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HANFORD ENVIRONMENTAL MONITORING ANNUAL REPORT

1958

By

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Exposure Evaluation and Records
Radiation Protection Operation

August 27, 1959

HANFORD ATOMIC PRODUCTS OPERATION
RICHLAND, WASHINGTON

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I. INTRODUCTION

The Hanford plant releases small amounts of radioactive materials to the atmosphere and the Columbia River; these materials are a potential source of radiation exposure to the people in the environs. The radiation exposure to the general population residing near Hanford has been measured and evaluated routinely since the establishment of the plant in 1944. The year 1958 was one during which the measurement of the radiation dosage rates in the environs was complicated by significant contributions from frequent fallout from nuclear detonations. The actual concentration of radioactive materials found in the environs is small enough that the radiation exposure from Hanford sources cannot be accurately separated from that due to natural background and nuclear bomb debris. Estimates of Hanford's contribution to radiation exposure in the environs are made and summaries of the release rates from various waste sources are provided. The major emphasis of this report is on the evaluation of the radiation exposure to the population adjacent to Hanford with no attempt made to tabulate all of the sample and monitoring results for the year. The Hanford plant environs are shown in Figure 1. The project is located in a semi-arid region in southeastern Washington with an annual rainfall of less than eight inches. The Columbia River flows through a portion of the area and forms the eastern boundary with free access to the eastern shore of the river for a distance of ten miles above the southern boundary. The areas of highest population density near the plant are Richland, Pasco, and Kennewick.

This report contains data for non-occupational groups. Non-occupational or public exposure limits are one tenth (1/10) of the occupational limits which are based on values recommended by the NCRP[5, 4] and the ICRP.[3]

