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^{239}Pu Uptake Estimates for Marshall Islands Residents

Presented by

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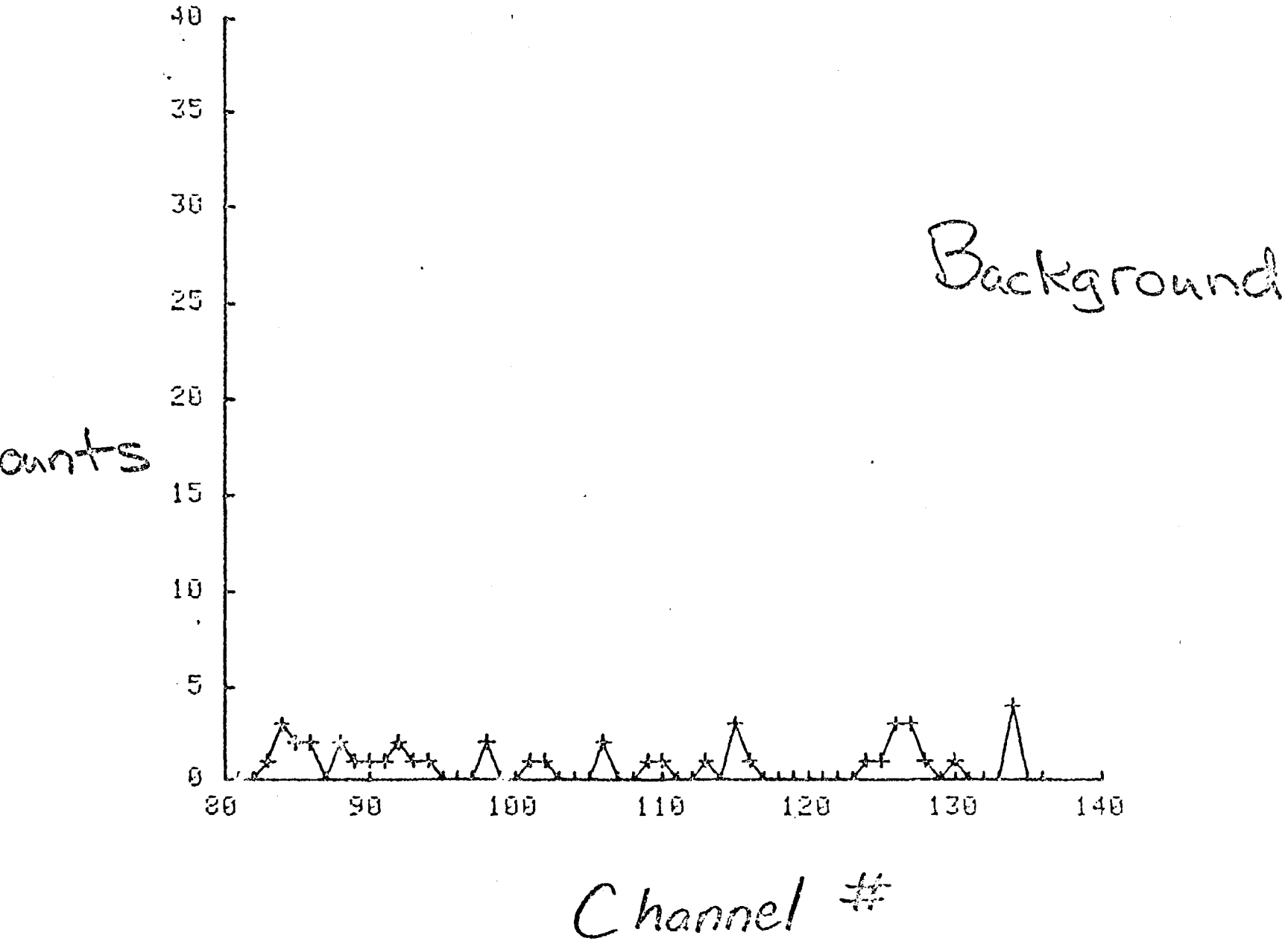
DESCRIPTION OF

