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Health and Safety

CRITERIA USED TO ESTIMATE RADIATION DOSES RECEIVED BY PERSONS LIVING IN THE VICINITY OF HANFORD: INTERIM REPORT NO. 2

By

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Radiation Protection Department
Technical Services Division

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for the typical Richland resident from recreational use of the Columbia River. Radionuclide intakes from poultry and eggs were added to the total dietary intakes. An improved method of estimating GI (gastro-intestinal) tract doses from drinking water was also initiated.

GUIDES AND STANDARDS

Chapter 0524 of the AEC Manual[4] provides alternative radiation protection standards for its contractors based either on concentrations in air and water or on accumulated doses. For population groups in uncontrolled areas, standards of accumulated dose are most appropriate for the complex of sources, nuclides, and pathways existing at Hanford.

The Federal Radiation Council (FRC),[5] the International Commission on Radiological Protection (ICRP),[6] and the National Council on Radiation Protection and Measurements (NCRP),[7] provide guides and recommendations for assessing environmental radiation doses. The Radiation Protection Guide has been defined by the Federal Radiation Council 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 received the maximum dose, and to the average dose received by a "suitable sample" of the general population. Small children are normally considered as part of the "suitable sample" of the general population, but where applicable (as in the case of the thyroid gland), radiation doses should be estimated on the basis of a small child. In its initial publications, the FRC provided numerical dose standards for nonradiation workers only for the whole body, gonads, bone, and thyroid, with intake guides for specific isotopes. It has therefore been necessary to use ICRP-NCRP parameters to make dose estimates for other body organs.

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AEC RESEARCH & DEVELOPMENT REPORT

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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 taken to be 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 large populations should not for planning purposes exceed one-thirtieth of the MPC values of continuous occupational exposure given in the 1962 report of Committee II.[6]

The significance of bone seekers such as ^{32}P and ^{90}Sr has required special consideration and treatment because the rate of intake of ^{32}P has not been specifically studied by the FRC 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 would result in a maximum permissible rate of intake substantially greater than that recommended by the ICRP. 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) has not been considered directly comparable with the dose specified in the FRC guide (1.5 rem/year). In view of the AEC instruction that ICRP-NCRP[6,7] dosimetry methods be used where direct FRC guidance is lacking, and of the more conservative rate of intake for ^{32}P implied by the ICRP-NCRP recommendations, use of ICRP permissible intake values has been continued. 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).

BASIS FOR CHOICE OF POPULATION GROUPS

Part of the area around the Hanford plant is sparsely populated, undeveloped, and semiarid, while other parts 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 50,000 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 small radiation doses attributable to Hanford sources.

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 for suitable population samples, a disproportionate fraction of the average dose should not be received by the most sensitive population elements.[5] To estimate radiation doses received by people within the Hanford environs in consonance with FRC established guidelines, a composite diet from the maximum intakes found in several dietary studies[8-12] was assumed for a hypothetical adult "Maximum Individual."

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 that uses the Columbia River as a source of drinking water. Average diets from predominant food sources were assumed for a "Typical Richland Resident."

In addition to the above two population categories, special consideration has been given to the dose received by the thyroid glands of small children, primarily because of differences both in the thyroid mass and differences in the diet between small children and adults. Child and adult thyroids were considered to have masses of 2 and 20 grams respectively. Doses received by the thyroids of a "maximum" small child and "typical" small child were estimated for comparison with appropriate limits.

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 established solely for computation of thyroid dose.

Compliance with Radiation Protection Standards for "average exposures of a suitable sample of the exposed population" was determined by considering a Typical Richland Resident and a Typical Richland Child. The Typical Richland Resident's diet consisted of foods purchased from local stores and of drinking water from the Richland system. The Typical Richland Child, like the Maximum Child, was 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,[8,9] U.S. Department of Commerce,[10] diets compiled by Bustad and Terry,[11] and the Adequate Diet proposed by the National Research Council.[12] Tables 1 and 2 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 3 and 4. 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 3 and 4. The maximum 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. The 2 liters/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. The 0.8 liters/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. The 1.2 liters/day were based wholly upon the ICRP "standard man" parameters for water balance in the body.