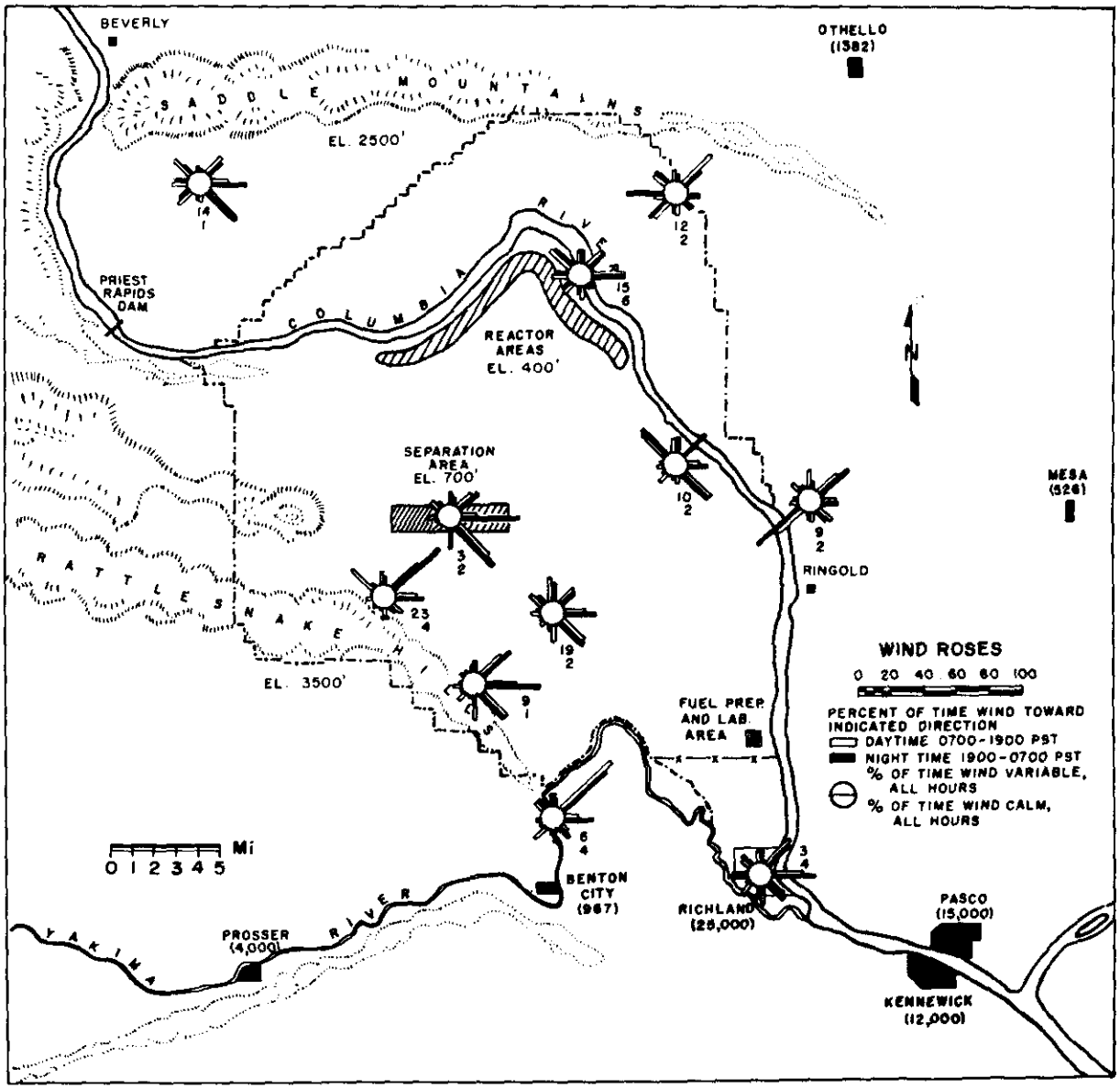

FIGURE 1

Hanford Plant Environs

AEC-GE RICHLAND, WASH

II. ATMOSPHERIC MONITORING

The primary sources of radioactive materials released to the atmosphere are small quantities of fission and activation products found in effluent gases discharged from 200-foot high ventilation stacks at the separations and reactor areas. In the separations plants, off-gas treatment removes some 99 per cent of the radioactive materials present in gaseous effluents before release to the atmosphere. The rates of discharge from separations plant stacks are shown in Table I.

TABLE I

EMISSION RATES FROM SEPARATIONS PLANT STACKS

1958

Isotope	Average Curie/Day
I-131	1.2
Rare Earth - Y	0.02
Nb-95	0.01
Zr-95	0.004
Ru-103	0.004
Ru-106	0.002
Sr-89	0.0035
Sr-90	0.0005

Emission from the reactor stacks is on the order of 5 to 15 mc/day of beta emitters with three to six microcuries per day of sulfur-35 and carbon-14 and traces of tritium. Discharge of alpha emitters from Hanford stacks averages less than one microcurie per day.

Air-borne concentrations of radioactive materials and radiation dosage rates are measured by equipment located in 31 atmospheric monitoring stations, and by portable ionization chambers placed at selected field locations. Measurements are made of total beta emitters, I-131, total alpha emitters and radiation dosages. Selected samples are checked

for specific isotopes by conventional radiochemical means or by use of a 256-channel gamma ray spectrometer. Twenty-four filter samples are operated within the project, four others in nearby towns and nine others are located throughout the Pacific Northwest. These filters are autoradiographed for the determination of radioactive particles, and the concentration of beta emitters. Table II is a summary of results obtained during 1958.

TABLE II

AVERAGE ATMOSPHERIC CONCENTRATIONS

1958

Location	I-131 μc/cc	Alpha Emitters μc/cc	Beta Emitters μc/cc	Radioactive Particles per Cubic Meter
On Plant	5.0×10^{-13}	2.0×10^{-15}	1.4×10^{-12}	0.04
Plant Perimeter	2.4×10^{-13}	2.0×10^{-15}	1.2×10^{-12}	0.04
40-100 Miles	--	--	1.2×10^{-12}	0.06
Over 100 Miles	--	--	1.4×10^{-12}	0.08

The perimeter locations are primarily in the Richland - Pasco - Kennewick area, while those over 100 miles from the plant are in Washington, Southern Oregon, Southern Idaho, and Western Montana. The influence of debris from nuclear detonations is evident in these data as examination of the monitoring results from air sampling at individual monitoring stations indicates that locations upwind and crosswind from the project have atmospheric concentrations of radioactive particulates equal to or greater than those locations immediately downwind of the project.