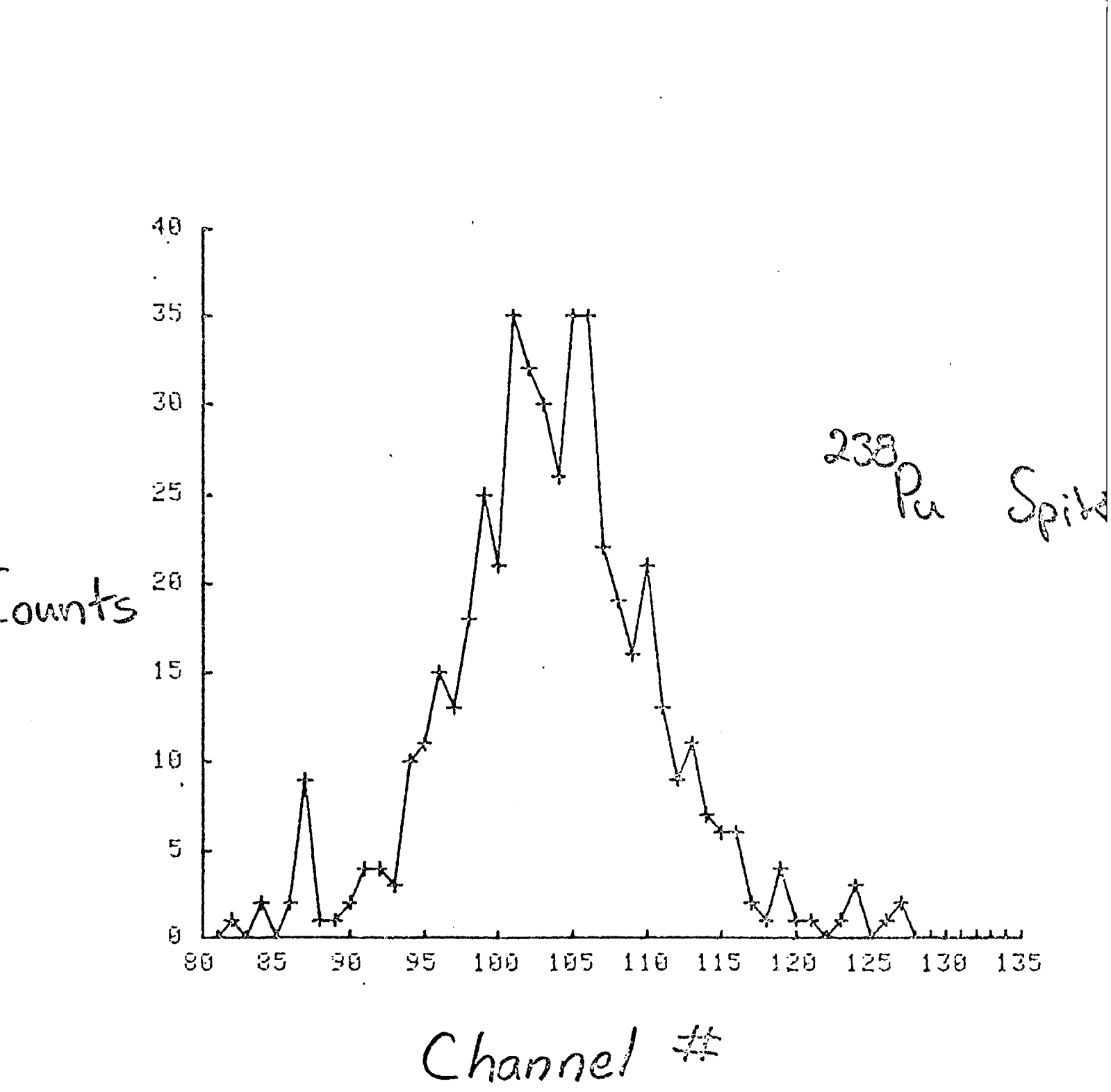
MEASUREMENT TECHNIQUE

PERALS CHEMISTRY

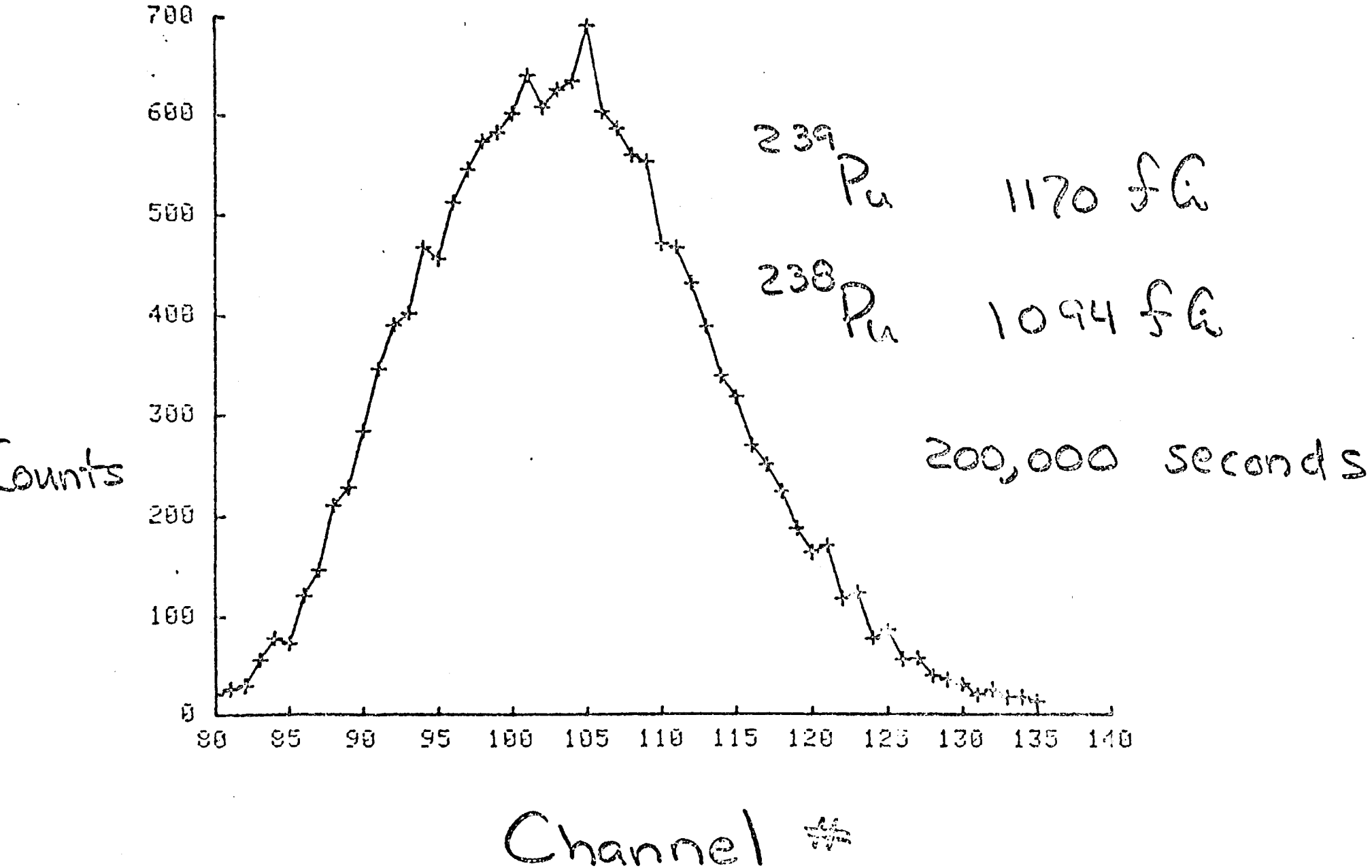
PERALS SPECTROSCOPY

Recovery of Elements	
Element	% Recovery
Uranium	$<10^{-3}$
Thorium	$<10^{-3}$
Americium	$<10^{-3}$
Plutonium	88 ± 6
Bismuth	$<10^{-3}$
Radium	$<10^{-3}$
Neptunium	88 ± 6
Polonium	0.015 to 2
Lead	$<10^{-3}$ (Literature Value)

