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Department of Energy
Nevada Operations Office
P. O. Box 98518
Las Vegas, NV 89193-8518

September 5, 1989

The Honorable Jeton Anjain, Senator
Republic of The Marshall Islands
Majuro, MI 96960

Dear Senator Anjain:

Enclosed is the recently published report by Lawrence Livermore National Laboratory (LLNL) entitled "Estimates of the Radiological Dose from Ingestion of ^{137}Cs and ^{90}Sr to Infants, Children, and Adults in the Marshall Islands." I bring this to your attention specifically because of the concerns raised as to infant doses for Rongelap children who might be returning to live on Rongelap. The discussion on pages 21 and 22 summarize the results of the research and indicate that the estimated integral dose equivalent for adults is conservative when applied to infants and children. We believe this then should satisfy one of the concerns identified first by Dr. Kohn.

We will keep you apprised of further progress on all related issues as data becomes available.

Sincerely,

Original Signed By
HARRY U. BROWN

Harry U. Brown
Program Manager
Marshall Islands

Enclosure:
As stated

cc:
J. E. Rudolph, HQ (DP-242) GTN (w/o encl.)
The Honorable Oscar De Brum, Chief
Secretary, Majuro, MI (w/o encl.)
Peter Oliver, Majuro, MI (w/encl.)
W. L. Robison, LLNL, Livermore, CA (w/o encl.)
J. H. Dryden, Director, PASO (w/o encl.)

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UCRL-53917

Estimates of the Radiological Dose from Ingestion of ^{137}Cs and ^{90}Sr to Infants, Children, and Adults in the Marshall Islands

W. L. Robison
W. A. Phillips

February 1989

Lawrence Livermore National Laboratory

UCRL-53917
Distribution Category UC-702

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Manuscript date: February 17, 1989

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CONTENTS

Estimates of the Radiological Dose from Ingestion of ^{137}Cs and ^{90}Sr to Infants, Children, and Adults in the Marshall Islands

Abstract

In this report, we examine whether the radiological dose equivalent due to the intake of ^{137}Cs and ^{90}Sr at a contaminated atoll in the Marshall Islands would be greater when intake begins as an adult than when intake begins as an infant or child. We found that generally ^{137}Cs contributes 97 to 98% of the dose and ^{90}Sr contributes only 2 to 3%. We also found that the integral 30-, 50-, and 70-y effective dose equivalent estimated for intake beginning as adults is greater than that for intake beginning at any other age. There are two factors that cause the adult estimated dose to be greater than the dose to infants and children. The major factor is the consistently higher intake of local foods, and consequently higher intake of ^{137}Cs, for adults. The second is a combination of changing body weights, fractional deposits, and biological half-life for ^{137}Cs with age, and the reduced concentration of ^{137}Cs in food with time. Consequently, the estimated effective integral dose equivalents for adults due to ingestion of ^{137}Cs and ^{90}Sr can be used as a conservative estimate for intake beginning in infancy and childhood.

Introduction

The purpose of this report is to determine whether the radiological dose equivalent due to the intake of ^{137}Cs and ^{90}Sr at a contaminated atoll in the Marshall Islands would be greater when intake begins as an adult than when intake begins as an infant or child.

In previous publications, we have estimated the radiological doses to adults at several atolls in the northern Marshall Islands resulting from external gamma exposure and internal ingestion of ^{137}Cs, ^{90}Sr, $^{239+240}Pu$, and ^{241}Am (Robison et al., 1982a, 1982b, 1987; Robison, 1983). We have mentioned in all of these reports that the radiological dose from the ingestion of ^{137}Cs and ^{90}Sr beginning in infancy or early childhood would lead to 30- and 50-y integral doses that are about the same or less than similar doses estimated for intake beginning as an adult. These statements were based on dietary data for the daily intake of ^{137}Cs and ^{90}Sr at the Marshall Islands, differences in physiological parameters (such as biological half-life and deposition patterns for ^{137}Cs and ^{90}Sr), body mass as a function of age, and dosimetry; we published a preliminary evaluation of the relative estimated radiological doses for infants, children, and adults in 1974 (Robison et al., 1975).

In this report, we discuss in more detail the methods for estimating the relative radiological dose to infants, children, and adults as a result of ingestion of ^{137}Cs and ^{90}Sr. We have included recent data on physiological parameters, dosimetry models, and diet.

The total dose equivalent (D) from ingestion of a radionuclide to a person (or an organ in a person) is the product of several factors:

$$D \propto \Sigma_i C_i \times I_i \times f_1 \times \frac{T_E^{1/2}}{0.693} \times \bar{d}$$

where

- C_i = the radionuclide concentration in food i, pCi/g,
- I_i = the intake of food i, g/d,
- $T_E^{1/2}$ = the effective half-life of the radionuclide, d,
- f_1 = the fractional deposition of the radionuclide in the body or selected organ, unitless,
- $\bar{d}$ = the dose equivalent rate conversion constant for a unit activity in the body, rem/pCi.

The effective half-life, $T_E^{1/2}$, is the combination of radioactive decay ($T_R^{1/2}$) and biological elimination after ingestion ($T_B^{1/2}$). This combination is $T_E^{1/2} = (T_B^{1/2} + T_R^{1/2})/T_B^{1/2}T_R^{1/2}$, or in terms of elimination constants, $\lambda_E = \lambda_R + \lambda_B$.

Including $T_E^{1/2}$ and f_1 in an overall umbrella of "deposition and retention," there are four separate categories for which data must be available in order to estimate the dose to people from ingestion:

1. The diet—the g/d intake of various foods.
2. The radionuclide concentrations in the various foods.
3. The deposition and retention of the radionuclides in the body.
4. The dosimetry of the ingested radionuclides.