External radiation dosage rates in the project environs result from radioactive materials suspended in the atmosphere, deposited on the ground, or natural radioactive materials in the ground. Measurement of the low

dosage rates encountered is accomplished through the use of pocket ionization chambers and a chamber reader developed at Hanford.[7] The results average about 0.3 to 0.4 milliroentgen (mr) of gamma radiation per day. It has not been possible to assign portions of this figure with certainty to natural background, fallout, and Hanford sources; however, the major portion is believed to be natural background.

III. VEGETATION AND GROUND MONITORING

Vegetation sampling is performed weekly to monthly in 27 geographical zones in and around the project and in Eastern Washington and Northern Oregon. The pattern of the annual average deposition for I^{131} based on an emission rate of one curie per day has been presented in previous reports.[1,6] This pattern shows the influence of the prevailing winds and the frequent temperature inversions which tend to carry the stack gas plume a long distance before it reaches the ground. Compositing of vegetation samples with the pattern as a guide permits efficient monitoring of large ground areas. The 150 gram composite sample is packed into a 9-ounce jar and its radioactive content measured on a 256 channel gamma ray spectrometer.[8] Specific isotopic concentrations are calculated from counting rates obtained at their characteristic gamma energies after applying corrections for scattering and natural background radiation. Strontium-89 and 90 concentrations are determined by radiochemical separation and beta particle counting.

The pattern of deposition of I^{131} and particulates from the atmosphere is measured by performing radiological surveys of the ground. These surveys are made with portable transistorized equipment employing a gamma sensitive scintillation crystal; 5 inches in diameter by 5 inches thick. The equipment is carried by car, boat or airplane. In the event that unusual ground contamination is detected, more detailed surveys can be made with hand portable instruments and by collecting supplemental vegetation samples.

TABLE III

SUMMARY OF VEGETATION CONTAMINATION

1958

Location	I-131 μc/gm	Other Gamma Emitters μc/gm	Alpha Emitters μc/gm
On Plant	4.8×10^{-6}	1.4×10^{-4}	6.0×10^{-7}
Plant Perimeter	2.5×10^{-6}	0.9×10^{-4}	0.7×10^{-7}
40-140 Miles	3.0×10^{-6}	1.0×10^{-4}	--

Of interest is the possible uptake of radioisotopes in edible crops which are irrigated with Columbia River waters containing Hanford effluents. Also of interest is the possibility of crop uptake of airborne radioactive wastes from the Hanford Facilities and from nuclear weapons fallout. Indication that such uptake may take place has been previously reported.(1) The following briefly describes the 1958 milk and produce program and the more significant findings of isotopic uptake.

Crop samples were collected from farms and truck gardens in the Riverview District (irrigated by Columbia River water containing Hanford effluents), Finley District (irrigated by Yakima River water), and from Walla Walla (not influenced by Hanford liquid effluents and well removed from Hanford sources of air-borne effluents). In general, a six to ten pound sample was obtained of each crop. The crops analyzed were: milk (from a farm in the Riverview District), local store composite milk, potatoes, carrots, tomatoes, onions, squash, green beans, cucumbers, watermelon, sugar beets parsley, corn, apricots, peaches, cantaloupe, grapes and alfalfa. The crops were not treated before analysis by washing, peeling, etc.

A 256-channel gamma spectrometer was used to analyze for the following gamma emitters: K-40, Cr-51, Zn-65, Zr-Nb-95, I-131, Cs-137, Ba-La-140, and Ce-141-144. Radiochemical methods and beta counting were used in the determination of strontium content.