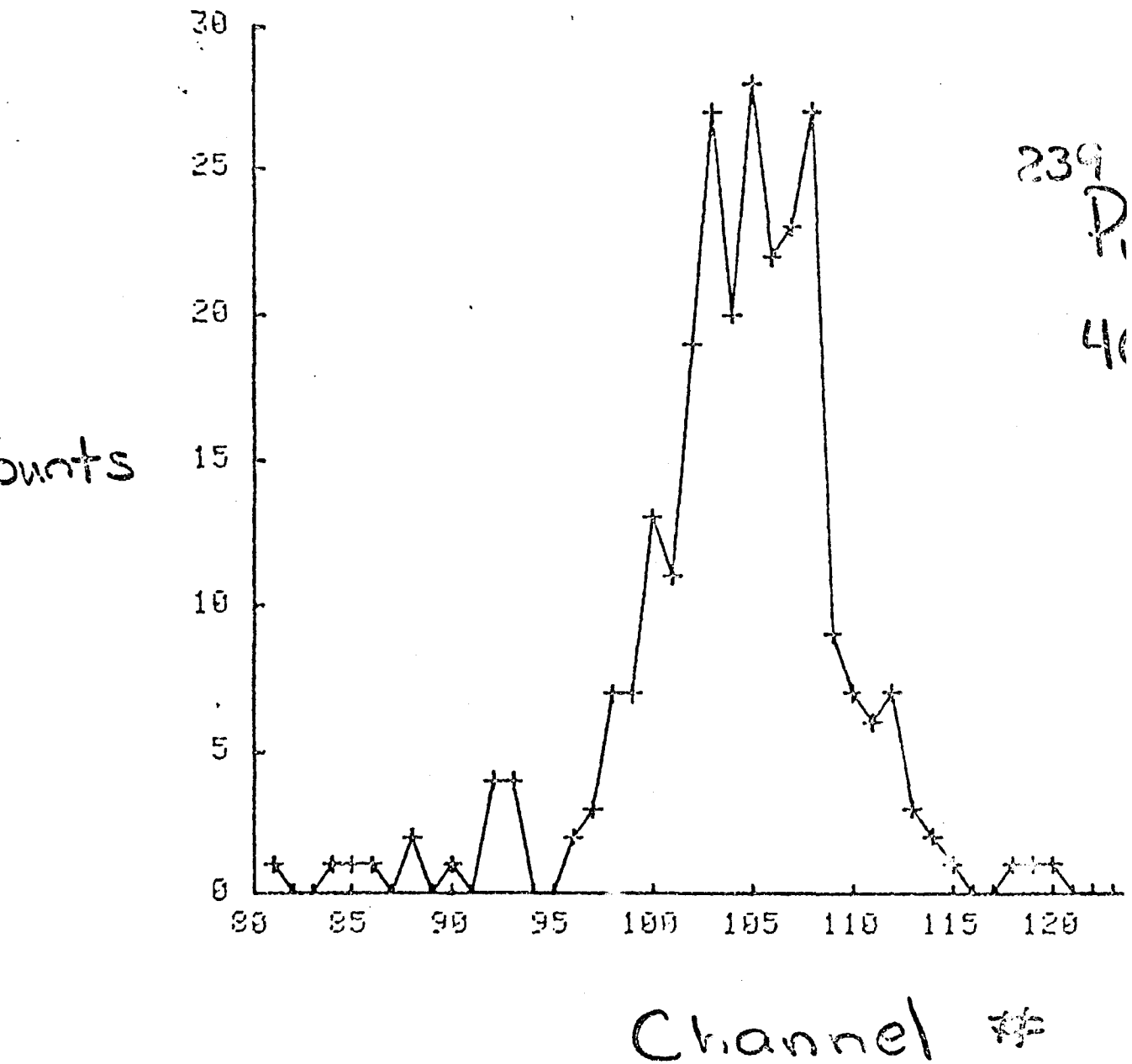

Background
ounts
40
35
30
25
20
15
10
5
0
80
90
100
110
120
130
140
Channel #

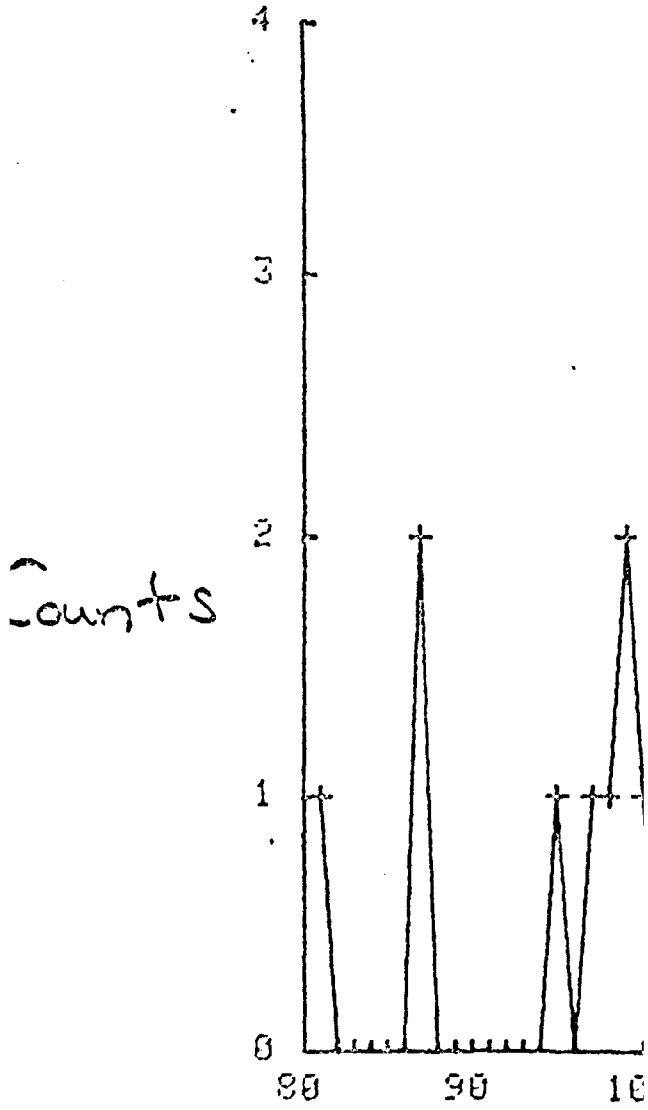

Counts
40
35
30
25
20
15
10
5
0
80
85
90
95
100
105
110
115
120
125
130
135
Channel #
238Pu Spike

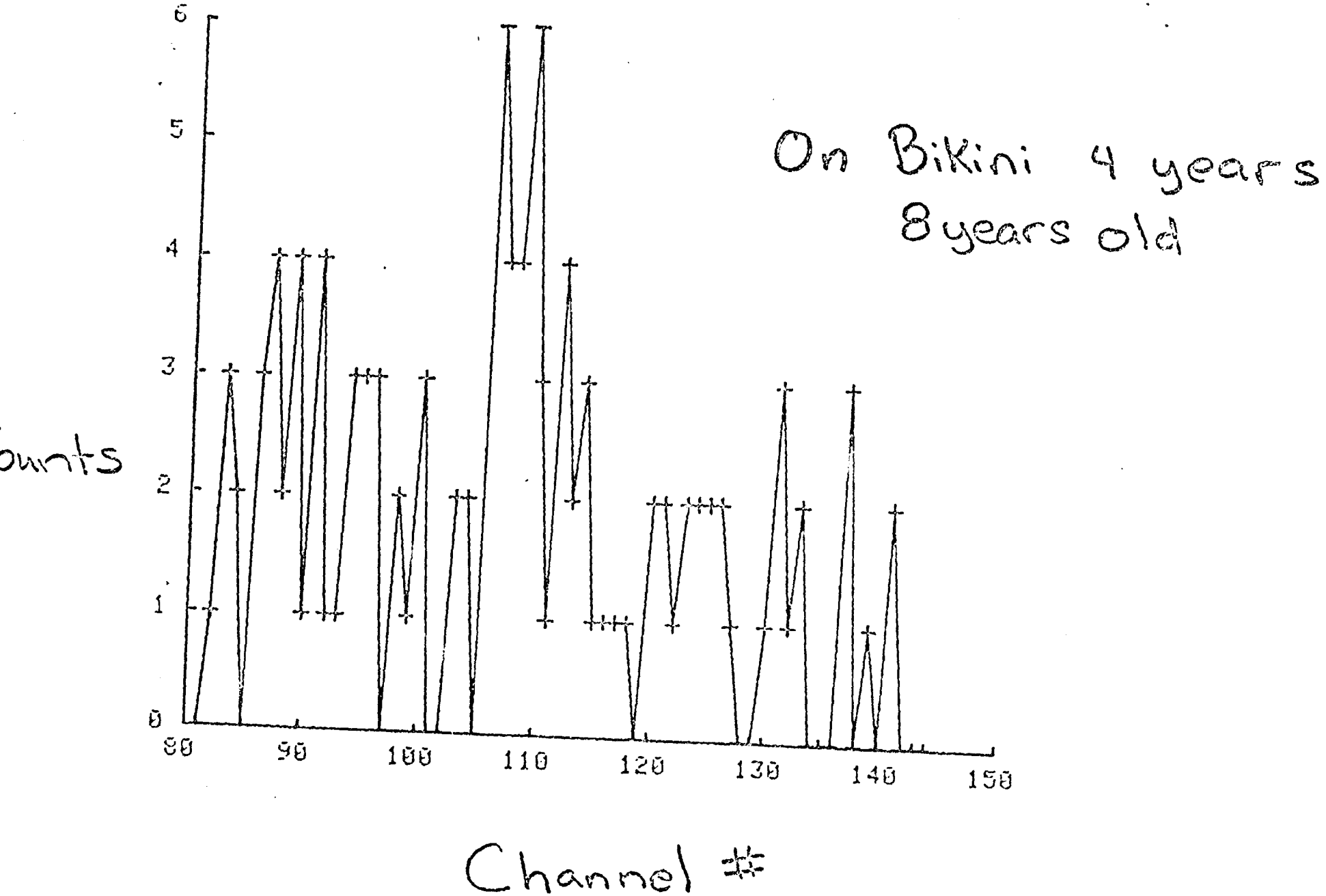
Spike

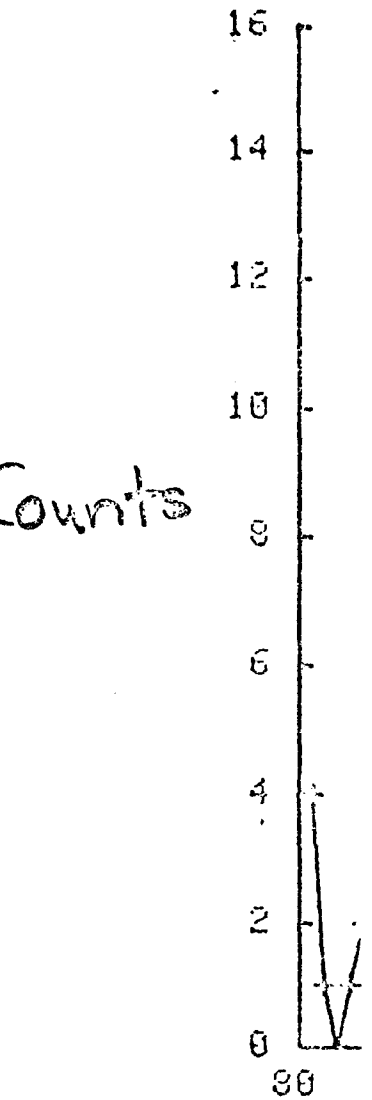

700
600
500
400
300
200
100
0
80
85
90
95
100
105
110
115
120
125
130
135
140
Counts
Channel #
239Pu 1170 fG
238Pu 1094 fG
200,000 seconds

Urine From Bikini Male




Counts
4
3
2
1
0
80
90
10


On Bikini 4 years
8 years old
ounts
0
1
2
3
4
5
6
80
90
100
110
120
130
140
150
Channel #


