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DRAFT: ENIWETOK EXTERNAL POPULATION EXPOSURES

Jim McLaughlin and Hal Beck have produced the enclosed first cut at estimating external population exposures. You will note that it is a draft for discussion purposes only. McLaughlin and Beck will be discussing this with LLL staff this week. While it is very preliminary information and undoubtedly will be significantly revised, it gives perspective on the external dose problem and the effects of actions to reduce these exposures.

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Preliminary Estimates for Dose to Eniwetok Population from External Exposure

1. Table I gives the age and sex breakdown of the 432 people expected to return to Eniwetok based on Tobin's census. Note that almost 2/3 are under 19 years of age.

2. Table II gives suggested models for living patterns based on Tobin's report and the announced desires of the Eniwetok people to utilize the entire atoll. Case Ib differs from case Ia in that more time is allotted to temporarily residing on islands other than Engebi (JANET) while less time is spent in the Engebi village area. Case Ib probably represents an upper limit exposure with regards to any large group of people. Case IV is typical of the least exposed population.

3. Table III gives the dose rates used for the present calculation. These are based on the TLD data (LiF, primarily) using the E.G. and G. data mainly as an indication of whether the TLD data are representative of larger areas. While the exposure rates on all the northern islands have a wide range, the values given in Table III are thought to be ? conservative average values consistent with our evaluation of the validity of the various dose rate measurements made. They do not represent the highest exposures found in each of the locales. In fact, many of the northern islands interiors had exposure rates in some places of several hundred μR/h. Considering the wide range ? from island to island and the variation across a given island from

? ocean beach to lagoon beach, a mean exposure of 100 μR/h is probably on the conservative side.

Table III also gives the estimated fractions of the exposure due to Cs-137 and Co-60 at the present time based on Gudiksen's soil sample data and HASL calculated dose rate ratios. These ratios are also conservative (too much Cs-137). The estimated depth distribution (relaxation length is the depth the activity is e^{-1} times the surface activity) is also based on the soil data. These quantities are also highly variable and in all cases I tried to pick conservative values. Contributions to external dose from isotopes other than Cs and Co are negligible and have been neglected.

4. Table IV gives the calculated values of integrated dose for 5, 10, 30 and 70 year periods. These are the doses the population distribution given in Table I would receive assuming an immediate return to the Atoll. The doses have been weighted by the population distribution to account for the fact that different population groups receive slightly different doses. In actuality, however, it was found that the differences in exposure to the various population groups for the models chosen are minor (see Table V) considering the uncertainties involved. Also we note that the dependence on the time breakdown is also minor since the doses for cases Ia and Ib are not very different. Case II indicates that having the village area on a "clean" island lowers the short term doses by only about 50%, indicating the large influence of the 25-30% of the time spent on the "hotter" outer islands.

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In contrast restricting the population to only areas 3 and 4 (Case IV) results in very low integrated exposures.

For comparison purposes, the mean integrated dose to the Northeast U.S. population (~ 80 mrad/year) are also shown in Table IV. We note that even for the most exposed groups (Cases I and III) the calculated 30 year population doses are likely to be only a few times that received by the Northeast U.S. population. If one considers the mean dose to the ~~ent~~ entire returning population assuming 25% of the people will be represented by Case I (a and b), 25% by Case II 25% by Case III and 25% by Case IV, as shown in Table IV, then the mean exposure for 30 years is only 50% greater than that for the U.S. population.

5. The preceding discussion assumes no modification of the present radiation fields. It is general practice in Micronesia to cover the village areas with 1 to 2 inches of coral rock (Tobin). This action can be expected to reduce the exposure levels in the village area by approximately a factor of two. The second row of doses for each case in Table IV reflects this modification.

Since clearing the islands for agricultural use and housing will result in some mixing of the top soil and since plowing all of the islands to a depth of about 1 foot would not appear to be impractical, we also calculated the expected modification in dose due to an assumed uniform mixing down to this depth. (Plowing presumably results more in mixing than in burying the topsoil. Were the present topsoil to be covered by 12" of relatively inactive soil, this would reduce all levels down to those represented approximately by Case IV.) An average reduction of a factor of 3 was computed from HASL transport calculations (Beck and de Planque, 1968; Beck, 1974) based on the apparent4-5 cm relaxation lengths for the present activity. This additional modification results in the doses shown in row 3 for each case which are in general less than the external doses which the U.S. population would receive for comparable time periods.

6. Table V gives the fraction of the 30 year unmodified dose received by each age group for case Ia to indicate the large fraction of the dose resulting in this case from travel to outer "hot" islands. The dose breakdown by population group is also shown to indicate the relative insensitivity to population distribution. Similar insensitivity to age was obtained for the other cases.

7. The calculated doses are believed to be conservative estimates of the mean doses to the population group as a whole. Because some of the northern islands have dose rates in some areas several times those chosen for our model. Some individuals could (although it is probably unlikely) receive doses perhaps 2 or 3 times those calculated if they happened to build houses in an unmodified area on an island with larger gamma-ray levels.

8. Beta Dose - As a general guideline, for sources distributed in the soil with a 3-5 cm relaxation length we estimate the ^{90}Sr-^{90}Y beta free air dose will be about four times that due to ^{137}Cs γ exposure.

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(This assumes the ^{90}Sr activity is always about 1.5 times the Cs activity which is consistent with the soil analyses in general.) We would thus expect free air beta exposures to average ~ 200 μR/h or more in the interior of Engebi and ~ 100 μR/h in the village areas. Assuming (based on O'Brien's estimates) the skin dose to be ~ 1/2 of the free air exposure and the testes dose to be ~ 1% of the free air exposure we would expect at most additional contributions to the gonadal dose from beta rays of ~ 10 mrad/yr. Beta doses are thus insignificant compared to gamma doses when considering gonadal or bone doses. Note, however, the high free air beta exposure rates may have influenced some of the field TLD results, thus adding to the conservatism assumed in our models.

