^{-2}$ | 21 | $1.0 \times 10^{-1}$ | 48 | 8309 |
| | $6.2 \times 10^{-2}$ | 19 | $4.3 \times 10^{-2}$ | 17 | $5.3 \times 10^{-2}$ | 36 | 9225 |

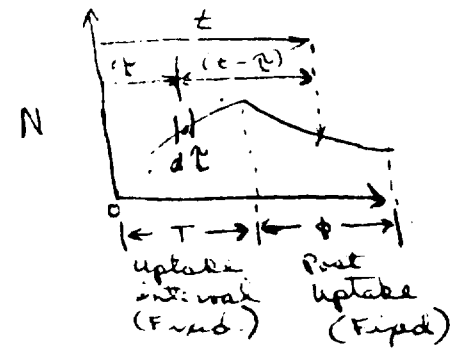
D = Ratio derived body burden
NA = Not available
* = Measured at Argonne National Laboratory

Table 4

Total Body Dosimetric and Physiologic Data

| Nuclide $^{A}_{Z}X$ | Compartment Deposition Fraction $X_i$ | Compartment Removal Rate Constant $K_i$ $d^{-1}$ | GI Tract to Blood Transfer $f_1$ | Fraction Excreted in Urine $f_u$ | Decay Constant $\lambda$ $d^{-1}$ | Significant Progeny $^{A}_{Z}X$ | Branching Ratio |
|---|---|---|---|---|---|---|---|
| $^{137}_{55}Cs$ | 0.13<br>0.87 | 0.50<br>0.0051 | 1.0 | 0.90 | $6.3\times10^{-5}$ | $^{137m}_{56}Ba$ | 0.946 |
| $^{65}_{30}Zn$ | 0.25<br>0.75 | 0.058<br>0.0022 | 0.35 | 0.25 | $2.8\times10^{-3}$ | $^{65*}_{29}Cu$ | 0.49 |
| $^{90}_{38}Sr$ | 0.89<br>0.059<br>0.051 | 0.21<br>$7.1\times10^{-4}$<br>$1.0\times10^{-4}$ | 0.20 | 0.85 | $6.5\times10^{-5}$ | $^{90}_{39}Y$<br>$^{90*}_{40}Zr$ | 1.0<br>0.0002 |
| $^{60}_{27}Co$ | 0.5<br>0.3<br>0.1<br>0.1 | 1.4<br>0.12<br>0.012<br>$8.7\times10^{-4}$ | 0.05 | 0.70 | $3.6\times10^{-4}$ | $^{60*}_{28}Ni$ | 1.0 |
| $^{55}_{26}Fe$ | 1.0 | $3.5\times10^{-4}$ | 0.1 | 0.0 | $7.0\times10^{-3}$ | | |

# DEVELOPMENT OF DOSIMETRIC EQUATIONS




$f_1 P(\tau) \equiv f_1 P^0 e^{-(k_e+\lambda)\tau}$, GI tract to blood function

$r(t-\tau) \equiv \sum_i x_i e^{-(\lambda+k_i)(t-\tau)}$, whole body retention function

Instantaneous number of atoms injected into blood during $d\tau$,

$$f_1 P^0 e^{-(k_e+\lambda)\tau} d\tau .$$

instantaneous number of atoms at time $t-\tau$ that remain following input during $d\tau$,

$$f_1 P^0 e^{-(k_e+\lambda)\tau} d\tau \; r(t-\tau) .$$

Instantaneous number of atoms @ $t-\tau$ that remain following input during $T$,

$$N = \int_{\tau=0}^{\tau=T} f_1 P^0 e^{-(k_e+\lambda)\tau} d\tau \; r(t-\tau) .$$

$$N = f_1 P^0 \int_{t=0}^{t=T} \sum_i x_i e^{-(k_e+\lambda)\tau} e^{-(\lambda+k_i)t} e^{(\lambda+k_i)\tau} d\tau$$

$$N = f_1 P^0 \sum_i x_i e^{-(k_i+\lambda)t} \left(e^{(k_i-k_e)T} - 1\right)$$

for $t = T$

$$\lambda N = \lambda P^{\circ} f_1 \sum_i x_i \frac{\left(e^{-(\lambda+K_e)T} - e^{-(\lambda+K_i)T}\right)}{K_i - K_e}$$

for $t = T + \phi$

$$\lambda N = \lambda P^{\circ} f_1 \sum_i \frac{x_i \left(e^{-(\lambda+K_e)T} - e^{-(\lambda+K_i)T}\right) e^{-(\lambda+K_i)\phi}}{K_i - K_e}$$

for $t = T + \phi$ and initial contamination

$$\lambda N = \frac{\lambda P^{\circ} f_1 \sum_i x_i \left(e^{-(\lambda+K_e)T} - e^{-(\lambda+K_i)T}\right) e^{-(\lambda+K_i)\phi}}{K_i - K_e} + q_b^{\circ} \sum_i x_i e^{-(K_i}$$

Utirik June '59 to Jan '80
Rong June '57 to " "