Counts
16
14
12
10
8
6
4
2
0
00

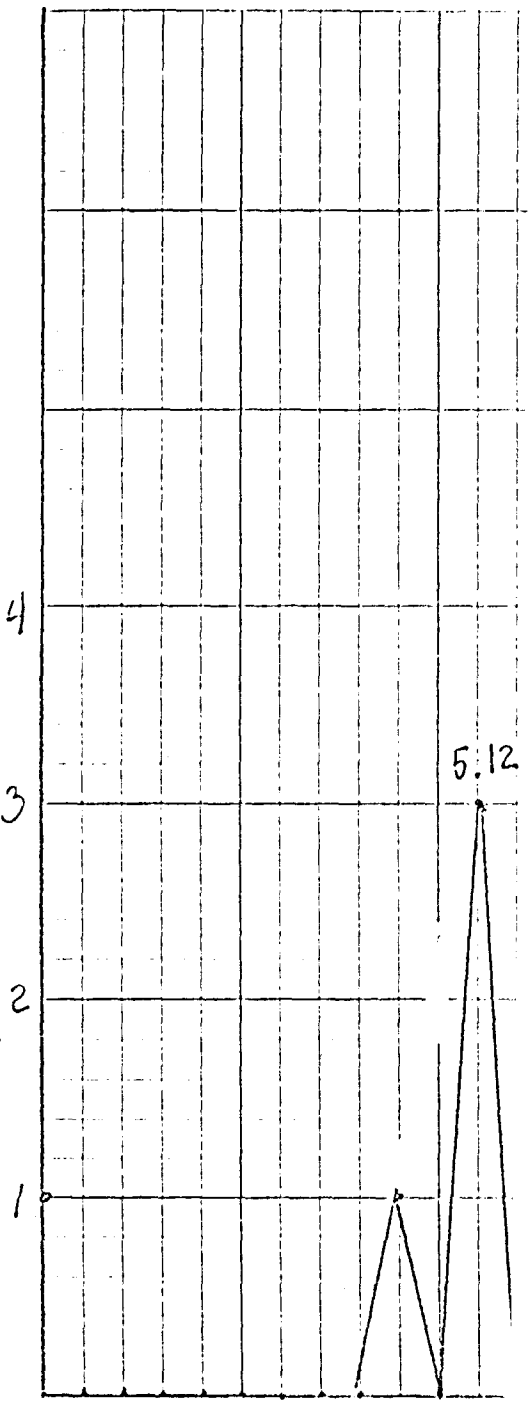
Rongelap Urine Sample Results

Laboratory	Collection Date, Sample Type	^{239}Pu fCi l^{-1}
EML	Spring 1973, 11 Adults	210 to 1,700 (Range)
EML	October, 1976, 1 Adult	14 ± 7 (Counting Error)
EML	October, 1976, Pooled	9 ± 2 (Counting Error)
LASL	October 1977, 1 Adult	90 (MDL 10)
LASL	October 1977, 2 Adults	<10 (MDL 10)
BNL (PERALS)	July 1982, 7 Year-Old	-2.7 ±2.0 (One Sigma Counting Error)
BNL (PERALS)	July 1982, 8 Year-Old	21 ± 13 (One Sigma Counting Error)
BNL (PERALS)	July 1982, 5 Year-Old	57 ± 50 (One Sigma Counting Error)
BNL (PERALS)	July 1982, Adult	-3.0 ± 2.7 (One Sigma Counting Error)
BNL (PERALS)	July 1982, Adult	-3.6 ± 3.7 (One Sigma Counting Error)

BNL Comparison Samples, PERALS

Location	Collection Date, Sample Type	Sample Alpha Activity[1] fCi l^{-1} ±One Sigma Counting Error
Majuro	July 1982, 1 Adult	200 ± 19
Kili	July 1982, 1 Adult	-4.5 ± 7.7
Majuro	July 1982, 1 Adult	1,100 ± 50
Majuro	July 1982, 1 Adult	140 ± 20

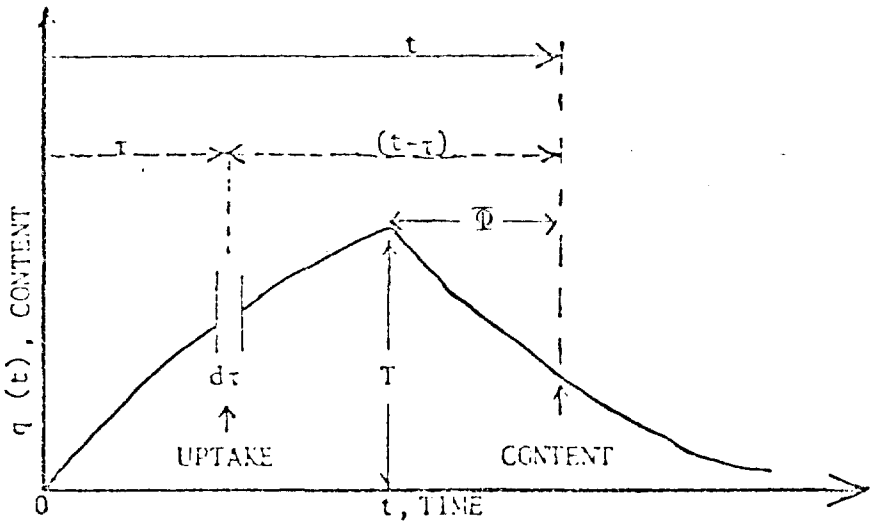
[1]Possible Po contamination. Peak spread over ^{239}Pu, ^{210}Po and ^{238}Pu region of spectra. These people have never been to Rongelap, Utirik, Bikini or Enewetak.


4
3
2
1
5.12

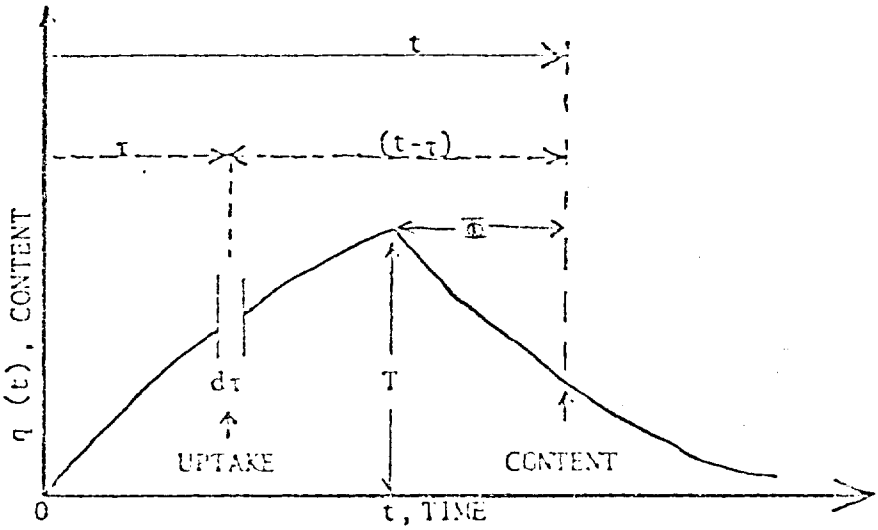
Bikini Urine Sample Results

Laboratory	Collection Date, Sample Type	^{239}Pu fCi l^{-1}
EML	Spring 1970, Pooled	3 (Comparison 3)
EML	Spring 1971, Pooled	4
EML	Spring 1974, 10 Adults	9 to 60 (Range)
EML	Fall 1975, Pooled	11 ± 2 (Counting Error)
EML	Spring 1976, Pooled	9 ± 2 (Counting Error)
EML	Fall 1976, Pooled	3 ± 2 (Counting Error)
EML	Fall 1976, 3 Adults	4.4 ± 1.4 (Mean ± 1 S.D.)
BNWL	Spring 1977, 8 Adults	0.73 ± 0.53 (Mean ± 1 S.D.)
LASL	Spring 1977, 3 Adults	<10 (MDL 10)
BNL & ORNL (PERALS)	Summer 1980, 10 Samples From One Pool	<12 ± 2.8 (Mean ± 1 S.D.)
BNL (PERALS)	Summer 1982, 8 Year-Old (4 Years On Bikini)	170 ± 38 (One Sigma Counting Erro
BNL (PERALS)	Summer 1982, 6 Year-Old (3 Months On Bikini)	22 ± 4.2 (One Sigma Counting Erro
BNL (PERALS)	Summer 1982, 6 Year-Old (3 Years On Bikini)	<1.0 ± 3.5 (One Sigma Counting Error)

