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Radionuclide Concentrations in Selected Foodstuffs and Wildlife from the Hanford Environs, 1971-1975

November 1977

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RADIONUCLIDE CONCENTRATIONS IN SELECTED
FOODSTUFFS AND WILDLIFE FROM THE HANFORD
ENVIRONS, 1971-1975

by

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November 1977

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INTRODUCTION

Foodstuffs such as milk, meat, chicken, eggs and leafy vegetables have been routinely collected from the Hanford environs to measure the presence of radionuclides potentially attributable to Hanford operations. Similarly, samples of fish, deer, and game birds from the Hanford environs, as well as oysters from Willapa Bay, have been analyzed. The data obtained from 1971 through 1975 are included in this document with the exception of game birds. The game bird data have been published in a separate report (BNWL-2089).⁽¹⁾

The results for the period 1971-1975 presented in this report provide an assessment of the impact from Hanford operations for these years in particular. However, they also serve to assess the significance of any cumulative buildup of the radionuclides observed during the 25 years of Hanford operations previous to this time period.

Whenever possible, the data were analyzed for apparent differences between locations potentially affected by Hanford operations and those unlikely to be affected. In all cases, differences from year to year which may be related to changes in Hanford operations were examined. In some cases, specific radionuclides were observed that were directly related to releases from the once-through cooling production reactors, the last of which was deactivated during January 1971.

All of the data for each year is presented in tabular form. Average values and range of values observed are included. Sequential time and/or log-normal probability plots of the data are provided whenever sufficient data are greater than the detection level. Dose estimates are provided wherever a specific impact is attributable or, in some cases, potentially attributable to Hanford operations.

SUMMARY

Selected foodstuffs and wildlife have routinely been collected from the Hanford Site environs to assess the significance of dose from radionuclides which may be attributable to Hanford operations. