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RADIOLOGICAL STATUS OF THE GROUNDWATER
BENEATH THE HANFORD PROJECT
JANUARY-JUNE 1970

By

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Radiation Protection Department
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INTRODUCTION

This report is prepared semiannually to provide an evaluation of the status of groundwater contamination resulting from disposal of Hanford plant effluents. The data presented in this report were collected during the first six months of 1970; the previous report in this series was BNWL-1392.⁽¹⁾

Of the wells that have been drilled to groundwater on the Hanford project, about 250 are used for the routine surveillance of radionuclide movement through the sediments both above and below the regional water table. Approximately one-third of the surveillance wells are located at disposal sites situated on the interior plateau 12 to 15 miles up-gradient from the nearest domestic water supply. These wells are used to determine when a disposal facility is to be retired. All other surveillance wells are sampled to determine the status of contaminants within the groundwater system. The locations of wells referred to in this report may be found by referring to the Hanford Wells document.⁽²⁾

It is assumed that ^{106}Ru , ^3H , and the nitrate ion (NO_3) move at essentially the same rate as groundwater. In addition, they can be detected in groundwater at low concentrations relative to their respective drinking water standards. Therefore, ^{106}Ru , ^3H , and NO_3 are used to trace the groundwater flow paths away from the major chemical processing disposal sites. All groundwater samples were analyzed by the Technical Analysis Section, Battelle-Northwest.

The groundwater contamination pattern beneath Hanford at the present time can be divided into three zones, based on the kinds and quantities of waste disposed to ground at each location:

- 200 Area (chemical processing areas) and associated 600 Area wells

- 100 Area (production reactor areas) and associated 600 Area wells
- 300 Area (fuel fabrication and laboratory area) wells.

Groundwater concentration data for these three zones are presented in this report.

SUMMARY

An evaluation of ^{106}Ru and ^3H concentrations measured in the unconfined groundwater during the first half of 1970 shows that the zones of detectable contamination extend in an easterly to south-easterly direction from 200-E Area (Figures 1 and 2) as observed in the past.⁽¹⁾ The few locations for which average groundwater concentrations exceeded the Concentration Guide (CG) for ^{106}Ru were all within either the 200-E or 200-W Areas. Water from only one well located outside of the 200 Area fences (Well 699-35-70) indicated a ^3H concentration greater than the CG. The highest average concentration of ^{51}Cr measured in unconfined groundwater within or near the 100 Areas (Well 199-K-20) was less than 1 percent of the CG for ^{51}Cr (2000 pCi/ml).⁽³⁾ Concentrations of uranium, the principal radionuclide observed in 300 Area groundwater, averaged less than 0.5 pCi/ml (<3 percent CG).

Although water from several wells with piezometer tubes extending to confined groundwater aquifers was sampled and analyzed during this report period, all such samples had gross beta concentrations less than the analytical limit (0.2 pCi/ml).

Nitrate ion concentrations greater than 10 percent of the Public Health Service recommended drinking water limit of 45 ppm⁽⁴⁾ were observed in most groundwater samples from wells surrounding the 200 and 300 Areas. However, groundwater from these zones is not consumed by humans or animals.

EVALUATION OF GROUNDWATER SURVEILLANCE DATA

Radionuclide concentrations in the groundwater beneath Hanford are evaluated in terms of their respective CG's, while the NO_3^- concentrations

are compared to the PHS recommended drinking water standard.⁽⁴⁾ It is recognized that these guides are intended only for drinking water, and at present no groundwater from zones having concentrations >10 percent of the CG (Figures 1-3) is used for human or animal consumption. However, they do provide a rapid, meaningful method of evaluating the potential significance of most water-borne materials. The CG's used in this report are those which apply to individuals of the general public.⁽³⁾

Data from all 200 Area and associated 600 Area wells for which average total beta, ^3H , or NO_3 concentrations were above the respective analytical limits appear in Tables 2 and 3. All 100 Area and associated 600 Area wells routinely sampled are listed in Table 4 along with the concentration data for those wells showing detectable activity. In addition, the average concentration data for the first half of 1970 and the second half of 1969 are shown in Tables 2, 3, and 4 for rapid comparison of the respective trends. The analytical data for wells within or near the 300 Area appear in Table 5. A number of other wells, particularly those immediately adjacent to the outermost down-gradient contours shown in the accompanying figures, were sampled and analyzed on a routine schedule. However, because the results were below the respective analytical limits, no data were tabulated.

