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CRITERIA USED TO ESTIMATE RADIATION
DOSES RECEIVED BY PERSONS
LIVING IN THE VICINITY OF HANFORD:
INTERIM REPORT

R. H. Wilson and T. H. Essig

July 1968

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INTERIM REPORT

By

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July 1968

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CRITERIA USED TO ESTIMATE RADIATION DOSES
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ABSTRACT

Rationale for dietary habits used in computation of radiation doses through calendar-year 1964 for selected population groups in the vicinity of Hanford are presented. Also discussed is the method used to compute environmental radiation doses based on these dietary habits and on measured concentrations of radionuclides in several environmental media.

INTRODUCTION

Information about the distribution of radioactive effluents released to the environs from the Hanford facilities was obtained through a comprehensive environmental surveillance program. This program was conducted by the General Electric Company until January, 1965, and since then by Battelle-Northwest. Many types of samples are collected throughout the four seasons of the year for determining concentrations of various radionuclides. Direct measurements also were made of radiation levels over land and in the Columbia River. These measurements of radionuclide concentrations and external radiation levels in the environs, coupled with reasonable assumptions of living habits, provide the basis for calculating probable radiation doses received by persons living near the Hanford project.

For purposes of evaluating radiation doses received by persons living near the plant perimeter, two hypothetical cases, (1) the "maxi-

mum individual" living in the neighborhood of the Hanford plant, and (2) a "suitable sample" of the general population, were considered. The "maximum individual" and "suitable sample" of the general population and the methods and criteria used to evaluate radiation dose were chosen to be responsive to the Atomic Energy Commission Manual⁽¹⁾ and to be compatible with the intent expressed in the recommendations of the Federal Radiation Council (FRC),⁽²⁾ the International Commission on Radiological Protection (ICRP),⁽³⁾ and the National Council on Radiation Protection and Measurements (NCRP).⁽⁴⁾

In addition to the above two population categories, it is necessary to give special consideration to the dose received by the thyroid glands of small children, primarily because of differences in both the thyroid mass and in the diet between small children and adults. Child and adult thyroids were considered to have masses of 2 and 20 g, respectively. Doses received by the thyroids of a "maximum" small child and

a "typical" small child were also estimated for comparison with appropriate limits.

GUIDES AND STANDARDS

The FRC and the ICRP-NCRP provide similar guides and recommendations for assessing environmental radiation doses. The Radiation Protection Guide (RPG) has been defined by the FRC as: "The radiation dose which should not be exceeded without careful consideration of the reasons for doing so. Every effort should be made to encourage the maintenance of radiation doses as far below this guide as practicable." These guides are applied in reference to a hypothetical individual in the general population who receives the maximum dose, and to the average dose received by a "suitable sample" of the general population. Small children are considered as part of the "suitable sample" of the general population and, where applicable (as in the case of the thyroid gland), radiation doses should be estimated on the basis of a small child.

The ICRP and NCRP recommendations are expressed as "maximum permissible dose" or, in the case of internally deposited emitters, as tertiary standards of "maximum permissible concentrations" (MPC) of radionuclides in air and water for occupationally exposed persons. MPC values for individuals of the general public are one-tenth of these concentrations. The ICRP further suggests that, because of the existing uncertainty

as to the dose effect relationships for somatic effects, the average concentrations of such isotopes, or mixtures thereof, in air or water, applicable to the population at large, should not, for planning purposes, exceed one-thirtieth of the MPC values of continuous occupational exposure given in the report of Committee II.

BASIS FOR CHOICE OF POPULATION GROUPS

In its Radiation Protection Guides, the FRC specifically refers to a "maximum" individual in the general population, and to the "average" of a suitable sample of the general population. The council also states that suitable population samples should neither contain a disproportionate fraction of small children, nor should a disproportionate fraction of the average dose be attributed to this sensitive population element. Therefore, to most accurately estimate radiation doses received by people within the Hanford environs, in consonance with FRC established guidelines, a diet composited from the maximum intakes found in several dietary studies⁽⁵⁻⁹⁾ was assumed for a hypothetical adult individual.

Some of the area around the Hanford plant is sparsely populated, undeveloped, and semi-arid, while other areas have become productive farmland through irrigation. The Tri-Cities (Pasco, Kennewick, and Richland), situated on the Columbia River immediately downstream from the Hanford facilities, are the most densely populated local areas. These

three communities together provide the largest population group (about 60,000) in the plant perimeter area. Other small communities and rural families raise the total population in the immediate plant environs to about 90,000. The area along the river between the Tri-Cities and the Portland-Vancouver area (270 miles downstream from the Hanford reactors) is very sparsely populated and contains not more than 30,000 people. Since the Columbia River is used for dilution and dispersal of aqueous effluents from Hanford's reactors, the Tri-Cities as well as communities farther downstream may receive low-level doses attributable to Hanford sources.

Residents of the city of Richland were selected as a suitable sample of the general population near the plant because they represent the largest single group with similar living conditions and sources of food. In addition, Richland is the first large community downstream from the Hanford reactors using the Columbia River as a source of drinking water.

In summary, two hypothetical persons have been established in the Hanford environs for comparison with Radiation Protection Standards for individuals, i.e., the Maximum Individual and the Maximum Child. The Maximum Individual has been assigned a diet consisting of river-irrigated crops from the Riverview farm area (Pasco), fish caught from the Columbia River, and drinking water from the Pasco system. The Maximum Child (who also resides in the Riverview area) has been estab-

lished solely for computation of thyroid dose.

Compliance with Radiation Protection Standards for "average exposures of a suitable sample of the exposed population" is determined by considering a Typical Richland Resident and a Typical Richland Child. The Typical Richland Resident's diet consists of foods purchased from local stores and of drinking water from the Richland System. The Typical Richland Child, like the Maximum Child, is considered only from the standpoint of thyroid dose.

DIETARY ASSUMPTIONS

The dietary habits selected for the population categories used in environmental dose estimation were taken from several sources. Selection of individual food items and amounts were guided by dietary studies sponsored by the U.S. Department of Agriculture,^(5,6) U.S. Department of Commerce,⁽⁷⁾ diets compiled by Bustad and Terry,⁽⁸⁾ and the Adequate Diet proposed by the National Research Council.⁽⁹⁾ Tables I and II summarize the results of these several diet surveys.

The food items chosen for individual attention in the Maximum Individual and the Typical Richland Resident diet, and estimates of local consumption rates are summarized in Tables III and IV. Results of the various dietary surveys, together with local knowledge of dietary habits (as available), were used to obtain the consumption levels shown in Tables III and IV. The maximum

TABLE I. Average Dietary Values^(a) for Adults

Food	USDA ⁽⁵⁾ Bull. 127	USDA ⁽⁶⁾ Bull. 132 Table 52	USDA ⁽⁶⁾ Bull. 132	USDC ⁽⁷⁾	Bustad ⁽⁸⁾ & Terry	NRC ⁽⁹⁾ Adeq. Diet
Dairy Products l/d ^(b)	0.83	0.51	0.37		0.84	0.95
Fluid Milk l/d ^(b)	0.69			0.44	-	
Other	72			52	-	
Meat and Fish	265	200		234	266	209
Beef	63			93	63	
Pork	106			78	107	
Poultry	36			33	36	
Fish & Seafood	28			13	29	
Other	32			17	31	
Fresh Fruits	153	274		136	153	226
Vegetables						
Fresh	65	197	202	179		258
Leafy	18				22	
Potatoes	285	137	112	144	284	291
Other	5				104	24
Preserved Fruits and Vegetables	232	174	196	122	237	226
Other Foods						
Fats & Oils	83	58	55	55	83	88
Sugar	118	84	151	118	119	81
Eggs	80	48	69	62	80	85
Flour & Flour Equiv.	262	250	216	217	264	339
Total (grams/day) ^(c)	1566	1422	1405	1267	1612	1827
Total (kilograms/ year) ^(c)	572	519	513	463	589	667