TABLE 1. Average Dietary Values[a] for Adults

Food	USDA[8] Bull. 127	USDA[9] Bull. 132 Table 52	USDA[9] Bull. 132	USDC[10]	Bustad[11] and Terry	NRC[12] Adequate 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 and 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 and Oils	83	58	55	55	83	88
Sugar	118	84	151	118	119	81
Eggs	80	48	69	62	80	85
Flour and Flour Equiv.	262	250	216	217	264	339
Total, g/day[c]	1566	1422	1405	1267	1612	1827
Total, kg/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 2. Selected Maximum Dietary Values for Adults

Foodstuffs	Daily Intake	Reference
Milk and Milk Products	1.05 ℓ/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, and Flour Equiv.)	750 g/day	U.S. Dept. of Agr.
	3017 g/day[a]	
	1102 kg/year[a]	

a. *Excludes dairy products, water, and other liquids*

TABLE 3. 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)]
Vegetables and Fruits	1430 g/day (530 kg/yr)	550 g/day (200 kg/yr)

TABLE 4. 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

Typical Richland Child. The 0.4 liters/day was based arbitrarily on local estimates. A study[13] of water intake of normal children in another part of the country indicates that 0.4 liter may be somewhat high. The 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/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/day was based on findings of dietary surveys conducted by the USDA.

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

MEAT

Maximum Individual. A value of 227 g/day (1/2 lb/day) was selected from USDA dietary survey data which indicated that maximum diets included about 3/4 lb/day of meat and fish. In addition to these survey data, local fish consumption was known to be about 1/4 lb/day.[14]

Typical Richland Resident. A value of 227 g/day (1/2 lb/day) 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, etc., was in the range of 1/2 lb/day.

POULTRY AND POULTRY PRODUCTS

Consumption rates for chickens and eggs were added to local diets during 1965 to better estimate environmental radiation doses by considering an additional exposure pathway.

Maximum Individual. Values for chicken consumption of 3 meals per month (8.0 kg/year) and egg consumption of 1 dozen per week (30 kg/year) were based primarily on local estimates.

Typical Richland Resident. Values for chicken consumption of 2 meals per month (5.4 kg/year) and egg consumption of 1/2 dozen per week (15 kg/year) were based primarily on local estimates.

FISH

Maximum Individual. Dietary findings (see Table 1) and information gathered by the Washington State Department of Game[14] from local fishermen indicated this intake to be about 110 g/day (about 1/4 lb/day), based on the claims of a few people to eat as many as 200 meals per year of fresh fish caught in the Columbia River. Fresh Columbia River fish reported most frequently eaten were crappie, perch, and bass.

Typical Richland Resident. Dietary information gathered in 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 g/day (about 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 by Bustad and Terry[11] found that the maximum diets included about 200 g/day (1/2 lb/day) 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 seven months of the year, fresh leafy vegetables available in the diet come from commercial markets.

Maximum Child. The diet level of 50 g/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 base as for the maximum individual.

Typical Richland Resident. Dietary surveys conducted by the USDA and Bustad and Terry have indicated 100 g/day (about 1/4 lb/day) 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 g/day was established locally. Generally, dietary surveys have shown the average diet to be about one-half the maximum diet and, since 50 g/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 g/day (about 3 lb/day) was based on the dietary study of Bustad and Terry. 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 550 g/day (about 1-1/4 lb/day) is reasonable.* The assumed source is the local commercial market.

DEVELOPMENT OF DATA FOR DOSE CALCULATIONS

Radionuclide concentrations in various environmental samples were determined at frequencies and locations indicated by experience with the complex environmental surveillance program at Hanford. The actual foodstuffs and drinking water in the several diets of interest were represented as closely as possible in the sampling program.

DRINKING WATER

Radionuclides that are the major contributors to radiation doses from drinking water have been identified from a series of rather complete analyses of reactor cooling water effluents and Columbia River water. More than 60 individual radionuclides have been identified. Samples of water were routinely collected from each of the Tri-City (Pasco, Kennewick, and Richland) water plants as the water entered the distribution system after treatment. These samples were analyzed for the radionuclides (^{24}Na, ^{32}P, ^{51}Cr, ^{64}Cu, ^{65}Zn, ^{76}As, ^{131}I, ^{239}Np, and the Rare Earth plus Yttrium fraction) which contribute about 95% of the total radiation dose received by the GI tract of persons drinking the water.[15]

In addition to periodic isotopic analyses, water samples were collected on a daily to weekly basis from the Tri-City water plants for gross beta activity determination as a measurement of the variation of radionuclide concentrations with time. Experience has shown a good correlation between the gross beta

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* *The prior report[3] erroneously quoted 100 g/day instead of 550 g/day.*

count rate and the GI tract dose rate calculated from radiochemical analyses.[16] The ratio of the GI tract dose rate to the gross beta activity of a given sample was therefore used as a "calibration factor" for determining the variation of GI tract dose rates with time from the frequent gross beta analyses.