DESCRIPTION OF CALCULATIONS



At some variable time τ defined during a fixed intake interval T, the activity uptake rate to systemic organs is defined as $U(\tau)$



The whole-body retention of an element of activity taken up at time $d\tau$ is

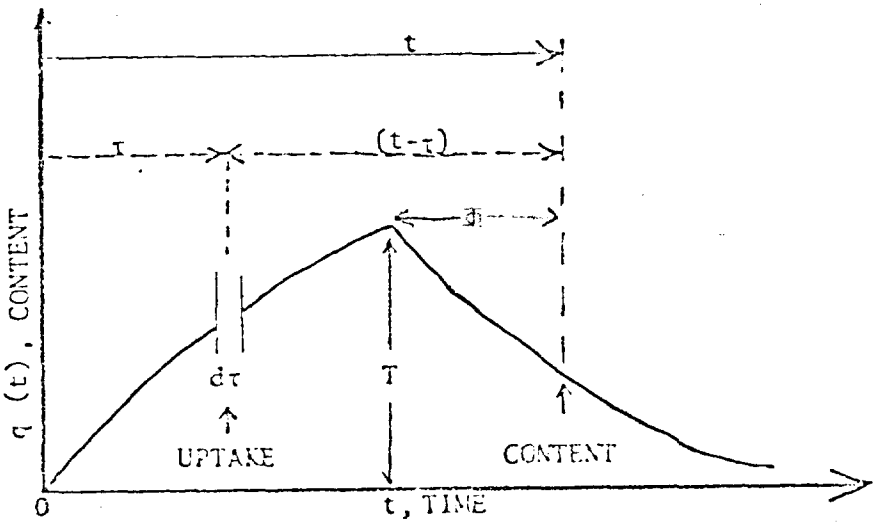
$$r_s\ (t - \tau)$$

where

r_s is the systemic whole-body retention for ^{239}Pu.

The activity taken up at $d\tau$ and remaining at t is

$$U\ (\tau)\ r_s\ (t - \tau)\ d\tau.$$



Since the retention of each element of uptake is independent of all others, the activity taken up during the whole intake interval which remains at t is

$$q(t) = \int_0^t U(\tau)\, r_s\, (t - \tau)\, d\tau \qquad (1)$$

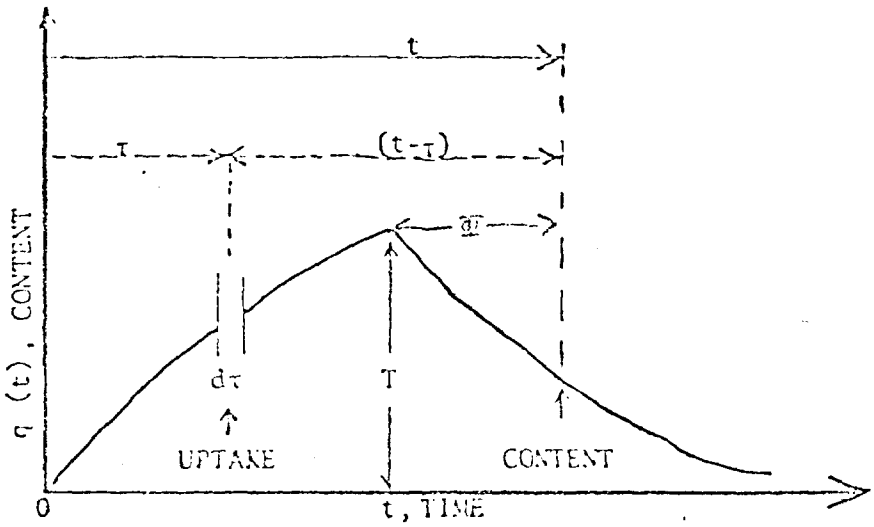
The rate of change of q(t) will be the result of flow rates into and out of the systemic region

$$\frac{dq(t)}{dt} = U(t) - E(t) - \lambda q(t) \qquad (2)$$

where $E(t)$ = systemic excretion rate,

$\lambda q(t)$ = decay rate of systemic activity, and

$U(t)$ = systemic uptake rate.



Differentiating Equation 1

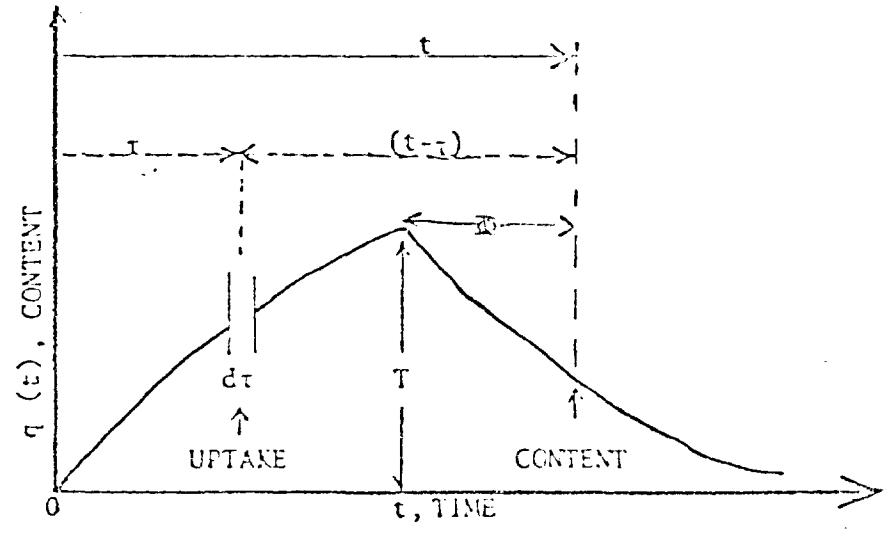
$$\frac{dq(t)}{dt} = U(t)\ r_s(o) + \int_o^t U(\tau)\ \frac{dr_s(t-\tau)}{dt}\ d\tau$$

By definition

$$r_s(t-\tau) = R_s\ (t-\tau)\ e^{-\lambda(t-\tau)}.$$

Therefore

$$\frac{dq\ (t)}{dt} = U(t) + \int_o^t U(\tau)\ \frac{dR_s(t-\tau)}{dt}\ e^{-\lambda(t-\tau)}\ d\tau - \lambda q\ (t) \qquad (3)$$