Chronic Phase

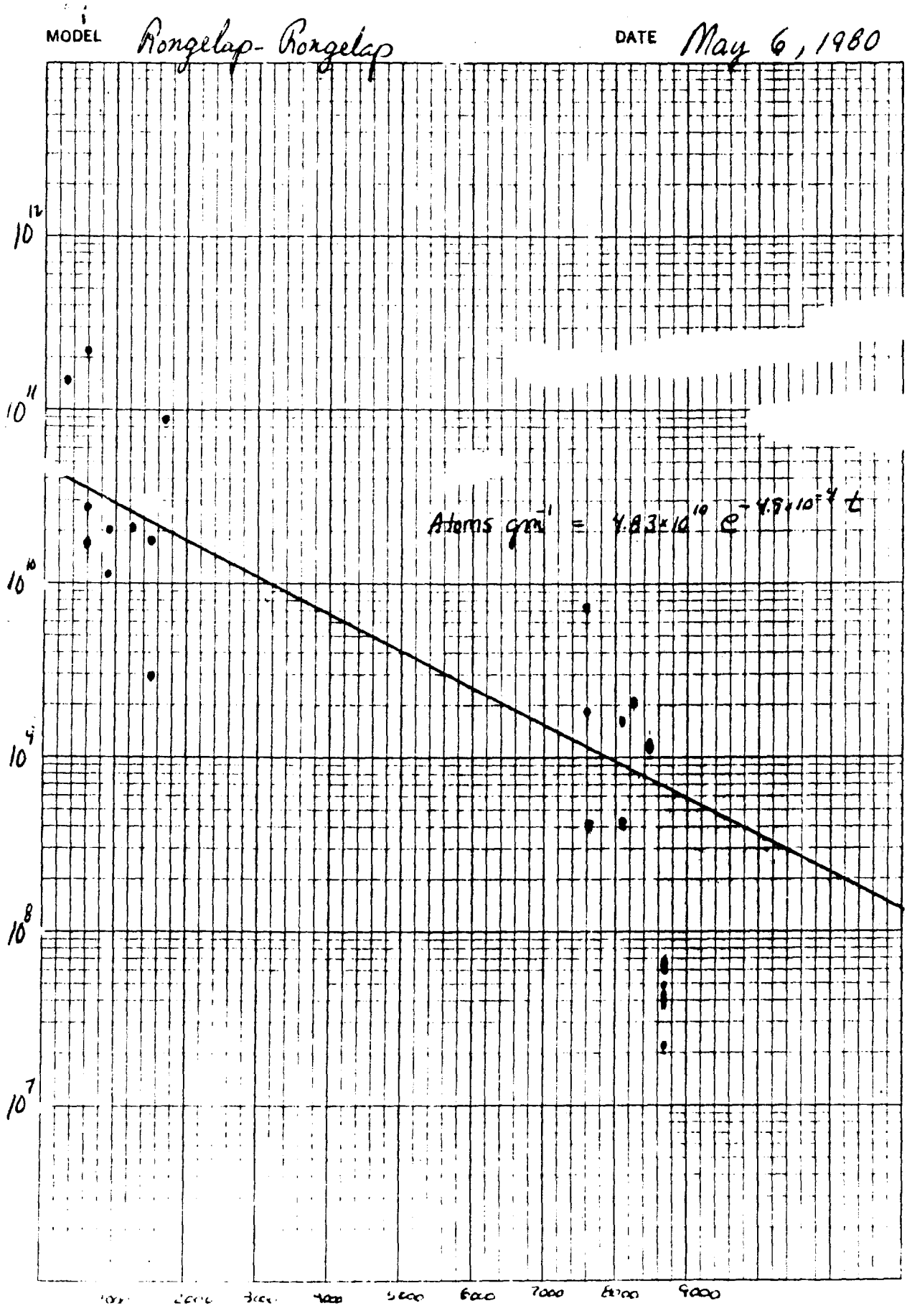
D.E and Committed Dose Equivalent Summary, Rem

| Nuclide | Total Body: Utirik Adults | Total Body: Rongelap Adults | Thyroid: Utirik Adults | Thyroid: Rongelap Adults |
|---|---|---|---|---|
| $^{90}Sr$ | .0118 | .0267 | .000749 | .00169 |
| $^{55}Fe$ | .0329 | .0230 | .0594 | .0415 |
| $^{137}Cs$ | 1.13 | 1.71 | 1.55 | 2.35 |
| $^{60}Co$ | .507 | .0143 | .359 | .0101 |
| $^{65}Zn$ | 12.5 | .0757 | 11.1 | .0672 |
| Internal | 14.2 | 1.85 | 13.1 | 2.47 |
| External | 3.19 | 2.02 | 3.19 | 2.02 |
| Total | 17.4 | 3.87 | 16.3 | 4.49 |

| | Red Marrow | | Testes-Ovaries | |
|---|---|---|---|---|
| $^{90}Sr$ | .0537 | .123 | .000749-.000749 | .00169-.00169 |
| $^{55}Fe$ | .0603 | .0422 | .0583-.0620 | .0736-.0433 |
| $^{137}Cs$ | 1.70 | 2.57 | 1.54-1.74 | 2.33-2.63 |
| $^{60}Co$ | .629 | .0177 | .443-1.78 | 0.12-.0502 |
| $^{65}Zn$ | 17.2 | .103 | 11.3-16.3 | .0685-.0988 |
| Internal | 19.6 | 2.86 | 13.3-19.9 | 2.49-2.82 |
| External | 3.19 | 2.02 | 3.19 | 2.02 |
| Total | 22.8 | 4.88 | 16.5-23.1 | 4.51-4.84 |

| | Lower Large Intestine Wall | | Liver | |
|---|---|---|---|---|
| $^{90}Sr$ | .225 | .567 | .000671 | .00152 |
| $^{55}Fe$ | .0666 | .0465 | .115 | .0804 |
| $^{137}Cs$ | .591 | .895 | 1.81 | 2.74 |
| $^{60}Co$ | 4.66 | .132 | .792 | .0223 |
| $^{65}Zn$ | 15.0 | .0910 | 16.5 | .136 |
| Internal | 20.5 | 1.73 | 19.2 | 2.98 |
| External | 3.19 | 2.02 | 3.19 | 2.02 |
| Total | 23.7 | 3.75 | 22.4 | 5.00 |

I-129 Average Atom Density of Soil Samples




K+E SEMI-LOGARITHMIC 7 CYCLES X 6½ DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 6460

## Soil Samples

Soil samples consisted of entire first inch of soil. Since, $\bar{x}$, the relaxation depth ~~mean free path~~ is 3 cm, the soil sample does not represent a kernel. It expresses the average activity in the sample.

The total number of atoms in an areal plot 2.54 cm deep is

$$\int_0^{2.54} N\,dx = \int_0^{2.54} N_0\, e^{-\mu x}\, dx ,$$

where $N_0 \equiv$ atoms $cm^{-3}$ at depth $x = 0$,

$N \equiv$ atoms $cm^{-3}$ at depth $x$,

$\mu \equiv$ instantaneous fraction of atom concentration remaining at depth $x$.

The average atom concentration is

$$\frac{\int_0^{2.54} N_0\, e^{-\mu x}\, dx}{2.54 \text{ cm}} .$$

The average atom density, $C$, is

$$C = \frac{N_0 \left[1 - e^{-2.54\mu}\right]}{\mu\, \rho_{soil}\, (2.54 \text{ cm})} .$$

The total number of atoms $cm^{-2}$ in an areal plot of infinite depth

$$C_A = \int_0^{\infty} N_0\, e^{-\mu x}\, dx = \frac{N_0}{\mu} .$$

## Soil Samples

Thus,

$$C_A = 6.23\,C, \text{ atoms cm}^{-2},$$

where $C$ has units of atoms I-129 per gm.

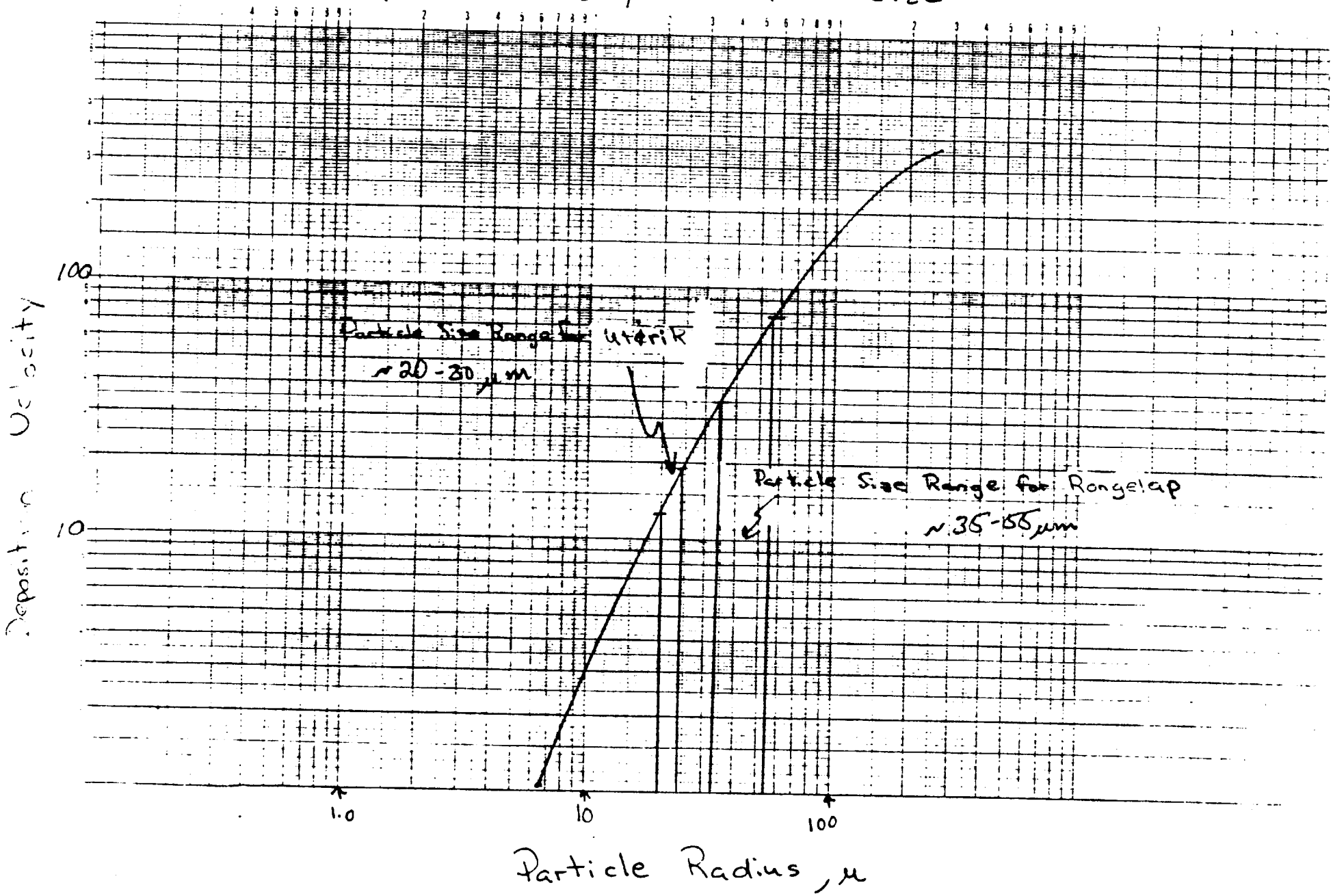
At one year post Bravo I-129 ingrowth had finished. Soil samples were taken post the ingrowth interval, thus the corrected I-129 deposited after fallout deposition is

$$C_A = 6.23 \times 4.83 \times 10^{10} \times .659 = \underline{{}^{*}1.98 \times 10^{11} \text{ atoms cm}^{-}}$$

Additionally, the maximum and minumum values for I-129 atoms in Rongelap soil are taken from the graph. This results in a maximum and minimum value of approximately 8 times the mean value.