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 semimonthly for commercial brands. Sampling locations were strategically placed about the plant perimeter to obtain samples from all nearby milk-producing areas. 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, ^{131}I) found in milk from the Riverview district were used as the basis for estimating doses from this source. The pastures and hay fields in this area, irrigated during the entire growing season with Columbia River water, are also 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

Creel surveys[14] conducted along the Columbia River by Washington State Game Protectors have 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 g (about 1/2 lb) of fish flesh for a total consumption of 40 kg/year. The amount of each species eaten was estimated by assuming an average weight for the flesh of each fish. The average weights used were 600 g for bass, 100 g for crappie, and 100 g for perch, determined from fish caught for the environmental surveillance program. The weight of flesh of each of the three species was then prorated to make up the total annual consumption of 40 kg. The total radionuclide intake was derived from concentrations measured in the flesh of 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 the assumed market dilution.

The annual average concentration of radionuclides found in meat consumed by the Maximum Individual were determined from samples of various cuts of beef and pork 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 seven 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 for dose estimates.

EXTERNAL RADIATION

In addition to the exposure caused by internally-deposited radionuclides, residents of the Hanford environs may receive doses from external sources other than the natural 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 fishermen, 500 hr/year (revised from the preliminary 1964 value of 200 hr/year) was used in 1965 and 1966 as a reasonable estimate of the time spent along the river shoreline by the Maximum Individual. 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. The exposure time (500 hr/year) was multiplied by the annual average exposure rate (background corrected) at the river shoreline near Richland to determine the Maximum Individual's external dose. This dose was added to the internal doses received by the GI tract, total body, and thyroid. No external doses were assigned to the Maximum Child.

The Typical Richland Resident, on the other hand, received his external radiation dose from other types of recreational use of the Columbia River, e.g., swimming, water skiing, and boating. Immersion exposure rates measured in the Columbia River at Richland were multiplied by an exposure time of 24 hr/year, estimated from local observations, to determine the Typical Richland Resident's external dose. This dose was added to the internal doses received by the GI tract, total body, and thyroid. No external doses were assigned to the Typical Richland Child.

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 to 95%) of radiation doses in the Hanford environs are contributed by a relatively few radionuclides: ^{24}Na, ^{32}P, ^{51}Cr, ^{64}Cu, ^{65}Zn, ^{76}As, ^{131}I, ^{239}Np, and Rare Earths plus Yttrium fraction. In order to ease the calculation of 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 a unit intake (1 μCi) of each specific radionuclide was prepared (Table 5). The parameters set forth in the ICRP Publication No. 2[6] and in the FRC Reports[5] were used in preparing this table. Many of these factors have been tabulated previously by J. Vennart and M. Minski and published in the British Journal of Radiology.[17]

The maximum permissible rate of intake (MPRI) of bone-seekers for individuals was taken as one-tenth the product of the maximum permissible concentration (MPC) in water for a given radionuclide, as recommended by the ICRP for continuous occupational exposure, and the rate of water intake as given by the ICRP for the standard man (2.2 liters/day). In the case

TABLE 5. Microcurie-Dose Factors for Calculating Environmental Doses

Isotope	Units of mrem/μCi Intake: GI Tract[a]	Total Body[a]	Thyroid[a]	Units of %MPRI/μCi Intake: Bone[b]
Maximum Individual				
^{24}Na	6.2	1.7	-	-
^{32}P	21	7.4		6.2
^{51}Cr	1.2	-	-	-
^{64}Cu	4.6	-	-	-
^{65}Zn	9.6	6.5		0.12
^{76}As	77	-	-	-
^{131}I	-	-	1700 Adult	-
			17000 Child	-
^{239}Np	19	-	-	-
RE+Y[c]	50	-	-	-
Typical Richland Resident				
^{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~~ 6.5	-	0.37
^{76}As	77	-	-	-
^{131}I	-	-	1700 Adult	-
			17000 Child	-
^{239}Np	19	-	-	-
RE+Y[c]	50	-	-	-

a. *Microcurie-dose factor: The dose in mrem that 1 μCi 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.