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TABLE I

POPULATION DISTRIBUTION - ENIWETOK

AGE GROUPS		PERCENT OF TOTAL POPULATION
Infants (0-5 years)	Male	12
	Female	10
Children (6-18 years)	Male	21
	Female	21
Adults (19-50 years)	Male	18
	Female	14
Adults (over 50)	Male	2
	Female	2

TOTAL POPULATION 432

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TABLE II

ESTIMATED GEOGRAPHICAL LIVING PATTERNS

Case	Group	Village	Beach	Interior	Lagoon	Other Islands
Ia Village on Engebi, visits to area 1	Infants	85	5	0	0	10
	Children	55	10	15	5	15
	Men	50	5	15	10	20
	Women	60	10	10	0	20
Ib Village on Engebi, visits to area 1	Infants	70	5	5	0	20
	Children	50	5	15	10	20
	Men	40	5	20	10	25
	Women	50	5	15	5	25
II Village on Eniwetok, visits to area 1	Infants Children Men Women	Same as Case Ib				
III Village on Engebi, visits to areas 3 & 4 only	Infants Children Men Women	Same as Case Ia				
IV Village on Eniwetok, visits to areas 3&4 only	Infants Children Men Women	Same as Case Ib				

TABLE III

Cases Ia, Ib

Mean exposure rates (μR/h)

	Engebi	
	Village:	25 (Cs-137) 5 (Co-60) 3.5 (cosmic)
	Interior:	47 (Cs-137) 8 (Co-60) 3.5 (cosmic)
	Beach:	1.5 (Cs-137) 3.5 (cosmic)
	Lagoon:	3.5 (cosmic)
	Outer Islands:	67 (Cs-137) 33 (Co-60) 3.5 (cosmic)

Isotope depth distribution - α^{-1} = 3-5 cm.

Case II

Mean exposure rates (μR/h)

	Village, Beach, [illegible] Interior:	1.5 (Cs-137) 3.5 (cosmic)
	Lagoon:	3.5 (cosmic)
	Outer Islands:	67 (Cs-137) 33 (Co-60) 3.5 (cosmic)

Isotope depth distribution - α^{-1} = 3-5 cm.

Case III

Mean exposure rates (μR/h)

	Village, Beach, Lagoon same as Cases Ia & Ib	
	Outer Islands:	1.5 (Cs-137) 3.5 (cosmic)

Isotope depth distribution - α^{-1} = 3-5 cm.

Case IV

Mean exposure rates (μR/h)

	Village, Beach, [illegible] Lagoon same as Case II	
	Outer Islands:	1.5 (Cs-137) 3.5 (cosmic)

Isotope depth distribution - α^{-1} = 3-5 cm.

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TABLE IV

ESTIMATED INTEGRAL EXTERNAL DOSES (RADS)

		Time interval - years			
		5	10	30	70
Ia	Unmodified	1.52	2.75	6.72	11.4
	Village Graveled	1.16	2.11	5.24	8.93
	Gravel & Plow	0.40	0.73	1.82	3.16
Ib	Unmodified	1.71	3.09	7.30	12.3
	Village Graveled	1.40	2.53	6.06	10.4
	Gravel & Plow	0.48	0.87	2.10	3.51
II	Unmodified	0.91	1.79	4.00	6.88
	Village Graveled	0.91	1.79	4.00	6.88
	Plow Outer Islands	0.65	1.33	2.93	5.15
III	Unmodified	1.00	1.86	4.42	7.78
	Village Graveled	0.64	1.22	2.95	5.32
	Gravel & Plow	0.25	0.48	1.19	2.24
IV	Unmodified	0.18	0.50	1.03	2.25
Mean Pop. (see notes)	Unmodified	0.92	1.77	4.11	7.19
	Village Graveled	0.75	1.46	3.40	6.03
	Gravel & Plow	0.38	0.78	1.78	3.24
NE USA		0.40	0.80	2.40	5.60

TABLE V

Case Ia

TOTAL INTEGRATED DOSE (RADS)

Group	5 years	10 years	30 years	70 years
Infants	1.37	2.33	6.41	11.1
Children	1.51	2.78	6.71	11.4
Men	1.62	2.98	6.90	11.6
Women	1.63	3.00	6.94	11.6

% OF 30 YEAR DOSE FROM VARIOUS LOCALES

Group	Village	Beach	Interior	Lagoon	Outer Islands
Infants	50	1	16	.5	32
Children	43	1.5	18	.5	37
Men	38	1	20	1.0	40
Women	45	2	13	0	40

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NOTES

a. 3.5 cosmic includes $\sim$ 0.2 from natural and water immersion.

b. near beach areas and lower dose areas $\alpha > 3$-5 cm so reduction due to plowing is smaller. However, initial dose in these situations is small to begin with, i.e., 3-5 cm relaxation lengths α factor of 3 reduction factor are for higher dose areas and thus are conservative.

c. outer island dose rate is average for all locales (beach, lagoon, perimeter, interior) and thus 100 μR/h values should be very conservative even for hotter islands. Alternative would be to further assign fractions of times and people to various locales on specific islands and to various outer islands, an exercise of dubious value.

d. calculated doses are free air exposures - uncorrected for body or structure shielding.

e. values in Table III for fraction of dose due to Co-60 are probably too low. Thus, doses in Table IV are overestimates from this standpoint (Cases Ia and Ib particularly). Additional calculations indicate using more realistic Co-60 fractions would lower doses in Table IV about 15%.

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