* Sandhaus suggests boomerting upper + lower bounds on "$\mu$" + resultant $C_A$ values

Deposition Velocity vs Particle Size*




(A)

# [illegible] of [illegible] Isotope Atoms [illegible] 10,000 Fissions

Thermonuclear Fission of U-238 At Times

Post Creation

| t Hours | I-129 Atoms | I-131 Atoms | I-132 Atoms | I-133 Atoms | I-134 Atoms | I-135 Atoms |
|---|---|---|---|---|---|---|
| 0 | $7.62\times10^{-4}$ | $4.34\times10^{1}$ | $4.80\times10^{0}$ | $1.40\times10^{2}$ | $5.20\times10^{1}$ | $2.53\times10^{2}$ |
| 2 | $1.68\times10^{1}$ | $3.04\times10^{2}$ | $8.99\times10^{0}$ | $5.01\times10^{2}$ | $2.02\times10^{2}$ | $4.44\times10^{2}$ |
| 4 | $4.63\times10^{1}$ | $3.50\times10^{2}$ | $1.13\times10^{1}$ | $5.22\times10^{2}$ | $6.63\times10^{1}$ | $3.60\times10^{2}$ |
| 6 | $7.31\times10^{1}$ | $3.52\times10^{2}$ | $1.24\times10^{1}$ | $5.01\times10^{2}$ | $1.66\times10^{1}$ | $2.92\times10^{2}$ |
| 8 | $9.43\times10^{1}$ | $3.52\times10^{2}$ | $1.30\times10^{1}$ | $4.71\times10^{2}$ | $3.86\times10^{0}$ | $2.37\times10^{2}$ |
| 10 | $1.10\times10^{2}$ | $3.51\times10^{2}$ | $1.31\times10^{1}$ | $4.42\times10^{2}$ | $8.52\times10^{-1}$ | $1.92\times10^{2}$ |
| 12 | $1.22\times10^{2}$ | $3.50\times10^{2}$ | $1.31\times10^{1}$ | $4.13\times10^{2}$ | $1.83\times10^{-1}$ | $1.56\times10^{2}$ |
| 14 | $1.31\times10^{2}$ | $3.50\times10^{2}$ | $1.30\times10^{1}$ | $3.87\times10^{2}$ | $3.87\times10^{-2}$ | $1.26\times10^{2}$ |
| 16 | $1.37\times10^{2}$ | $3.49\times10^{2}$ | $1.28\times10^{1}$ | $3.62\times10^{2}$ | $8.09\times10^{-3}$ | $1.02\times10^{2}$ |
| 18 | $1.42\times10^{2}$ | $3.48\times10^{2}$ | $1.27\times10^{1}$ | $3.39\times10^{2}$ | $1.68\times10^{-3}$ | $8.30\times10^{1}$ |
| 20 | $1.45\times10^{2}$ | $3.47\times10^{2}$ | $1.25\times10^{1}$ | $3.17\times10^{2}$ | $3.47\times10^{-4}$ | $6.73\times10^{1}$ |
| 22 | $1.48\times10^{2}$ | $3.45\times10^{2}$ | $1.22\times10^{1}$ | $2.97\times10^{2}$ | $7.16\times10^{-5}$ | $5.46\times10^{1}$ |
| 24 | $1.49\times10^{2}$ | $3.44\times10^{2}$ | $1.20\times10^{1}$ | $2.78\times10^{2}$ | $1.47\times10^{-5}$ | $4.42\times10^{1}$ |
| 26 | $1.51\times10^{2}$ | $3.43\times10^{2}$ | $1.18\times10^{1}$ | $2.60\times10^{2}$ | $3.03\times10^{-6}$ | $3.59\times10^{1}$ |
| 28 | $1.52\times10^{2}$ | $3.42\times10^{2}$ | $1.16\times10^{1}$ | $2.43\times10^{2}$ | $6.23\times10^{-7}$ | $2.91\times10^{1}$ |
| 30 | $1.53\times10^{2}$ | $3.40\times10^{2}$ | $1.14\times10^{1}$ | $2.28\times10^{2}$ | $1.28\times10^{-7}$ | $2.36\times10^{1}$ |
| 32 | $1.53\times10^{2}$ | $3.39\times10^{2}$ | $1.12\times10^{1}$ | $2.13\times10^{2}$ | $2.62\times10^{-8}$ | $1.91\times10^{1}$ |
| 34 | $1.54\times10^{2}$ | $3.38\times10^{2}$ | $1.10\times10^{1}$ | $1.99\times10^{2}$ | $5.38\times10^{-9}$ | $1.55\times10^{1}$ |
| 36 | $1.54\times10^{2}$ | $3.36\times10^{2}$ | $1.08\times10^{1}$ | $1.87\times10^{2}$ | $1.10\times10^{-9}$ | $1.26\times10^{1}$ |
| 38 | $1.54\times10^{2}$ | $3.35\times10^{2}$ | $1.06\times10^{1}$ | $1.75\times10^{2}$ | $2.27\times10^{-10}$ | $1.02\times10^{1}$ |
| 40 | $1.54\times10^{2}$ | $3.33\times10^{2}$ | $1.04\times10^{1}$ | $1.63\times10^{2}$ | $4.67\times10^{-11}$ | $8.26\times10^{0}$ |
| Peak | $1.85\times10^{2}$ | $3.52\times10^{2}$ | $1.31\times10^{1}$ | | | |

Borg - what about <u>other</u> thyroid-seeking nuclides?

See Shellabarger, Van Middlesworth @ ORNL
Jan Wolf @ NIH

# I-129 Deposition

| i | ~20 min intervals Interval, H + Hour | Particle Radius, μm | F Fraction of Total Atoms Deposited During Interval* | I Ingrowth Factor, I-129 atoms at mid / I-129 atoms at H+ |
|---|---|---|---|---|
| 1 | 5.5 – 5.825 | 55.6 – 53.3 | .0927 | .563 |
| 2 | 5.825 – 6.150 | 53.3 – 51.3 | .0891 | .600 |
| 3 | 6.150 – 6.475 | 51.3 – 49.4 | .0888 | .619 |
| 4 | 6.475 – 6.800 | 49.3 – 48.2 | .0581 | .656 |
| 5 | 6.800 – 7.125 | 48.2 – 47.0 | .0556 | .684 |
| 6 | 7.125 – 7.45 | 47.0 – 46.0 | .0532 | .712 |
| 7 | 7.45 – 7.775 | 46.0 – 45.0 | .0512 | .740 |
| 8 | 7.775 – 8.10 | 45.0 – 44.1 | .0491 | .768 |
| 9 | 8.10 – 8.425 | 44.1 – 43.2 | .0468 | .791 |
| 10 | 8.425 – 8.750 | 43.2 – 42.4 | .0454 | .813 |
| 11 | 8.750 – 9.075 | 42.4 – 41.6 | .0434 | .835 |
| 12 | 9.075 – 9.40 | 41.6 – 40.9 | .0418 | .856 |
| 13 | 9.40 – 9.725 | 40.9 – 40.2 | .0404 | .877 |
| 14 | 9.725 – 10.050 | 40.2 – 39.5 | .0386 | .898 |
| 15 | 10.050 – 10.375 | 39.5 – 38.9 | .0376 | .918 |
| 16 | 10.375 – 10.70 | 38.9 – 38.2 | .0361 | .932 |
| 17 | 10.70 – 11.025 | 38.2 – 37.7 | .0346 | .946 |
| 18 | 11.025 – 11.350 | 37.7 – 37.1 | .0336 | .960 |
| 19 | 11.350 – 11.675 | 37.1 – 36.6 | .0325 | .973 |
| 20 | 11.675 – 12.0 | 36.6 – 36.1 | .0313 | .986 |