A part of each sample was analyzed on the spectrometer in the "raw" state to estimate the I^{131} content. The samples were then ashed and analyzed again for content of less volatile isotopes. Subsequent to the gamma analysis the samples were analyzed for strontium-89 and strontium-90. Table IV presents the seasonal average isotopic concentration for milk and produce from Riverview District, Finley District, and Walla Walla. Produce here includes all fruits and vegetables.

TABLE IV

SEASONAL AVERAGE CONCENTRATIONS FOR SEVERAL ISOTOPES IN MILK AND PRODUCE FOR 1958

Units of 10^{-7} $\mu c/gm$ ("raw" weight)

Isotope	Riverview Milk (4 Samples)	Riverview (28 Samples)	Finley (7 Samples)	Walla Walla (9 Samples)
$Ba\text{-}La^{140}$	1.0	3.8	1.4	3.4
Zn^{65}	0.48	1.8	0.49	0.89
$Zr\text{-}Nb^{95}$	0.3	6.1	7.1	12
Cs^{137}	0.23	0.62	1.3	1.1
$Ru^{103\text{-}106}$	2.0	3.2	3.5	4.1
I^{131}	1.5	2.1	1.8	1.6
Cr^{51}	2.0	3.3	2.9	3.4
$Ce^{141\text{-}144}$	2.0	11	13	18
Sr^{89}	0.19	0.27*	0.1**	0.11***
Sr^{90}	0.06	0.06*	0.06**	0.06***

* Based on 16 samples only - no leafy vegetables included.

** Based on 5 samples only - no leafy vegetables included.

*** Based on 6 samples only - no leafy vegetables included.

The data indicate that Zn^{65} is found in crops irrigated with Columbia River water containing Hanford effluents in slightly greater amounts than in other crops. Comparison of the isotopic contents of Riverview produce with that from Finley and Walla Walla for other isotopes indicate that there is no significant difference between localities of isotopes present in

air-borne effluents from Hanford and nuclear weapons fallout. Since sample collections from Walla Walla are about 80 miles distant from the source of all Hanford radioeffluents, nuclear weapons fallout is strongly indicated as the source of isotopic concentration found in these produce samples.

An estimate of exposure to persons consuming produce was made utilizing the following assumptions:

1. A representative dietary breakdown, here taken crudely as 6 kgm/week milk and milk products, 1.5 kgm/week potatoes, 1.5 kgm/week fruit, 0.5 kgm/week leafy vegetables, and 1.0 kgm/week of all other vegetables.
2. Consumption of such produce was on a year around basis, consistently containing the season's average concentrations.
3. The produce sampled was truly representative of that consumed.
4. A realistic percentage of permissible exposures could be determined by ratioing the radioisotopic intake (developed on a weekly basis from "standard man" data on water intake) to the estimated weekly isotope ingestion from produce consumption (developed from dietary considerations and isotopic concentration in the particular produce).

It should be reiterated that the analysis leading to these estimates admits to many uncertainties in dietary habit, permissible limits, and the like. As a result of these and some of the above assumptions the estimates presented are believed to be biased toward the high side.

The percentage of the non-occupational exposure under the above assumptions are estimated as probably more than 4 per cent but less than 9 per cent for the gastrointestinal tract (of which $Ce^{141-144}$ and $Ru^{103-106}$ are the principal contributors); probably more than one half per cent and less than 2 per cent for the thyroid (principally I^{131}) and more than 1 per cent but less than 7 per cent bone (principally Sr^{90}). The contribution

to these exposures by those isotopes for which analysis was made and which occur appreciably in Hanford effluent water amounts to less than one-tenth of one per cent in each case.

IV. WATER MONITORING

Reactor cooling water is the major source of radioactive material released to the Columbia River by the Hanford Works.

Samples for measurements of gross beta emitter concentrations in river water are taken regularly from upstream of the plant to Portland, Oregon, and occasionally to the mouth of the Columbia River. Detailed analyses of the river and sanitary waters derived therefrom are made of large-volume samples from Pasco and Kennewick. The concentrations of beta emitters in river samples are shown in Table V.