a. Units of grams/day unless otherwise noted

b. l/d = liters per day

c. Excludes dairy products, water, and other liquids

TABLE II. Selected Maximum Dietary Values for Adults

Foodstuffs	Daily Intake	Reference
Milk & Milk Products	1.05 liter/day	U.S. Dept. of Agr.
Meat (Beef, Pork, Poultry)	227 g/day (1/2 lb)	U.S. Dept. of Agr.
Fish (Local fresh)	110 g/day (1/4 lb)	Local estimate and U.S. Dept. of Agr.
Fresh Leafy Vegetables	200 g/day	Bustad and Terry
Fruits and Vegetables	1430 g/day (3 lb)	Bustad and Terry
Preserved Fruits and Veg.	300 g/day	U.S. Dept. of Agr.
Other Foods (Fats, Oils, Sugar, Eggs, Flour, & Flour Equiv.)	750 g/day 3017 g/day 1102 kg/yr	U.S. Dept. of Agr.

TABLE III. Dietary Assumptions for the Adult

Foodstuffs	Maximum Individual	Typical Richland Resident
Drinking Water	2.0 l/day (730 l/yr)	1.2 l/day (438 l/yr)
Milk	1.05 l/day (380 l/yr)	0.85 l/day (310 l/yr)
Meat	227 g/day (80 kg/yr)	227 g/day (80 kg/yr)
Fish [Seafood]	110 g/day (40 kg/yr)	[15 g/day (5.5 kg/yr)]
Fresh Leafy Vegetables	200 g/day (73 kg/yr)	100 g/day (36.5 kg/yr)
Vegetables and Fruits	1430 g/day (520 kg/yr)	100 g/day (36.5 kg/yr)
[Other Foods (Includes Flour, Cereal Grains, Sugar, Fats, etc.)]	[Based on ⁹⁰ Sr in Milk Being 40% of the Total Intake.]	[Based on ⁹⁰ Sr in Milk Being 40% of the Total Intake.]

TABLE IV. Dietary Assumptions for the Small Child

Foodstuffs	Maximum Child	Typical Richland Child
Drinking Water	0.8 l/day	0.4 l/day
Milk	1.0 l/day	0.6 l/day
Fresh Leafy Vegetables	50 g/day	25 g/day

consumption rates found by these dietary surveys were composited to establish a diet for the Maximum Individual.

Bases for the particular quantities of individual food items in the diets used for dose estimation at Hanford are discussed below.

- Drinking Water

Maximum Individual--Two liters per day were based on local dietary questionnaires in which it was found that many coffee drinkers consume 10 to 12 cups per day.

Maximum Child--0.8 liter per day was based primarily on local estimates and the fact that maximum intakes found during dietary surveys were usually about double the average intake.

Typical Richland Resident--1.2 liters per day were based wholly

upon the ICRP "standard man" parameters for water balance in the body.

Typical Richland Child--The 0.4 liter per day was chosen arbitrarily on local estimates. A study⁽¹⁰⁾ of water intake of normal children in another part of the country indicates that 0.4 liter may be somewhat high. That study also indicated that water directly from the tap provided less than half the total fluid intake. Prepared juices and drinks account for the remainder.

- Milk and Milk Products

Maximum Individual--The consumption rate of 1.05 liters per day was based on findings of a dietary study of rural families by the USDA. Milk is a readily available and reasonably priced food commodity

both in the USDA survey area and in the Hanford environs.

Maximum Child--One liter per day was based primarily on local knowledge that small children living in rural communities near the Hanford perimeter often consume this amount of milk.

Typical Richland Resident--The consumption rate of 0.85 liters per day was based on findings of dietary surveys conducted by the USDA.

Typical Richland Child--The consumption rate of 0.6 liters per day was based on information obtained from dietary surveys and local estimates.