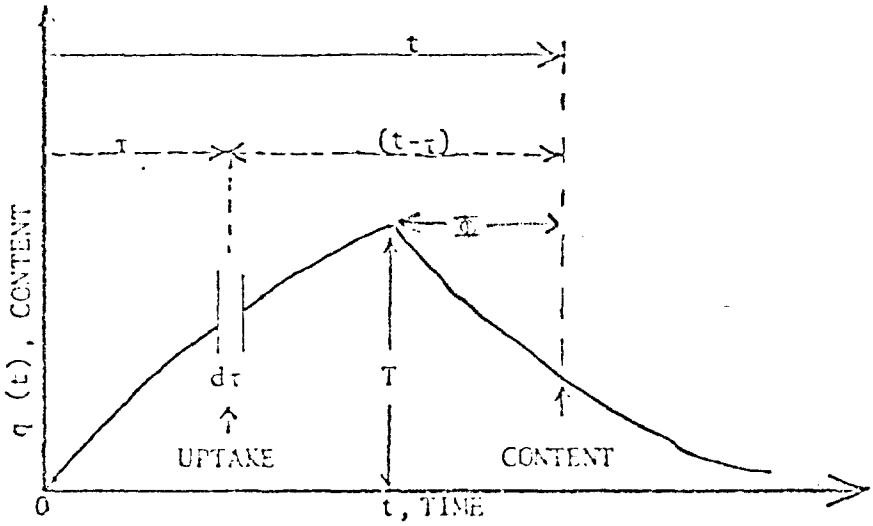
Comparing Equation 3 to Equation 2 term by term yields

$$E(t) = -\int_0^t U(\tau) \frac{dR_s(t-\tau)}{dt} e^{-\lambda(t-\tau)} d\tau$$

In our case

$$R_s(t-\tau) = \sum_{i=1}^{n} A_i e^{-k_i(t-\tau)}$$

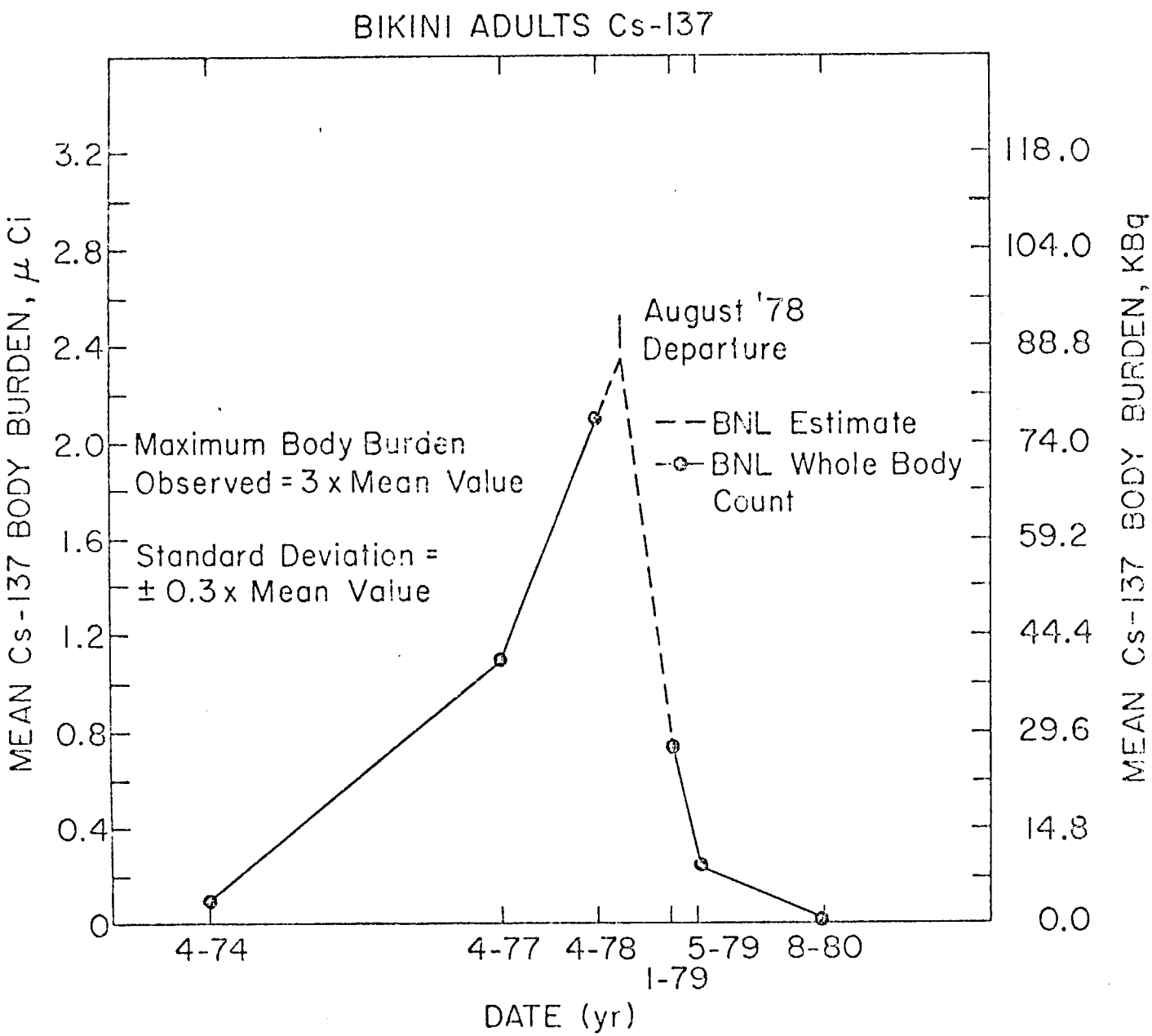
where A_i and k_i are constants.