Difficulty was experienced with the evaluation of total beta and NO_3 concentrations in wells 699-32-42 and 699-33-42. The concentrations (less than the detection limit) were much lower than expected; further, it has been shown that samples from these wells were non-representative of the groundwater in that area.⁽⁵⁾ Hence, results from these wells were not included during the preparation of Figures 1 and 3.

200 AREA AND ASSOCIATED 600 AREA WELLS

Groundwater samples collected from wells within and near the zone in

which 200 Area effluents are present are analyzed for total beta, ^3H , and NO_3^- . The total beta activity is calculated as ^{106}Ru , since radiochemical analyses have shown that this nuclide accounts for a large fraction (~80 percent) of the radioactivity* in this groundwater zone. In a joint program with ARHCO, groundwater samples from beneath some inactive and all of the active crib sites (Table 1) are analyzed for total alpha, ^{60}Co , ^{90}Sr , and ^{137}Cs , in addition to total beta, ^3H , and NO_3^- .

TABLE 1. *Active Disposal Sites--Cribbs, Ditches, Ponds, Swamps*

<u>200 East Area</u>		<u>200 West Area</u>	
<u>Site Designation</u>		<u>Site Designation</u>	
<u>Purex</u>	<u>B Plant</u>	<u>Redox</u>	<u>U Plant</u>
216-A-6	216-B-2	216-S-6	216-U-4A,B
216-A-8	216-B-3	216-S-11	216-U-10
216-A-10	216-B-10B	216-S-16	216-U-12
216-A-25	216-B-12	216-S-19	216-U-14
216-A-27	216-B-50	216-S-23	
216-A-29	216-B-55		<u>Z Plant</u>
216-A-30	216-B-57	<u>T Plant</u>	216-Z-11
216-A-36B		216-T-4	216-Z-12
		216-T-19	216-Z-16
			216-Z-18

No detectable (>0.3 pCi/ml) concentrations of ^{137}Cs were observed in groundwater samples collected from the 200 Area disposal sites during the first half of 1970. Groundwater near four crib sites (216-A-36B, 216-A-10, 216-S-1, and 216-S-2) indicated average ^{90}Sr concentrations (0.07, 0.05, 20, and 0.12 pCi/ml, respectively) above the detection limit (0.03 pCi/ml) during the first half of 1970. During the second half of 1969⁽¹⁾ groundwater near only one crib site (216-A-36B) indicated an average ^{90}Sr concentration (0.05 pCi/ml) above the detection limit. Low but detectable alpha

* Not including ^3H , whose low energy beta emission does not contribute to the total beta activity measured.

TABLE 2. Average Total Beta, Tritium, and Nitrate Ion (NO_3^-) Concentrations in 600 Area Wells)

Well No. (699-)	Total Beta ^(a) (pCi/ml)		Tritium (pCi/ml)		NO ₃ (ppm)	
	Jan- June '70	July- Dec. '69	Jan- June '70	July- Dec. '69	Jan- June '70	July- Dec. '69
Analytical Limit ^(b)						
	0.16		1.0		0.5	
S3-E12	-	-	-	-	2.1	-
S6-E4C-0	NA ^(c)	-	-	-	0.6	4.
S6-E14	NA	-	NA	-	1.3	0.75
S8-19	NA	-	-	-	<5.2	1.
1-18	-	-	100	82.	<0.6	3.
2-3	NA	-	4.6	3.1	<0.6	-
8-17	-	-	37.	24.	22.	15.
8-32	NA	-	-	-	1.4	0.9
9-E2	NA	-	-	NA	0.6	<0.6
14-38-0	NA	-	-	-	3.4	1.
15-26	0.40	0.50	540	530	30.	30.
17-5	-	-	-	-	2.4	2.
20-20	0.29	0.35	700	740	33.	31.
20-39-0	NA	-	-	-	6.7	2.
24-1-T	NA	-	-	-	NA	1.
24-33	0.24	-	480	380	8.8	3.
24-46	NA	-	-	-	3.7	7.
25-55	NA	-	NA	NA	7.4	<2.7
25-70-0	NA	-	-	NA	0.6	<0.9
26-15	1.0	1.2	1500	1500	46.	37.
27-8	<0.18	-	860	720	7.1	-
28-40	-	-	76.	25.	6.6	10.
29-78	-	-	1.6	NA	1.4	2.
31-31-0	0.59	0.96	1900	2000	13.	23.
31-53B	-	-	-	-	5.6	4.
31-65	NA	-	-	-	0.8	-
32-42	-	-	485	430	-	-
32-43	0.59	0.64	740	610	29.	17.
32-70	NA	-	NA	28.	NA	23.
32-72	-	-	35.	51.	<0.6	-
32-77	-	-	1.1	NA	18.	14.
33-42	-	-	1100	1200	-	-
34-39A	0.84	0.58	2000	1900	29.	18.
34-51	NA	-	5.6	-	5.1	7.
34-88	NA	-	NA	1.7	4.5	3.
35-9	-	-	9.4	4.1	6.6	NA
35-70	0.34	0.32	6200	5100	5.5	2.
35-78	-	-	1.8	1.7	1.4	1.
36-46-R	0.29	0.52	2100	2100	5.4	-
37-43-0	-	-	365	650	3.6	1.