TABLE V

COLUMBIA RIVER RADIOACTIVITY

Units of 10^{-8} μc/cc

	Concentration of Gross Beta Emitters				
Period	100 Area	300 Area	Pasco Kennewick	McNary-Paterson	Arlington to Portland
1957 Average	2800	1200	560	80	70 to 20
1958					
First Quarter	7400	2000	880	120	108 to 30
Second Qrtr.	5380	1200	460	90	80 to 20
Third Qrtr.	3900	1400	630	40	70 to 10
Fourth Qrtr.	6500	1800	1700	150	80 to 20
1958 Average	5700	1600	920	95	90 to 20

Table VI presents a summary of calculated non-occupational exposure to the gastrointestinal tract from drinking Columbia River water or sanitary waters obtained from the Columbia River. The calculation is

made using the measured concentration of 17 isotopes or groups of isotopes routinely analyzed in these waters with other isotopes analyzed occasionally and factored into the calculations according to reactor power level and coolant variations.

TABLE VI

SUMMARY OF CALCULATED EXPOSURE TO GASTROINTESTINAL TRACT FROM COLUMBIA RIVER WATER

	Per Cent of Non-Occupational Exposure		
	Pasco		Kennewick
1958	Raw	Sanitary	Sanitary
First Quarter	24	5.3	9.3
Second Quarter	12	2.4	4.8
Third Quarter	11	3.4	1.5
Fourth Quarter	20	3.2	2.0
1958 Average	17	3.6	4.4

The residents of Pasco and Kennewick receive an average 4 per cent non-occupational exposure, assuming that these sanitary waters were their only source of drinking water. Other factors, such as Kennewick's partial dependence on wells for water supply probably reduce actual gastrointestinal tract exposure.

One isotope, Arsenic-76, contributes more than all others combined to gastrointestinal tract exposure. Table VII illustrates relative isotopic importance from the view point of gastrointestinal tract exposure.

TABLE VII

RELATIVE CONTRIBUTIONS TO GASTROINTESTINAL TRACT EXPOSURE OF THE ROUTINELY ANALYZED ISOTOPES IN COLUMBIA RIVER WATER AT PASCO, DECEMBER, 1958

Isotope	Contribution	Cumulative Per Cent
Arsenic-76	78	78
Neptunium-239	10	88
Rare Earth and Yttrium Group	4	92
Copper-64	2	94
Chromium-51	2	96
Phosphorus-32	1.3	97.3
Sodium-24	0.9	98.2
Zinc-65	0.7	98.9
Barium-40	0.4	99.3
Scandium-46	0.4	99.7
Strontium-89	0.1	99.8
Silicon-31	---	---
Manganese-56	---	---
Iron-59	---	---
Strontium-90	---	---
Iodine-131	---	---

More than 80 per cent of the arsenic is removed by filtration and decay from Pasco raw water, corresponding approximately with the difference in calculated exposure rates of the raw and filtered water. The filter floc containing As^{76} is returned to the river in backwash, but the short half-life of this isotope, the slow movement in the McNary Pool, and dilution afforded by the Snake River entering the Columbia below Pasco, reduce its effect to insignificance downstream from Pasco.

Table VIII illustrates the comparative potential exposures to several organs from ingestion of Pasco waters.

TABLE VIII

PER CENT OF NON-OCCUPATIONAL EXPOSURE FROM DRINKING WATER CONSUMPTION

	GI Tract	Bone	Thyroid	Kidney
Pasco Raw Water	17	3.8	1.3	0.45
Pasco Sanitary Water	3.6	0.7	0.9	0.15
Exposure Reductions by Water Treatment	79%	81%	32%	67%

The biological monitoring of the environs at Hanford is conducted by the Biology Operation. A summary of their activities for 1958 has been published in several progress reports,[9, 11] and includes a graph of the concentration of beta emitters in small fish at Hanford.