- Meat

Maximum Individual--A value of 227 grams per day (1/2 lb) was selected from USDA dietary survey data which indicated that maximum diets included about 3/4 lb per day of meat and fish. In addition to these survey data, local fish consumption was known to be about 1/4 lb per day.⁽¹¹⁾

Typical Richland Resident--A value of 227 grams per day (1/2 lb) was chosen from dietary surveys by the U.S. Department of Agriculture, the U.S. Department of Commerce, and from recommendations of the NRC for an adequate diet. These all indicated that the intake of beef, pork, and poultry was in the range of 1/2 lb per day.

- Fish

Maximum Individual--Dietary findings (see Table I) and information gathered by the Washington State Department of Game⁽¹⁰⁾ from local

fishermen indicated this intake to be about 110 grams per day (~1/4 lb). This survey disclosed that a few people claimed to eat as many as 200 meals per year of fresh fish caught in the Columbia River. Fresh fish reported most frequently eaten were crappie, perch, and bass.

Typical Richland Resident--Dietary information gathered on fish and seafood consumption was sketchy since, in most dietary information, fish is classified in the general meat category. The U.S. Department of Commerce survey was used as a guide along with local information in estimating the intake of fish to average 15 grams per day (~1 lb/month). Seafoods such as shellfish were also included in this category. Selective sampling of Willapa Bay, Washington oysters determined the concentration of radionuclides considered for dose contribution, and an arbitrary market dilution factor of 10 was applied to allow for consumption of other kinds of seafood whose concentration of radionuclides was negligible.

- Fresh Leafy Vegetables

Maximum Individual--A dietary survey conducted among young adults in two Washington State communities⁽⁸⁾ found that the maximum diets included about 200 grams per day (nearly 1/2 lb) of fresh leafy vegetables. Fresh leafy vegetables of local origin are generally available for inclusion in the diet only during a five-month local growing season of May through September. During the remaining 7 months of the year, fresh leafy vegetables

as available in the diet come from commercial markets.

Maximum Child--The diet level of 50 grams per day for the child was assigned from local estimates of food intake. Fresh leafy vegetables of local origin were considered available on the same time basis as those for the maximum individual.

Typical Richland Resident--Dietary surveys conducted by the USDA and Bustad and Terry have indicated 100 grams per day ($\sim 1/4$ lb) as a reasonable quantity of fresh leafy vegetables. Commercial markets are considered the chief supplier to the typical resident.

Typical Richland Child--A conservative intake rate of 25 grams per day was established locally. Generally, dietary surveys have shown the average diet to be about one-half the maximum diet and, since 50 grams per day was assigned as the maximum child's diet, this amount appears reasonable. The commercial market is considered as the source of these food items.

- Other Vegetables and Fruits

Maximum Individual--The value of 1430 grams per day (~ 3 lb) was based on a dietary study conducted among young adults in two Washington State communities.⁽⁸⁾ The source of these food items is considered the same as for fresh leafy vegetables.

Typical Richland Resident--Dietary surveys conducted by the USDA and Bustad and Terry indicated that an intake of 100 grams per day ($\sim 1/4$ lb) is reasonable. Source is the local commercial market.

- Other Foods

The radiation dose received by persons from ingestion of other foods not mentioned previously (such as grain and grain products, sugar, fats, and oils, etc.) is considered to be primarily from ^{90}Sr of fallout origin. As a basis for estimating the ^{90}Sr dose contribution, the findings of the Tri-City (New York, Chicago and San Francisco) dietary study conducted under the direction of the USAEC Health and Safety Laboratory were used. This study indicated that ^{90}Sr ingested with milk is equivalent to about 40% of the total amount of ^{90}Sr ingested from all food sources.⁽¹²⁾ Therefore, the concentrations of ^{90}Sr found in locally available milk are used as the basis for estimating the ingestion rate of ^{90}Sr from other foods. The ^{90}Sr intake from drinking water is combined with the ^{90}Sr intake from foods for inclusion in Hanford environmental dose estimates.

DEVELOPMENT OF DATA FOR DOSE CALCULATIONS

Radionuclide concentrations in various environmental samples were determined at frequencies established primarily through many years of experience operating a large and complex environmental surveillance program. Samples were collected from areas as near the points of human usage as possible to more truly represent the actual foodstuffs and drinking water in the diet.

DRINKING WATER

Radionuclides which are the major contributors to radiation doses from drinking water were identified from a series of rather complete analyses of Columbia River water for some 60 individual radionuclides. Samples of water were systematically collected from each of the Tri-City (Pasco, Kennewick, and Richland) water plants as it entered the distribution system after treatment. These periodic samples were analyzed for the radionuclides (RE+Y, ^{24}Na , ^{32}P , ^{51}Cr , ^{64}Cu , ^{65}Zn , ^{76}As , ^{90}Sr , ^{131}I , ^{239}Np) contributing about 95% of the total radiation dose received by the GI tract of persons drinking the water.⁽¹³⁾

Concentrations of each nuclide were averaged over the calendar year to provide a basis for computing an annual radiation dose. In addition to periodic isotopic analyses, water samples were collected 5 days per week from the Richland plant for gross beta activity determination as an additional check for unusual activity levels. Experience has shown a good correlation between the gross beta count rate and GI tract dose calculated from radiochemical analyses. Thus, routine GI tract dose estimates can also be made from the gross beta count rates.⁽¹⁴⁾

MILK

A comprehensive milk sampling program was maintained at farms around the plant perimeter and in local markets for commercial brands of milk.

Milk sampling frequencies varied from weekly for local farms to semi-monthly for commercial brands. Sampling locations were strategically placed about the plant perimeter in order to obtain samples from all areas surrounding the project. More emphasis, however, was placed on sampling locations downwind from the chemical processing plants (the major potential source of airborne radionuclides).

For the Maximum Individual and the Maximum Child, concentrations of radionuclides (^{32}P , ^{65}Zn , ^{90}Sr , ^{131}I , ^{137}Cs) found in milk from the Riverview district were used as the basis for estimating dose from this source. Many of the pastures and hay fields in this area, irrigated during the entire growing season with Columbia River water, are downwind of the chemical processing plants. For the Typical Richland Resident and Typical Richland Child, concentrations of radionuclides measured in milk from commercial outlets were used as the basis for dose estimation.

FISH AND MEAT

Information accumulated during a creel survey conducted along the Columbia River by State Game Protectors indicated that a few avid fishermen may eat as many as 200 meals of fresh Columbia River fish per year. It was also determined that these fish meals consisted mainly of bass, crappie, and perch.

In order to estimate a radiation dose from this source, a fish meal was estimated to consist of about

200 grams (~1/2 lb) of fish flesh for a total consumption of approximately 40 kg per year. The amount of each species eaten was estimated by assuming an average weight for the flesh of each fish. The average weights were 600 grams for bass, 100 grams for crappie, and 100 grams for perch. These weights were based on data accumulated from fish caught in the environmental surveillance program. The weight of flesh of each of the three species was then prorated with time to establish the total annual consumption of 40 kg. The total intake of ^{32}P , the most significant radionuclide present in fish in terms of dose, was derived by summing the uptake of ^{32}P estimated from each species of fish.

A small amount of seafood was assumed to have been eaten by the Typical Richland Resident. For purposes of estimating radiation doses from this source, the average annual concentrations of radionuclides found from periodic sampling of Willapa Bay oysters (routinely higher in concentrations of ^{65}Zn than other seafoods) were used. These concentrations, however, were reduced by a factor of 10 for an assumed market dilution.

The annual average concentrations of radionuclides found in meat consumed by the Maximum Individual were determined from samples of various cuts of beef, pork, lamb, and poultry periodically collected from farms in the Riverview district. The intake by the Typical Richland Resident was determined from the annual average concentrations found in samples of several

varieties of meat periodically collected from large commercial markets in the Tri-Cities.