* These fractions are relative to total I-129 atoms at H+12 and are not corrected for ingrowth, however they correct for non-uniform [illegible] of [illegible] atoms as a function of

# Areal Concentration of Iodine Isotopes

The areal deposition during interval $i$ is given by the product of, $C_A$, the total number of I-129 atoms per $cm^2$ after fallout deposition, the fraction of I-129 atoms deposited during interval $i$, and the ingrowth factor. Thus

$$A_i = C_A \times F \times I .$$

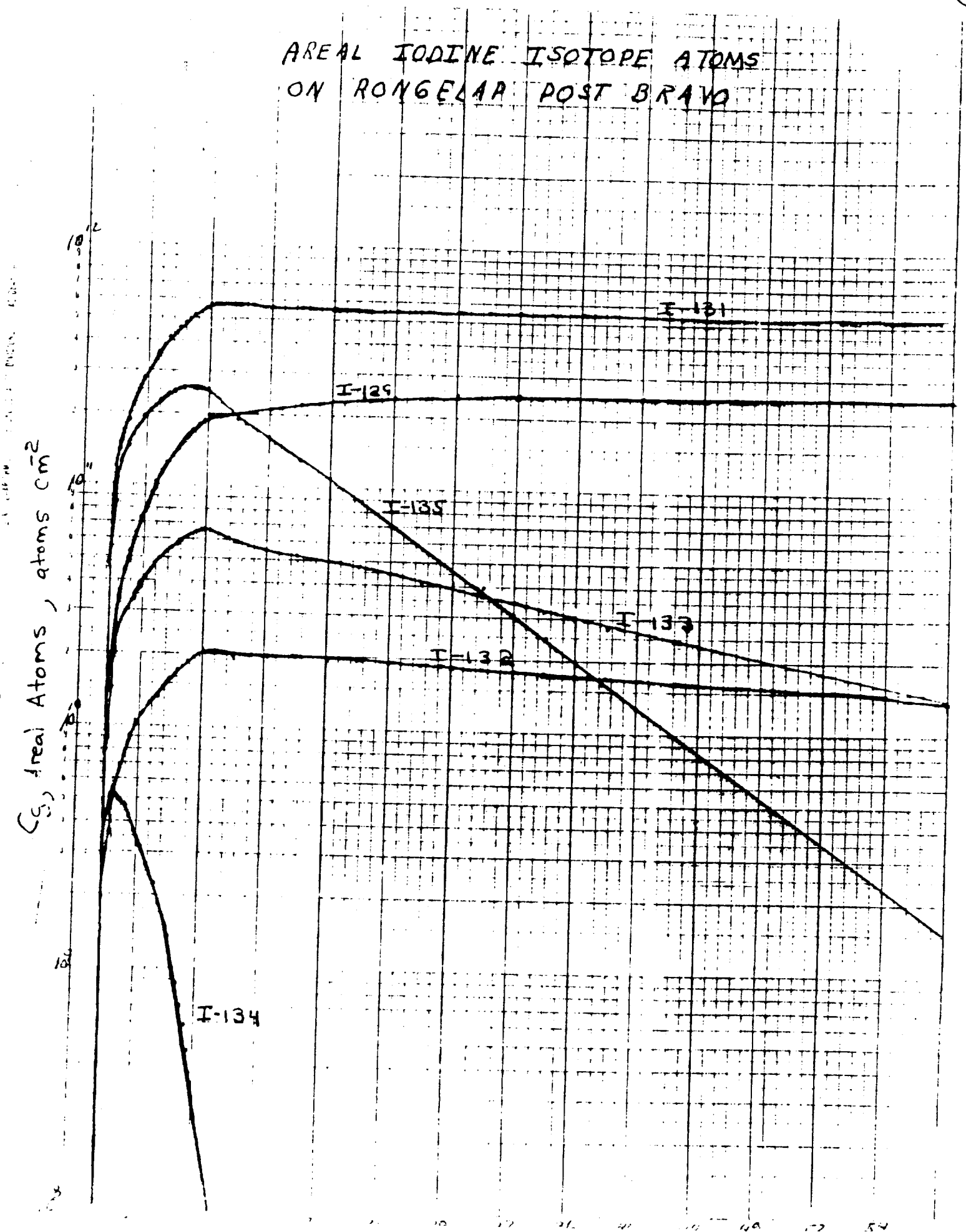
The above equation was used to determine the number of I-129 atoms per $cm^2$ versus time post detonation (Graph ). The areal concentrations of the remaining iodine isotopes were determined from the instantaneous ratio of the number of iodine isotope atoms to I-129 atoms per 10,000 thermonuclear fissions of U-238 at times post creation (Table ).

To obtain a point on graph , the following relationship was used,

$C_g$, the number of I-129 atom $cm^{-2}$ on the ground at the end of interval two =

atoms $cm^{-2}$ fallen during interval one $\times$ $\frac{\text{atoms of I-129 at end } t}{\text{atoms of I-129 at mid } t}$

+ atoms $cm^{-2}$ fallen during interval two $\times$ $\frac{\text{atoms of I-129 at end}}{}$


AREAL IODINE ISOTOPE ATOMS
ON RONGELAP POST BRAVO
I-131
I-129
I-135
I-133
I-132
I-134
(S) Areal Atoms, atoms cm⁻²

# Activity Ingested By Rongelapese

WT-938 → Depth of $H_2O$ = .67 ft = 20.4 cm

→ Drank 1 pt $day^{-1}$ = 19.7 $cm^3$ $hr^{-1}$

| Nuclide | Area During Deposition, atom $cm^{-2}$ hr | Activity * Ingested, μCi | Thyroid Rem |
|---|---|---|---|
| I-131 | $2.92 \times 10^{12}$ | 76. | 138. |
| I-132 | $8.14 \times 10^{10}$ | 179. | 11.6 |
| I-133 | $2.80 \times 10^{12}$ | 672. | 303. |
| I-134 | $1.48 \times 10^{10}$ | 85. | 2.54 |
| I-135 | $1.24 \times 10^{12}$ | 940. | 151. |
| Total | | | 605. |

| Nuclide | Area Post Deposition, atom $cm^{-2}$ hr | Activity * Ingested, μCi | Thyroid Rem |
|---|---|---|---|
| I-131 | $2.15 \times 10^{13}$ | 558. | 1910 |
| I-132 | $7.50 \times 10^{11}$ | 1649. | 107 |
| I-133 | $1.52 \times 10^{13}$ | 3649. | 1642 |
| I-134 | $2.83 \times 10^{8}$ | 1.62 | .49 |
| I-135 | $2.58 \times 10^{12}$ | 1961. | 314 |
| Total | | | 3074. |

* Activity Ingested = $\dfrac{\int_0^{\tau} \text{Areal Atoms } d\tau}{\text{Depth of Water}}$ × Water Intake Rate × Decay Constant

where $\tau$ = deposition or post deposition interval.

# Air Concentrations of Iodine Isotopes

Time Integral of Volumetric concentration is equal to the ratio amount of deposition per unit area and the deposition velocity, thus during interval $i$

$$\int_0^{t_i} C_i \, dt = \frac{A_i}{V_i} .$$

Thus,

$$C_i = \frac{A_i}{V_i \, t_i} .$$

where

$t_i \equiv$ length of interval, 335 hours,

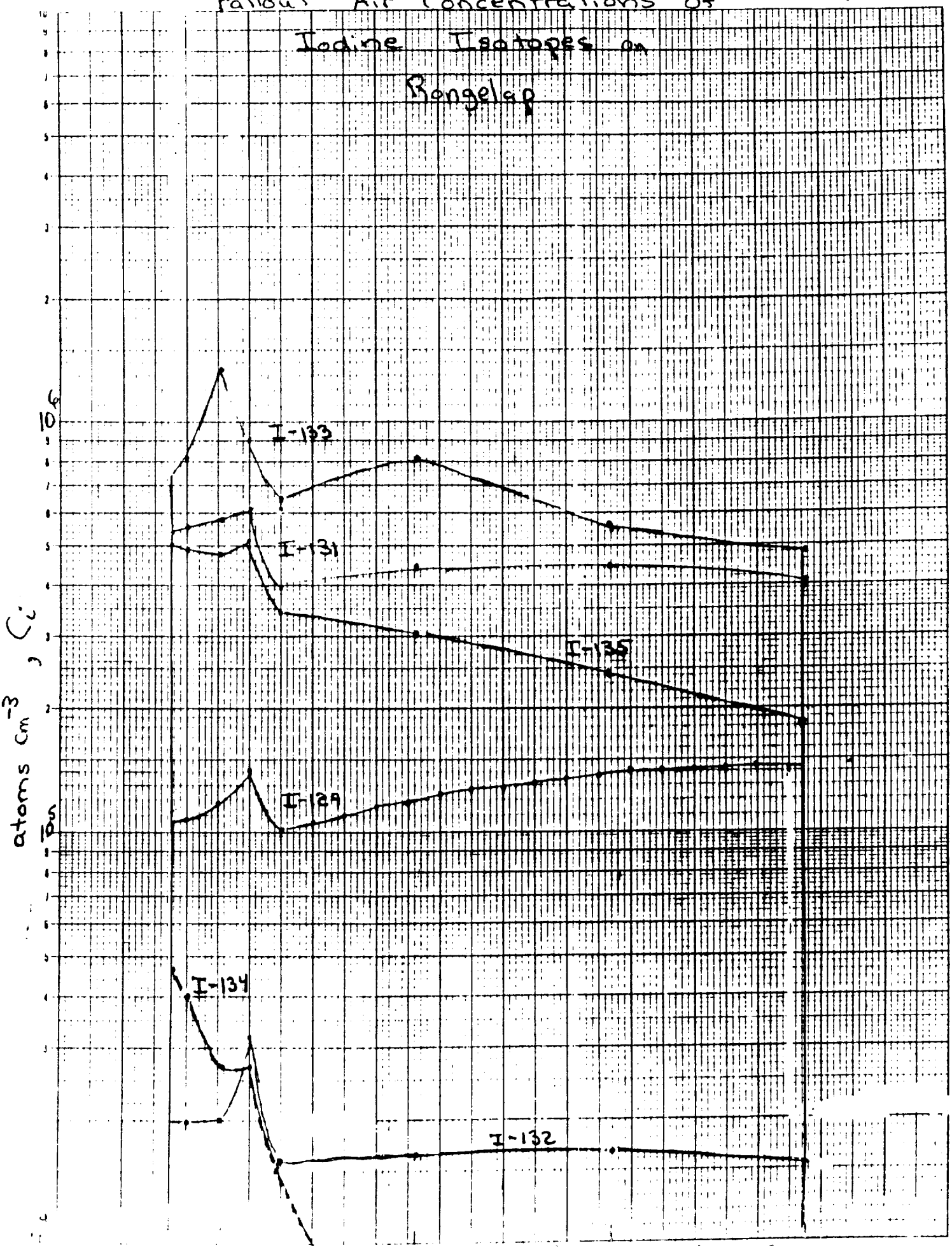
$V_i \equiv$ average deposition velocity during interval,

$A_i \equiv$ areal deposition during $t_i$

The above analysis was used for I-129 and a graph of I-129 atoms per $cm^3$ versus time post detonation was drawn (Graph 4). The air concentrations of the remaining Iodine isotopes were determined from the instantaneous ratio of the number of iodine isotope atoms to I-129 atoms per 10,000 thermonuclear fissions of

Graph 4

Fallout Air Concentrations of Iodine Isotopes on Rongelap



# Activity Inhaled During Fallout on Rongelap

| Thyroid Rem $\mu Ci^{-1}$ (30-100 $\mu$) | |
|---|---|
| .844 | I-131 |
| .0085 | I-132 |
| .163 | I-133 |
| .0145 | I-134 |
| .045 | I-135 |

Breathing Rate = $8.328 \times 10^5$ $cm^3$ $h^{-1}$

Atoms Inhaled = Area of Atom Concentration Curve on Graph 4 × Breathing Rate.

| Nuclide | Inhaled $\mu Ci$ | Thyroid Rem |
|---|---|---|
| I-131 | 69 | 58 |
| I-132 | 2118 | 18 |
| I-133 | 833 | 136 |
| I-134 | 218 | 3.2 |
| I-135 | 1293 | 58 |
| Total | | 273 Rem |

# Resuspension of Iodine Atoms

Resuspended Concentration in Air = areal atoms on ground × resuspension facto

$$C_r = C_g \times K,$$

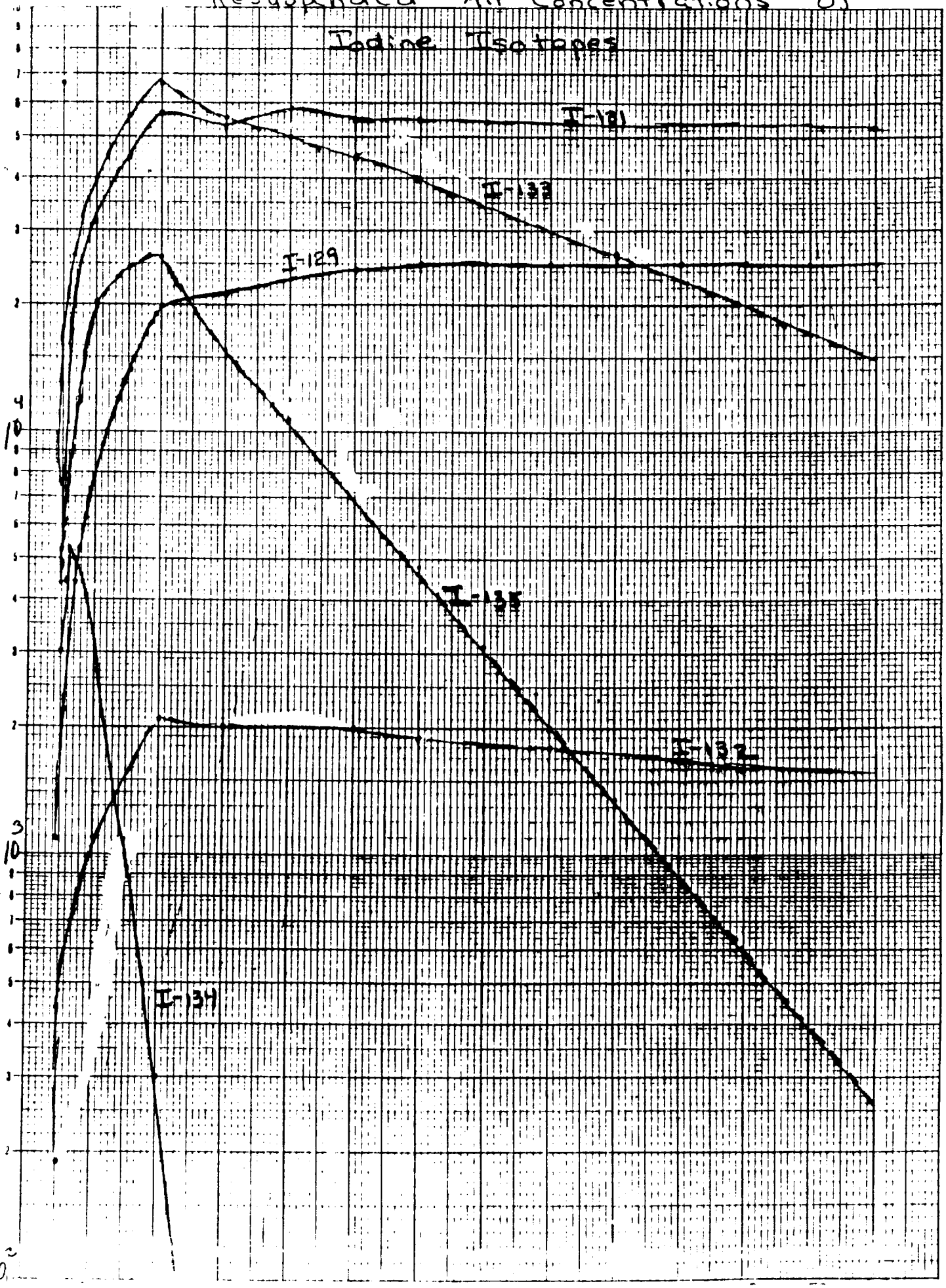
where $C_r$ = resuspended air conc., atoms $cm^{-3}$

$C_g$ = areal atoms, graph 3, atom $cm^{-2}$,

$K$ = $10^{-7}$ $cm^{-1}$, UNSCEAR A/AC.82/B.369.

The above expression was used to develop the resuspended air concentration of I-129 atoms post detonation. Resuspension occured during and post fallout cloud passage. The resuspended air concentrations of the remaining iodine isotopes were determined from the instantaneous ratio of the number of iodine isotope atoms to I-129 atoms per 10,000 thermonuclear fissions of U-238 at times post creation (Table 1). The resuspended air concentrations are shown on graph 5.