Small ionization chambers have been placed on the surface and submerged in the Columbia River to measure the external radiation exposure rates. A year of surface measurements above the plant areas, as well as on the Yakima and Snake Rivers, indicate about 3.0 mr per week background level.

It is estimated that at the closest public approach below the reactors, a swimming and boating enthusiast (4 to 6 hours every day) would receive no more than five per cent (25 mrem) of the non-occupational exposure limit of 500 mrem per year.

V. DISCUSSION

In order to evaluate the significance of the field measurements, they must first be reduced to fractions of their respective maximum permissible concentrations,[5] or limits. The exposures to internally deposited emitters are then summed as fractions of these limits using each "critical organ" as a separate summation. Exposures to external

radiation can also be expressed as fractions of maximum permissible limits and can be summed with the fractions calculated for internal exposures. Use of this method is discussed more fully by J. W. Healy, et al. in the 1958 Geneva Conference Paper No. 743. (1)

The non-occupational exposure limits used in the present summations are shown in Table IX.

TABLE IX

NON-OCCUPATIONAL EXPOSURE LIMITS

Situation	Limit
External Whole Body - penetrating	0.5 rem per year
External Whole Body - nonpenetrating	1.0 rem per year
Maximum Permissible Concentrations - based on GI tract, thyroid, bone, etc.	0.1 ICRP Values(3)
based on Whole Body	0.03 ICRP Values(3)

These values are in accord with the recommendations of the ICRP and the NCRP(2, 4) for populations in the vicinity of the plant.

Table X indicates the percentage of the maximum permissible levels for general populations estimated for the year 1958 for each of the possible methods of intake of isotopes. The figures generally represent exposure estimates from Hanford sources since background and fallout contributions have been deleted where possible. At the present time it is not possible to separate quantitatively natural background and weapons fallout from Hanford effluents.

TABLE X

ESTIMATED ENVIRONMENTAL EXPOSURES FROM HANFORD SOURCES

Source	Per Cent of Non-Occupational Exposure					
	Body	GI	Bone	Thyroid	Kidney	Lung
Drinking Water	---	4.0	0.7	0.9	0.15	---
Milk and Produce	---	<0.01	<0.01	<1.5	<0.01	<0.01
Air	---	---	---	0.04	---	<1.2
Fish and Wildfowl[10, 11]	---	2.0	10.0*	---	---	---
External-Swimming and Boating-Ringold to Richland	~5.0	<5.0	<5.0	~2.5	~5.0	~5.0
Max. Probable Totals	5.0	11	16	5	5.0	6.2

* It is conceivable that a very few individuals eat enough fish to raise the average body burden of P^{32} above 10 per cent but highly unlikely that anyone would routinely eat so great an amount that his body burden would approach the non-occupational limit.

In summary, from Table X it is apparent that the GI Tract and bone are the critical or limiting organs. The estimated representative contribution is in the range of 3 to 16 per cent of the non-occupational limit.

All of these numbers were derived by methods of calculation that are believed to tend to overestimate the magnitude of the exposure. The best estimates of actual exposures to people are still uncertain because of wide variety in diet, occupancy, and other factors. Throughout the history of the Hanford project, radiation exposures to persons adjacent to Hanford, due to Hanford contributions, are believed to have been within maximum non-occupational exposure limits.

The evaluation of waste disposal practices and effect of these practices on the Hanford environs has been thoroughly discussed in the testimony by Hanford personnel during public hearings on Industrial Radioactive Waste Disposal before a subcommittee of the Joint Congressional Committee of

Atomic Energy held in January, 1959.[10] The material presented contains a detailed analysis of possible mechanisms of transfer of radioactive wastes to the environs, estimates of the amounts of radioactive wastes found in the environs and evaluates the exposure to individuals residing in the Hanford environs.

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The author could not have prepared this report without the assistance and advice of J. K. Soldat, I. C. Nelson, and M. W. McConiga, all of whom participated in summarizing, interpreting, and evaluating the many field measurements collected. Editorial assistance was provided by J. W. Healy and R. L. Junkins.

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