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

c. *Rare earths plus yttrium.*

of ^{32}P, the MPRI is 16 μCi/year for the Maximum Individual. The MPRI for an average of the exposed population (the Typical Richland Resident) was taken to be one-third of the MPRI for individuals, of 5.3 μCi/year for ^{32}P.

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/day) was rounded off by the FRC from approximately 80 pCi/day, which if sustained over a one-year period, would result in a dose of approximately 500 mrem to a 2 g thyroid based upon current ICRP dose calculation factors. Using 80 pCi/day (0.029 μCi/year) intake of ^{131}I as a basis, the corresponding intake-dose factor was calculated to be 17,000 mrem per μCi ^{131}I ingested.

Table 5 summarizes the factors used in calculating radiation doses from environmental sources.

Figures 1 through 4 show the composite radiation doses for the Maximum Individual and the Typical Richland Resident for 1965 and 1966 as given in the annual environmental reports.[1,2]

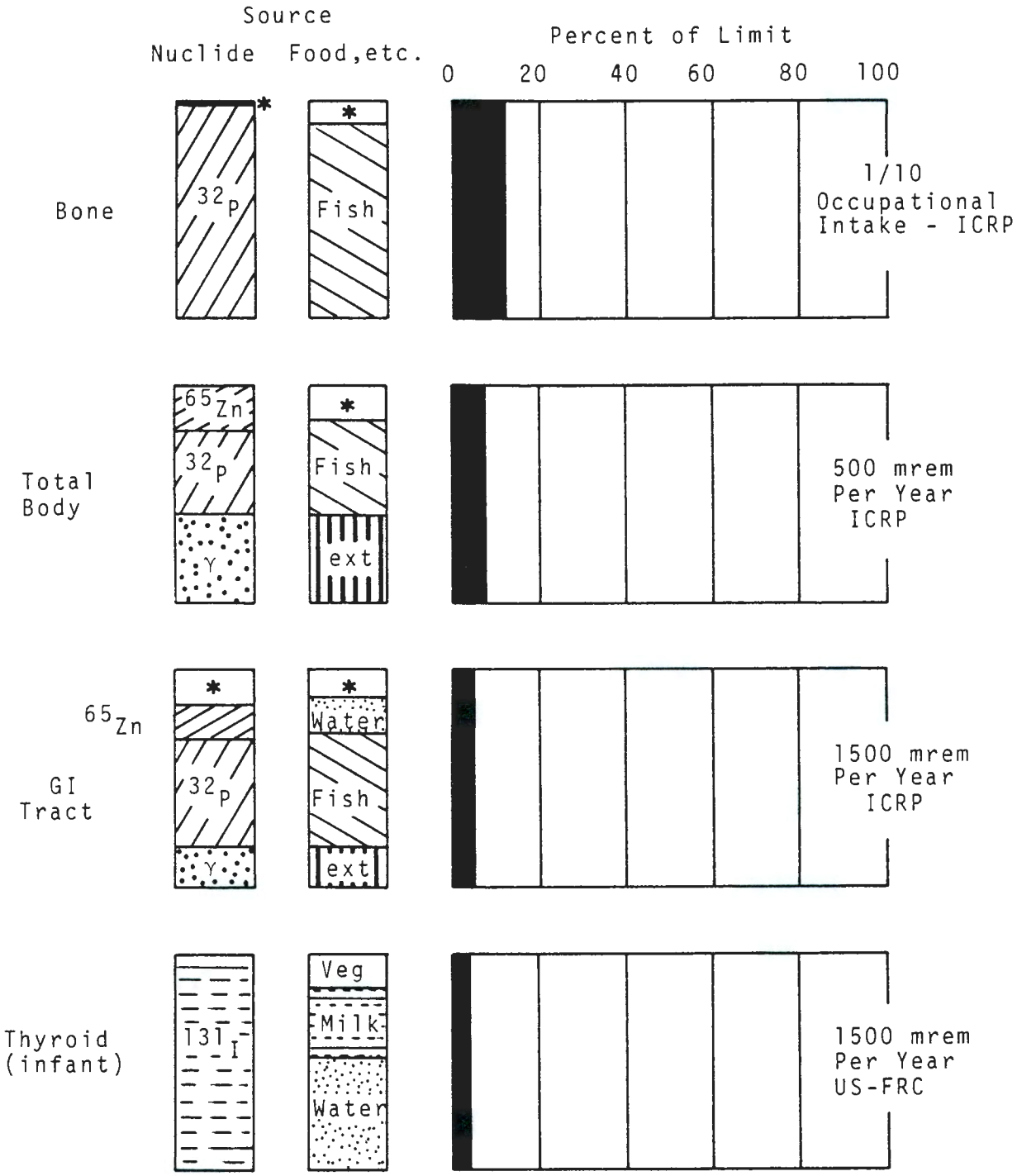


FIGURE 1. Exposure Received by Maximum Individual, 1965

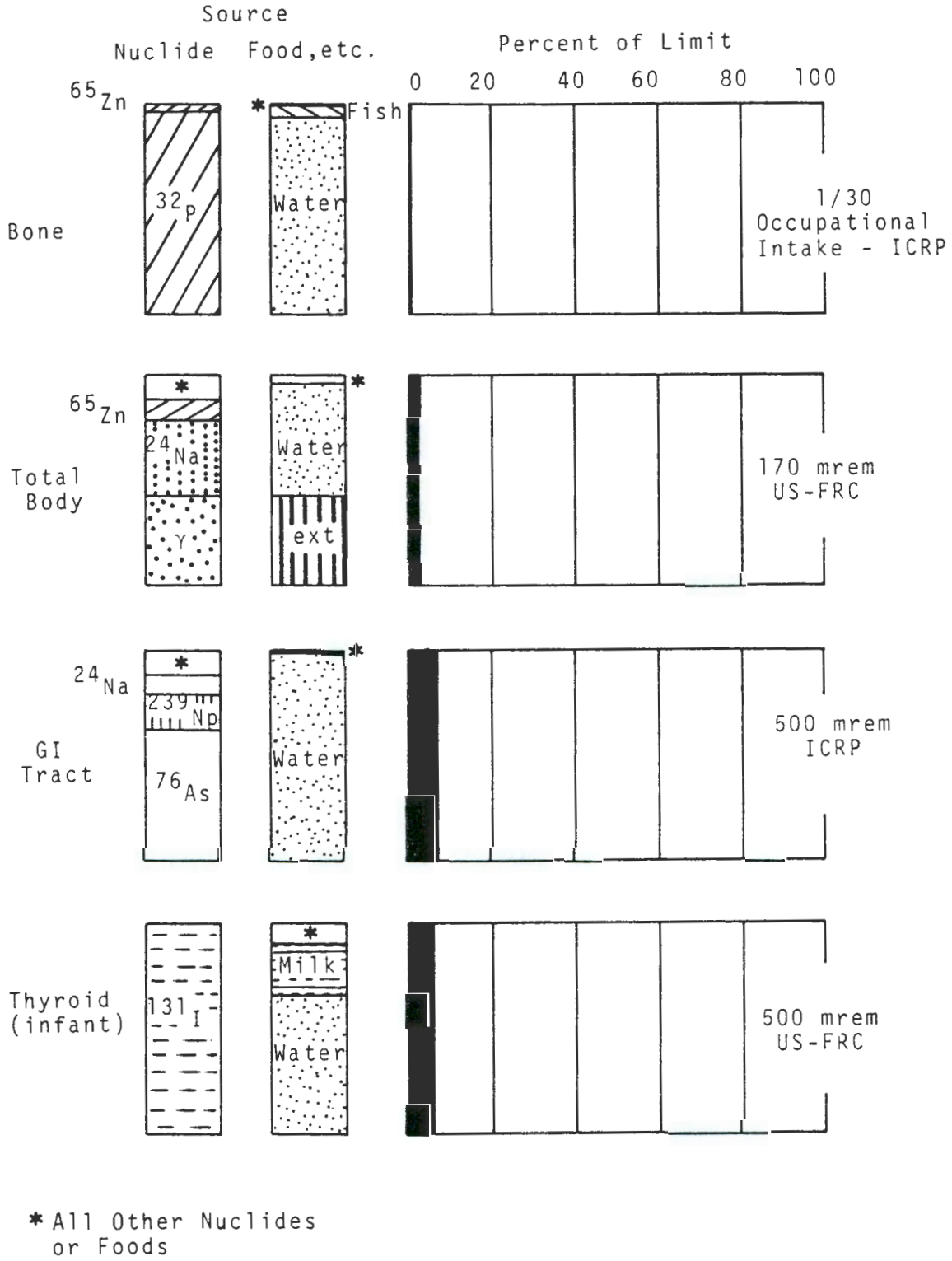
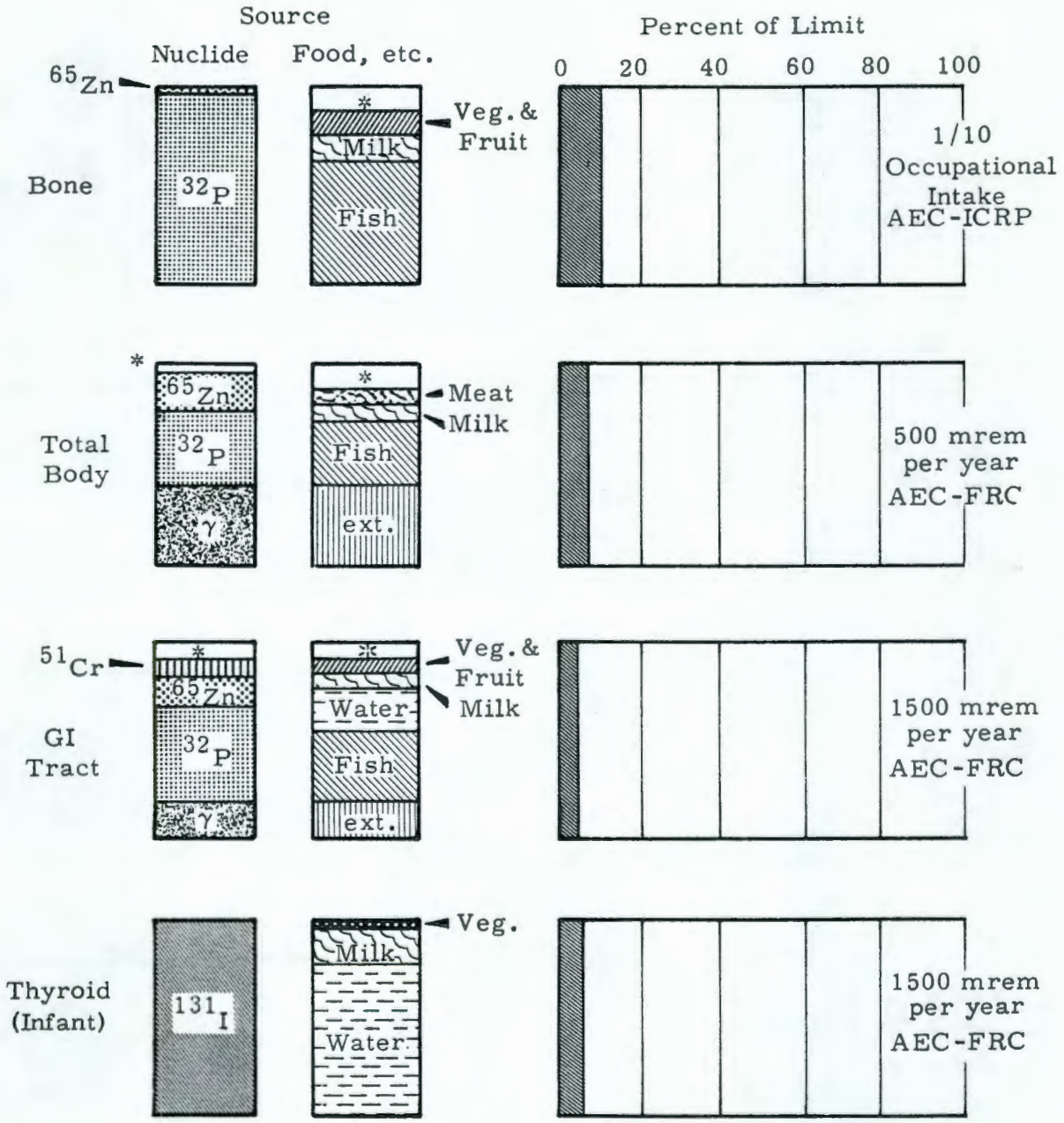