Resuspended Air Concentrations of Iodine Isotopes



# Activity Inhaled Due To Resuspension on Rongelap

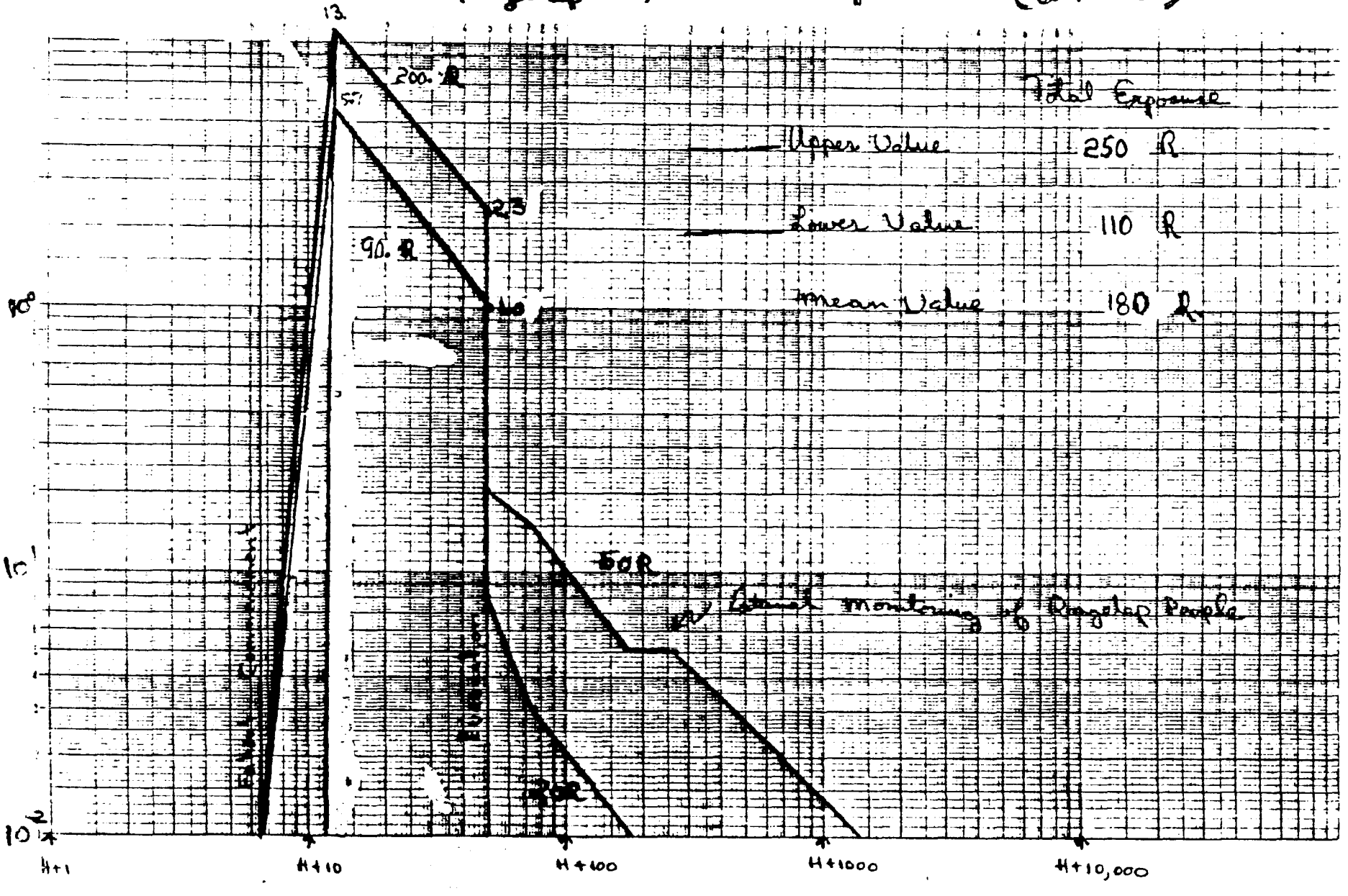
Atoms Inhaled = Area of Atom Concentration Curve on Graph 5

× Breathing Rate

During Deposition (H+5.5 to H+12)

| Nuclide | Atoms Inhaled | μCi/Atom | Activity Inhaled, μCi | Rem/μCi | Thyroid Rem |
|---|---|---|---|---|---|
| I-131 | $1.82\times10^{11}$ | $2.7\times10^{-11}$ | 4.9 | .844 | 4.1 |
| I-132 | $6.71\times10^{9}$ | $2.3\times10^{-9}$ | 15.4 | .0085 | .13 |
| I-133 | $2.33\times10^{11}$ | $2.5\times10^{-10}$ | 58.3 | .163 | 9.5 |
| I-134 | $1.24\times10^{10}$ | $6.0\times10^{-9}$ | 74.4 | .015 | 1.1 |
| I-135 | $1.04\times10^{11}$ | $7.9\times10^{-10}$ | 82.2 | .045 | 3.7 |
| Post Deposition (H+12 to H+51) | | | | | |
| I-131 | $1.72\times10^{12}$ | | 46.4 | | 39. |
| I-132 | $5.47\times10^{10}$ | | 126 | | 1.1 |
| I-133 | $7.84\times10^{11}$ | | 196 | | 32. |
| I-134 | $4.32\times10^{5}$ | | — | | — |
| I-135 | $2.2\times10^{11}$ | | 174 | | 7.8 |
| | | Total | | | 98.4 |

# Rongelap External Exposure (WT 938)* Graph 6




Hours Post Castle Bravo

# ACUTE PHASE

## Rongelap

## Adult Male Thyroid Dose Summary

| | Rem |
|---|---|
| Direct inhalation of passing cloud | 273 |
| Ingestion of water during deposition | 605 |
| Ingestion of water post deposition | 3070 |
| Resuspended and inhaled during deposition | 18 |
| Resuspended and inhaled post deposition | 80 |
| External exposure during residence | 51.9 |
| External exposure after evacuation | 25.6 |
| TOTAL | 4160 |