FRESH VEGETABLES AND FRUITS

The Maximum Individual was assumed to have consumed vegetables and fruits grown in the Riverview and Ringold areas where fields are irrigated with water obtained from the Columbia River below the reactors. Samples of several varieties of fruits and vegetables were collected from various farm areas around the plant perimeter during the local growing season of May through September. During the other 7 months of the year, residents obtain vegetables and fruits from the commercial markets and from home-canning. Fresh leafy vegetables were considered separately for dose determinations because concentrations of a few radionuclides, particularly ^{131}I , are sometimes found to be significantly different than in other fresh vegetables and fruits.

For the Typical Richland Resident and Typical Richland Child, radionuclide concentrations in vegetables and fruits obtained periodically throughout the year from local commercial markets were used as the basis for dose estimation.

EXTERNAL RADIATION

In addition to the exposure caused by internally-deposited radionuclides, the Maximum Individual's living habits are such that some radiation dose is received from external sources in addition to the naturally

occurring radiation background. The Maximum Individual's diet includes a significant amount of personally caught fresh Columbia River fish. In order to catch these fish, a considerable amount of time must be spent along the river bank. From information gathered from the more avid fisherman, 200 hr a year was chosen as a reasonable estimate of time spent along the river. Gamma radiation from radioactive materials deposited on the mud, sand, and debris was measured periodically along the river's edge in areas frequented by fishermen.

Immersion exposure rates were also routinely measured at several locations in the Columbia River below the Hanford reservation. Persons boating in the river, water skiing, or swimming have significantly lower external exposure rates than shoreline fishermen. No external dose contribution from these types of recreational uses of the river was assigned to persons in the Hanford environs.

FACTORS USED FOR CALCULATING RADIATION DOSES

The critical organs of persons receiving radiation doses from environmental sources in the Hanford environs were known from experience to be the total body, bone, GI tract, and thyroid. Study and experience have shown that a major portion (90-95%) of radiation doses in the Hanford environs are contributed by a relatively few radionuclides. These nuclides are ^{24}Na , ^{32}P , ^{51}Cr , ^{64}Cu , ^{65}Zn , ^{76}As , ^{90}Sr , ^{131}I , ^{239}Np ,

and RE+Y. In order to quickly estimate the radiation dose contributed by each of these radionuclides to the several critical organs, a table of factors based on the organ dose received from an intake of one microcurie of a specific radionuclide was established. The parameters set forth in the ICRP Publication No. 2, and in the FRC Radiation Protection Guides for calculating dose, were used. Many of the factors have been tabulated previously by J. Vennart and M. Minski, and were published in the British Journal of Radiology.⁽¹⁵⁾ Where possible, these dose factors were used directly.

The significance of bone seekers such as ^{32}P and ^{90}Sr require special consideration and treatment because the rate of intake of ^{32}P has not been specifically studied by the FRC⁽²⁾ in relation to a dose-equivalent for the bone or bone marrow. The FRC, in developing intake guides for ^{90}Sr and ^{89}Sr , apparently did not believe that a relative damage factor (n) should be used to change absorbed dose (rads) to a dose-equivalent (rem). Use of a computational scheme for ^{32}P similar to that used by the FRC for ^{90}Sr will result in a maximum permissible rate of intake substantially greater than that recommended by the ICRP.⁽³⁾ In the absence of definitive guidance, the dose equivalent for ^{32}P in bone derived by the ICRP (with the use of an n factor of 5) is not considered directly comparable with the dose specified in the FRC guide (1.5 rem/yr). In view of the AEC instruction that ICRP-NCRP^(3,4) dosimetry methods be

used where FRC direct guidance is lacking, and of the more conservative rate of intake for ^{32}P implied by the ICRP-NCRP recommendations, ICRP values have been continued in use as a reference base. Further, rather than introduce the additional confusion associated with dose-equivalents for bone derived by different techniques, the data for bone seekers have been expressed in terms of a maximum permissible rate of intake (MPRI).