The combination of the dietary intake and the concentration of the radionuclides in food items determines the intake of radionuclides. Consequently, the radionuclide intake is directly proportional to the g/d consumption of local foods at a contaminated atoll. Thus, the relative consumption of imported and local foods is very important for estimating the daily intake of ^{90}Sr and ^{137}Cs .

These four basic categories will be discussed and the results combined to indicate the relative dose equivalent for infants, children, and adults. We will use radionuclide concentration data in local foods at Rongelap Island at Rongelap Atoll as a specific example for the calculation. Moreover, the relative doses established by the methodology for the different age groups would be the same for any atoll; only the daily intake of radionuclides, and consequently the magnitude of the dose, would vary among atolls or islands within an atoll.

Because of the anticipated diverse audience of scientists and laymen to whom this report will be distributed, we have included a significant literature review on the intake and distribution, the retention, and the dosimetry of ^{137}Cs and ^{90}Sr to help lay the foundation for the results.

Table 9. The integral 30-, 50-, and 70-y dose equivalents for bone marrow and bone surfaces for intake of ^{90}Sr beginning at various ages.

	Integral dose equivalent, mrem								
	Bone marrow			Bone surface			Effective		
Age intake begins	30 y	50 y	70 y	30 y	50 y	70 y	30 y	50 y	70 y
Birth	41.4	62.0	75.0	122	182	223	8.6	12.9	15.7
4 months	41.7	62.5	75.6	123	184	224	8.7	13.0	15.8
9 months	43.1	63.7	76.6	127	187	227	9.0	13.3	16.0
1.5 y	43.8	64.3	77.1	129	189	229	9.1	13.4	16.1
4 y	43.2	64.0	77.0	126	187	228	9.0	13.3	16.1
12 y	49.3	70.4	83.5	137	199	241	10.0	14.4	17.3
18 y	48.5	69.8	82.9	116	175	217	9.3	13.6	16.5

Table 10. The integral 30-, 50-, and 70-y <u>effective</u> dose equivalent for continuous intake of ^{137}Cs and ^{90}Sr beginning at various ages.

	Integral effective dose equivalent, mrem[a]			Fraction due to ^{90}Sr		
Age intake begins	30 y	50 y	70 y	30 y	50 y	70 y
Birth	386	580	702	0.02	0.02	0.02
4 months	398	592	714	0.02	0.02	0.02
9 months	367	560	683	0.03	0.02	0.02
1.5 y	370	564	687	0.03	0.02	0.02
4 y	391	585	708	0.02	0.02	0.02
12 y	469	663	786	0.02	0.02	0.02
18 y	513	705	829	0.02	0.02	0.02

[a] The effective dose equivalent is a unit defined by the ICRP (1984) which allows for the different mortality risks associated with irradiation of different organs, together with a proportion of the hereditary effects.

Discussion

The result of our analysis is that the integral 30-, 50-, and 70-y effective dose equivalent estimated for intake beginning as adults at a contaminated atoll is greater than that for intake beginning at any other age. Consequently, the estimated integral dose equivalent for adults is a conservative estimate for infants and children. There are two basic reasons for this result. The first, and major, reason is the consistently higher intake of local foods, and thus ^{137}Cs , for adults found in the diet surveys from the Marshall Islands. Also, the higher intake of food in general by adults is supported by diet surveys of other societies; the intake for adults is greater than for infants and children.

The second reason is that even for continuous ^{137}Cs intake that declines at a rate equal to the radiological half-life of ^{137}Cs and where the initial intake is the same regardless of age, the integral 30-, 50-, and 70-y dose equivalents are slightly greater when intake begins as an adult than for intake beginning at any other age. This results from the combination of changing body weights, fractional deposits, and biological half-life for ^{137}Cs with age and the reduced concentration of ^{137}Cs in food with time. For example, when intake begins as an infant, the ^{137}Cs concentration in food has declined by about 35% by the time the infant reaches 18 y of age, when the dietary intake is greater and the biological half-life of ^{137}Cs longer. Consequently, if the intake of ^{137}Cs for an infant or child were equal to that for the adult (which it is not based on available dietary information from the Marshall Islands), the estimated integral 30-, 50-, and 70-y dose equivalent would still be similar to that estimated for adults.

In the case of ^{90}Sr, the dose commitment per unit intake is greater by about a factor of 5 for intake beginning at ages 0 to 5 y than for intake beginning as an adult. However, when age-dependent differences in intake of ^{90}Sr via the diet are accounted for, the estimated integral 30-, 50-, and 70-y dose equivalents are less when intake begins as an infant or child than when intake begins as an adult.

Even if the ^{90}Sr intake for infants and children were significantly higher than what we have estimated, the total integral 30-, 50-, and 70-y effective dose equivalent from both ^{137}Cs and ^{90}Sr would be greater for adults than for infants and children because ^{137}Cs accounts for about 97% of the total estimated effective dose equivalent at the atolls via the ingestion pathway and ^{90}Sr for less than 3%.

Doses from ^{137}Cs and ^{90}Sr are insignificant through the inhalation pathway as compared to that via ingestion (Robison et al., 1987; ICRP, 1979; Cristy et al., 1984; Kendall, 1986). Consequently, the relative magnitude of the integral dose equivalent among infants, children, and adults can be determined by evaluating the ingestion pathway; that analysis indicates that the estimated effective integral dose equivalents for adults due to ingestion of ^{137}Cs and ^{90}Sr is a conservative estimate for intake beginning in infancy and childhood.

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