TABLE 2. (Continued)

Well No. (699-)	Total Beta (pCi/ml)		Tritium (pCi/ml)		NO ₃ (ppm)	
	Jan- June '70	July- Dec. '69	Jan- June '70	July- Dec. '69	Jan- June '70	July- Dec. '69
37-82A-0	NA	-	-	1.4	0.7	2.
38-65-0	NA	-	5.0	1.4	30.	25.
38-70-0	1.5	0.79	180	190	170	120
39-79	NA	-	23.	2.0	3.2	1.
40-62	NA	-	NA	NA	NA	2.
41-23	0.46	0.53	810	750	46.	25.
42-12	-	-	110	79.	14.	12.
42-42-0	-	-	1100	100	22.	16.
44-64-0	NA	-	NA	NA	14.	NA
45-42	-	-	1000	940	7.4	9.
45-69	-	-	-	-	30.	26.
46-21	-	-	-	-	3.8	3.
47-35	NA	-	41.	-	2.2	1.
47-46	NA	-	-	NA	14.	3.
47-60	NA	-	-	NA	5.0	3.
48-71	NA	-	-	NA	3.8	3.
49-57	NA	-	3.6	1.6	1.6	1.
49-79	NA	-	-	-	42.	32.
50-28	-	-	<2.7	-	7.4	3.
50-53	1.4	1.0	3.8	7.2	214	120
50-85	NA	-	NA	NA	9.0	10.
51-63	NA	-	1.0	-	<5.	2.
51-75-0	NA	-	NA	NA	14.	19.
52-47	-	-	7.9	11.	-	-
53-55-0	-	-	2.4	2.0	-	-
54-42	NA	-	-	NA	3.5	NA
55-50A	NA	-	2.5	5.2	-	5.
55-70-0	NA	-	NA	NA	1.1	NA
61-66	NA	-	-	-	2.3	3.
65-59	NA	-	-	-	1.2	<0.8
67-51	NA	-	-	NA	1.9	NA
HAN-9	-	-	NA	NA	2.5	1.6

(a) Calculated as $^{106}\text{Ru-Rh}$.

(b) A (-) indicates that the concentration was less than the analytical limit.

(c) No analyses were performed during six-month period.

concentrations were observed beneath several cribs, but the only locations showing consistently detectable alpha activity were beneath the 216-S-13 and 216-S-21 cribs (0.20 and 0.09 pCi/ml, respectively). The alpha activity beneath the 216-S-13 crib was found to be entirely due to uranium. The highest average total beta concentrations beneath active disposal sites were observed at the 216-A-36B crib (37 pCi/ml) in 200-East Area and at the 216-S-23 crib (102 pCi/ml) in 200-West Area, as in the second half of 1969.⁽¹⁾

Total Beta Concentrations (unconfined aquifer)

Total beta concentrations are shown in Figure 1 for zones of 2 to 10 percent, 10 to 100 percent, and >100 percent of the CG for ^{106}Ru (10 pCi/ml).⁽³⁾ The outer boundary of each zone is the down-gradient edge and represents 2 percent, 10 percent, and 100 percent CG, respectively. The lowest level shown (2 percent CG) corresponds to a total beta concentration of 0.2 pCi/ml.

A comparison of contamination contours for the six-month periods ending December 1969 and June 1970, indicates that the inner contour (10 percent CG) located down-gradient from 200-East Area has almost disappeared. This contour is now only defined by results from one well (699-26-15). The portion of the inner contour near the 200-East disposal sites has remained relatively stable.

Tritium Concentrations (unconfined aquifer)

Tritium concentrations are shown in Figure 2 for zones of 0.03 to 1 percent, 1 to 10 percent, 10 to 100 percent, and >100 percent of the CG (3000 pCi/ml).⁽³⁾ The outer boundary of each zone is the down-gradient edge and represents 0.03 percent, 1 percent, 10 percent, and 100 percent CG, respectively.