The MPRI is taken as the product of the maximum permissible concentration (MPC) in water for a given radionuclide, as recommended by the ICRP for persons in the neighborhood of controlled areas and the rate of water intake as defined for the standard man. The resulting amount is one-tenth of the MPC for continuous occupational exposure multiplied by intake rates of 2.2 liters/day or 800 liters/yr (for annual estimates). In the case of ^{32}P and ^{90}Sr , the MPRI's are 16 and 0.32 $\mu\text{Ci/yr}$, respectively, for individuals in the exposed population. The ^{32}P MPRI for the average of the exposed population is one-third of the MPRI for individuals, or 5.3 $\mu\text{Ci/yr}$. The ^{90}Sr MPRI for the average of the exposed population was based on criteria given in FRC Report No. 2.⁽²⁾ The top of FRC Range II (200 pCi/d) was considered as 100% of the permissible daily intake or about 0.073 $\mu\text{Ci/yr}$.

Computation of the dose received by the thyroid gland was related to FRC intake guides recommended for ^{131}I . The top of Range II (100 pCi/d)

was rounded off by the FRC from approximately 80 pCi/d which, if sustained over a one-year period, would result in a dose of approximately 500 mrem for a two-gram thyroid based upon current ICRP dose calculation factors. Using 80 pCi/d (0.029 $\mu\text{Ci/yr}$) intake of ^{131}I as a basis, the microcurie-dose factor was 17,000 mrem/ μCi ingested for an infant 2-gram thyroid.

Table V summarizes the factors used in calculating radiation doses from environmental sources.

The following figures (1 and 2) show how the radiation doses for the Maximum Individual and the Typical Richland Resident were composited from various environmental media during 1964.

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TABLE V. Microcurie--Dose Factors for Calculating Environmental Doses

Isotope	GI Tract ^(a)	Total Body ^(a)	Thyroid ^(a)	Bone ^(b)
Units of mrem/ μ Ci Intake			Units of % MPRI/ μ Ci Intake	
<u>Maximum Individual</u>				
²⁴ Na	6.2	1.7	-	-
³² P	21	7.4		6.25
⁵¹ Cr	1.2	-	-	-
⁶⁴ Cu	4.6	-	-	-
⁶⁵ Zn	9.6	6.5		0.12
⁷⁶ As	77.	-	-	-
⁹⁰ Sr	38.	1560.	-	312.
¹³¹ I	-	-	1700 Adult 17000 Child	- -
²³⁹ Np	18.7	-	-	-
RE+Y	50.	-	-	-
<u>Typical Richland Resident</u>				
²⁴ Na	6.2	1.7	-	-
³² P	21.	7.4	-	19.
⁵¹ Cr	1.2	-	-	-
⁶⁴ Cu	4.6	-	-	-
⁶⁵ Zn	9.6	65.	-	0.37
⁷⁶ As	77.	-	-	-
⁹⁰ Sr	38.	1560.	-	1370.
¹³¹ I	-	-	1700 Adult 17000 Child	- -
²³⁹ Np	18.7	-	-	-
RE+Y	50.	-	-	-

a. Microcurie--dose factor: the dose in mrem that 1 μ Ci of an ingested radionuclide will deliver to a given organ either over an infinite period of time from an acute intake, or over a one-year period when equilibrium conditions are maintained by a constant daily intake. All radionuclides were considered to be in soluble form for computation of dose factors.

It is recognized that the dose limit for the total body is based on exposure to the gonads and red bone marrow. The dose factors used here for the total body assume a uniform distribution and are therefore inherently conservative, particularly in the case of ⁹⁰Sr.

b. In case of bone, the factor is expressed in per cent of maximum permissible rate of intake, i.e., 100% is equivalent to the MPRI.

FIGURE 1. Estimated Dose to
Maximum Individual, 1964

FIGURE 2. Estimated Dose to Typical Richland Resident, 1964

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