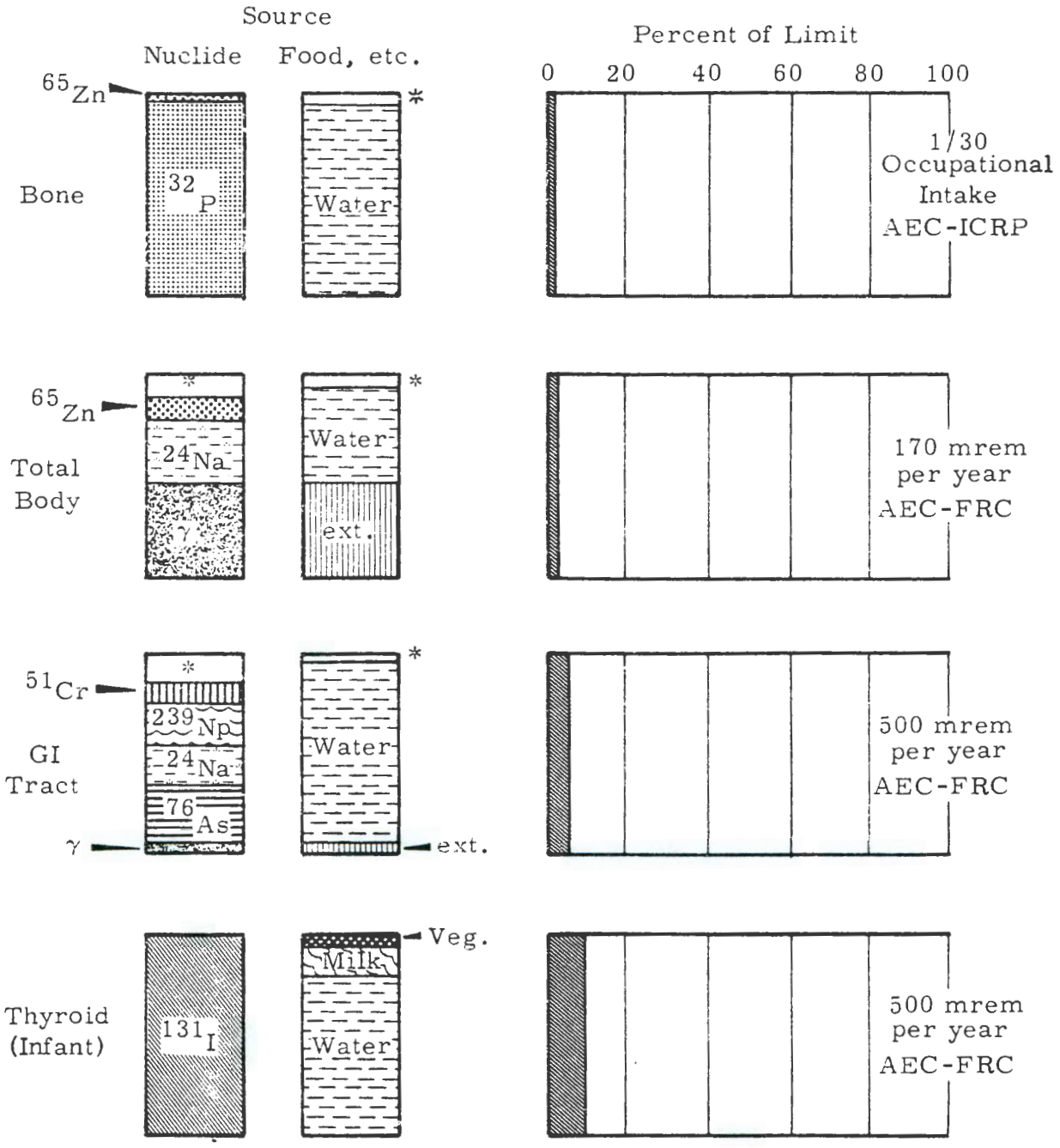
FIGURE 2. Exposure Received by Typical Richland Resident, 1965



*All Other Nuclides or Foods

Neg 0674246

FIGURE 3. Estimated Dose to Maximum Individual, 1966



*All Other Nuclides
or Foods

Neg 0671343-1

FIGURE 4. Estimated Dose to Typical Richland Resident, 1966

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