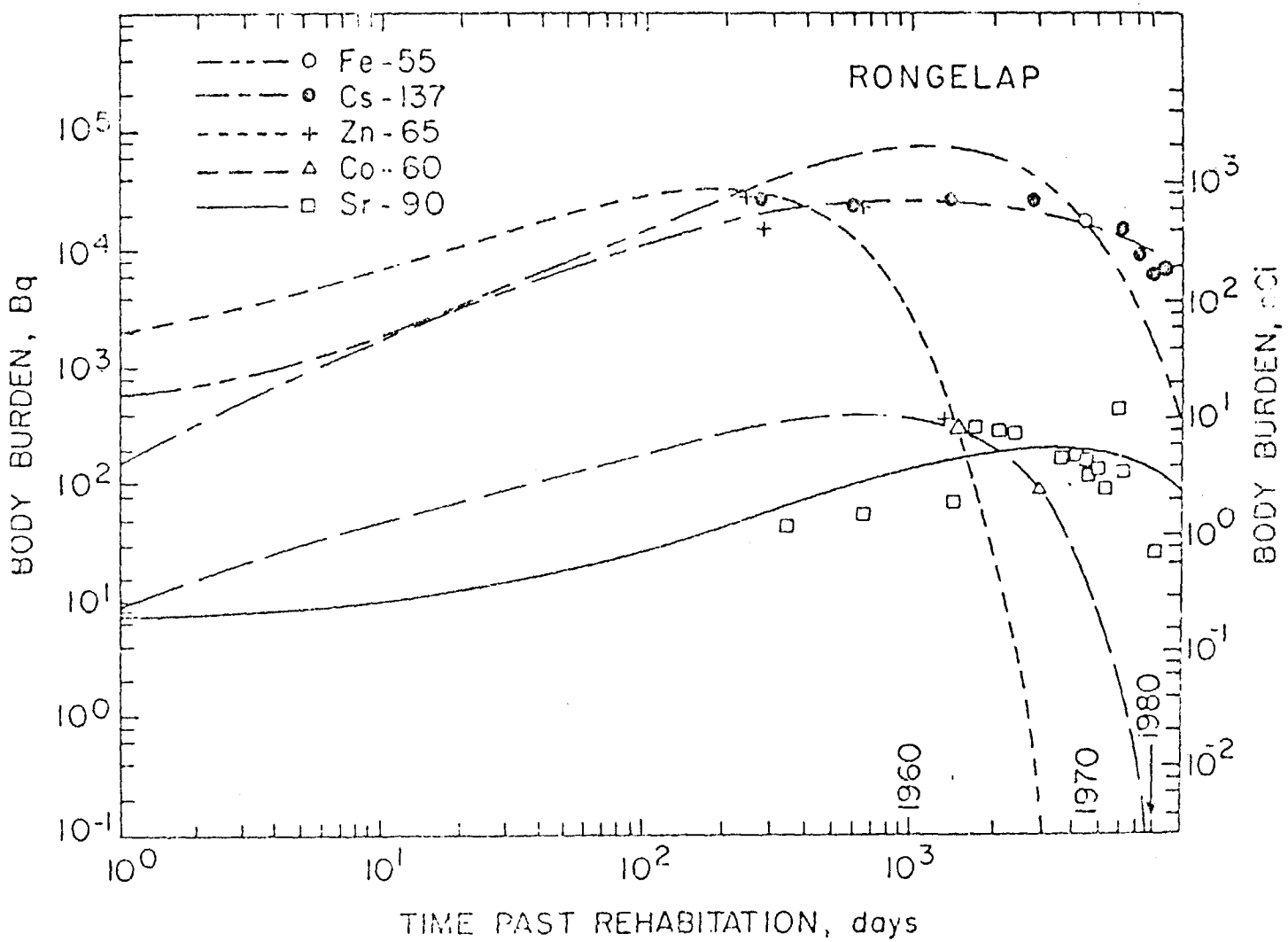
Combining terms

$$E_u(t) = f_u\, U(o) \sum_{i=1}^{n} \left[A_i k_i \left(\frac{e^{-\lambda c(T+\Phi)} - e^{-(k_i+\lambda)(T+\Phi)}}{\lambda + k_i + \lambda_c} \right) \right]$$

To estimate E_u we measure the activity concentration and multiply it by the age-dependent urine excretion rate. We calculate the activity uptake rate and integrate over the exposure interval.


BIKINI ADULTS Cs-137
MEAN Cs-137 BODY BURDEN, μ Ci
3.2
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0
118.0
104.0
88.8
74.0
59.2
44.4
29.6
14.8
0.0
MEAN Cs-137 BODY BURDEN, KBq
August '78
Departure
Maximum Body Burden
Observed = 3 x Mean Value
Standard Deviation =
± 0.3 x Mean Value
BNL Estimate
BNL Whole Body
Count
4-74
4-77
4-78
1-79
5-79
8-80
DATE (yr)

ADULT BODY-BURDEN HISTORY AT RONGELAP ATOLL



^{239}Pu Uptake Based On

ICRP 30 Excretion Model

Uptake Regime	λ_c	Estimated Systemic Uptake nCi
Constant Continuous	0	0.46
Declining Continuous	2×10^{-3}	1.2
Declining Continuous	2×10^{-4}	0.58
Increasing Continuous	-2×10^{-3}	0.35

	^{239}P Different
	Constan
Model	Re
ICRP 30 $f_u = 0.5$	$0.45e^{-4.8 \times 10^{-5}t} + 0.45e^{-1}$
Moss $f_u = 0.916$	$0.0108e^{-0.44t} + 0.0115e^{-5.0}$
Durbin $f_u = 0.107$	$0.0664e^{-0.58t} + 0.089e^{-0.1}$ $+0.122e^{-2.3}$
Leggett $f_u = 0.5$	$0.012e^{-0.69t} + 0.02e^{-3 \times 1}$ $+0.926e^{-2.2 \times}$

Range of Uptake Estimates

Model	Uptake Regime	Uptake, nCi
Moss	Increasing Continuous	0.01
Durbin	Declining Continuous	2.2

Bikini Adults

^{239}Pu Committed Dose Estimates[1], rem

Model	Bone Surface	Liver	Red Marrow	Effective
ICRP30	35	7.3	2.7	1.9
Leggett	49	10.	3.7	2.7
Durbin	49	10.	3.8	2.7
Moss	4.6	0.96	0.35	0.25

[1]Based on: T = 2617 days,
$\mathfrak{P}$ = 730 days,
$U(\tau)$ = constant,
$C(t) = 12\ fCi\ l^{-1}$
$P = 1.4\ l\ day^{-1}$, and
ICRP30 values for committed dose per unit uptake.

	mrem y^{-1}	
UCRL-52853 Pt. 4		
Rongelap (southern islands)	35 to 135	0.76 to 2.5
Utirik	3 to 29	0.25 to 0.72
	Mean/Maximum Effective Dose Equivalent Rate,[1] mrem y^{-1}	Mean/Maximum Committed Effective Dose Equivalent,[1] mrem
BNL, Health Physics V46,3, 1984		
Rongelap (southern islands)	50/120	0.64/1.2
Utirik	12/29	0.17/0.43

[1]Does not include Pu.

REPOSITORY PNNL

COLLECTION Marshall Islands

BOX No. 5690

FOLDER Enewetak

DOCUMENT DOES NOT CONTAIN ECI

Reviewed by DJ Kiesko Date 5/1/97