A comparison of concentration contours for the six-month periods ending December 1969 and June 1970 indicates that the following changes have occurred: East Area--The outermost contour (0.03 percent CG) has remained at about the same position, however, concentrations in most down-gradient wells have continued to increase; and the 1 to 10 percent contour has extended southeastward to include well 699-8-17. West Area--The outer boundary (0.03 percent CG) no longer includes wells 699-34-88 and 699-37-82A.

The concentration zone boundaries shown in Figures 1 and 2 should not be interpreted as indicating that no radioactivity is present in the groundwater beyond these outer boundaries. It is probable that some radionuclides do in fact reach the river, but because of dilution and decay, the concentrations are too low to be measured by current techniques in the groundwater or in the river.

Analyses of Samples Taken From Deep Aquifers

Water samples from specific depths below the Hanford project's groundwater table are obtained from either vertically separated tubes (piezometers) contained within a single well or from piezometer tubes drilled as separate wells. Those few wells which have shown detectable activity have not done so consistently with time. A few wells have exhibited ^3H concentrations detectable rather consistently; however, there is no certainty that the vertical separation of piezometer tubes is infallible; and in fact, Eliason⁽⁶⁾ has shown that interaquifer transfer within a well may occur.

At the present, it is believed that none of the deep aquifers being sampled contain any radioactivity at the points where they are sampled. Total beta concentrations in samples taken at various depths below the water table were all at or below the detection limit (<2 percent CG for ^{106}Ru) for the six months of 1970. Tritium concentrations in these same samples were all below the detection limit except for one sample collected from 699-36-61B-P in a zone 210 feet below the water table. The ^3H concentration in this sample was 4.0 pCi/ml.

A study of the hydrostratigraphy of these aquifers is being undertaken. One of the goals of this study is to establish a firmer base for evaluating radionuclide transport in aquifers which lie below the water table.

Groundwater Quality

The disposal of liquid wastes to the ground has caused measurable changes in groundwater quality adjacent to and down-gradient from the disposal sites. Water quality is directly affected by the concentrations of salts in the

TABLE 3. *Average Total Beta and ^{60}Co Concentrations in Unconfined Groundwater Within the 200 Areas at Crib Sites Active During July 1969 - June 1970*

Well No. (299-)	Total Beta ^(a) (pCi/ml)		^{60}Co (pCi/ml)	
	Jan- June '70	July- Dec. '69	Jan- June '70	July- Dec. '69
Analytical Limits ^(b)	0.16		0.2	
E17-2	1.2	2.0	-(b)	-
E17-9	20.	NA ^(c)	NA	NA
E24-2	5.8	5.2	0.24	NA
E25-3	-	1.1	NA	NA
E25-5	0.37	0.19	NA	-
E25-11	0.65	NA	NA	NA
E28-12	-	-	-	NA
E28-16	0.81	-	-	NA
E33-7	6.9	NA	NA	NA
E33-24	12.	NA	NA	NA
W10-4	-	0.22	-	-
W11-17	6.3	17.	-	-
W15-4	4.4	5.4	NA	NA
W15-7	14.	26.	8.1	9.5
W15-10	-	NA	NA	NA
W18-5	0.21	NA	NA	NA
W19-5	100	54.	-	-
W21-1	NA	0.9	NA	NA
W22-4	NA	0.25	NA	NA
W22-22	4.2	6.9	NA	NA
W26-1	0.88	NA	NA	NA

(a) Calculated as $^{106}\text{Ru-Rh}$.

(b) A (-) indicates that the concentration was less than the analytical limit.

(c) No analyses were performed during six-month period.

wastes and indirectly by the degradation of soil minerals by the wastes. The average concentrations of NO_3^- in the groundwater from the disposal of wastes in the 200 and 300 Areas are given in Tables 2 and 5, respectively.

The extent of NO_3^- contamination in the groundwater beneath the Hanford project is shown in Figure 3. Analyses of much of the Hanford project groundwater indicate detectable NO_3^- concentrations, probably as a result of previous farming and the use of fertilizers in addition to the disposal of wastes in the 200 and 300 Areas. However, only those wells having average NO_3^- concentrations consistently above 1 ppm are included within the contamination zones since these are most probably from waste disposal in the 200 and 300 Areas. Although water from a number of wells in the contaminated zones shows NO_3^- concentrations above the Public Health Service recommended drinking water limit of 45 ppm,⁽⁴⁾ no water from these particular wells is consumed by humans or animals or is used for irrigation.

100 AREA AND ASSOCIATED 600 AREA WELLS

The presence of radioactivity in the groundwater beneath the 100 Areas is due to disposal of wastes to trenches, although leaks in reactor effluent systems have contributed radioactivity to the groundwater in the past. Well water samples, collected from within and near the 100 Areas, were analyzed for total beta, ^{51}Cr , and Cr^{+6} . In addition, wells located in 100-N Area were analyzed for ^3H .

The estimated extent of detectable total beta radioactivity in groundwater beneath the 100 Areas is shown as a short-dashed line in Figure 1. Four small contaminated zones can be distinguished: 100-K, 100-N, 100-B, and 100-D, with the radioactivity level decreasing in that order. Radionuclide concentrations in the groundwater in these four zones have continued to drop as a result of reactor shutdowns and changes in liquid waste handling practices.

Virtually all of the total beta activity (excluding ^3H) in the groundwater beneath the 100 Areas has been found from periodic analyses to be due to ^{51}Cr . The maximum ^{51}Cr concentration for the first half of 1970 was 19 pCi/ml (well 199-K-20). This concentration represented only about 1 percent of the CG for ^{51}Cr (2000 pCi/ml).

TABLE 4. *Total Beta Concentrations in Unconfined Groundwater
(100 Area and Associated 600 Area Wells)*

Well No.	Units of pCi ^(a) /ml			
	Jan-June '70		Conc. In Latest Sample	July-Dec. '69 Avg. Conc.
	Avg. Conc.	Max. Conc.		
Analytical Limit(b)	0.16			
199-B3-2	0.52	0.87	0.27	0.92
199-B4-4	0.20	0.24	0.24	0.57
199-D5-12	0.23	0.29	-	0.18
199-K-20	2.3	6.6	0.32	4.6
199-N-3	0.87	1.2	0.86	1.0
699-86-60	0.35	0.46	0.34	0.18

The average total beta concentration was below the analytical limit for each of the following wells:

199-B5-1	699-71-77
199-K-25	699-71-84
199-N-8-U	699-72-73
	699-78-62

(a) Calculated as $^{106}\text{Ru-Rh}$.

(b) A (-) indicates that the concentration was less than the analytical limit.

Measurements of the ^3H concentration in 100-N Area groundwater were made at well 199-N-3 during the first six months of 1970. The average ^3H concentration in this well was 140 pCi/ml, somewhat lower than in the past.

300 AREA WELLS

The presence of radioactive and nonradioactive contaminants in groundwater beneath the 300 Area arises from the disposal of wastes to two process ponds located northeast and east of the 300 Area. Results of samples collected from 300 Area wells show that the radioactivity is primarily due to uranium, although ^{51}Cr , ^{60}Co , and ^{106}Ru have also been identified.

The concentration of NO_3^- in much of the groundwater beneath the 300 Area (Table 5) is above the Public Health Service drinking water limit⁽⁴⁾ of 45 ppm. However, sampling of the river adjacent to the disposal sites has shown measurable increases in NO_3^- concentrations only intermittently at locations along the river bank adjacent to the 300 Area.

TABLE 5. *Analytical Data - 300 Area and Associated 600 Area Wells, January-June 1970 Averages*

<u>Well No.</u> <u>(399-)</u>	<u>Alpha,</u> <u>pCi/ml</u>	<u>Beta,</u> <u>pCi/ml</u>	<u>NO₃,</u> <u>ppm</u>	<u>Cr⁺⁶,</u> <u>ppb</u>	<u>F⁻,</u> <u>ppm</u>
Analytical Limit(a)	0.02	0.16	0.5	2.	0.2
1-1	0.32	0.27	64.	14.	1.6
1-2	0.45	<0.33	23.	6.3	1.3
1-3	0.18	0.42	58.	11.	1.3
1-4	0.22	<0.45	8.8	2.9	1.1
3-1	0.30	0.57	73.	3.6	1.2
4-1	0.19	0.42	68.	8.6	1.4
4-7	0.26	0.60	54.	8.7	1.6
5-1	0.02	-	14.	-	0.6
6-1	<0.03	-	11.	4.6	0.6
8-1	0.11	<0.26	5.6	3.4	0.5
8-2	<0.03	-	5.6	-	0.6
8-3	0.09	-	7.5	2.9	0.6
699-S27-E14	0.05	-	9.0	-	0.8

(a) A (-) indicates that the concentration was less than the analytical limit.

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HANFORD PROJECT

FIGURE 1. Total Beta Concentrations Beneath the Hanford Project Expressed as Percent of ^{106}Ru Concentration Guide (10 pCi/ml)

HANFORD PROJECT

FIGURE 3. Nitrate Ion Concentrations Beneath the Hanford Project Expressed as Percent of Public Health Service Drinking Water Limit (45 ppm)

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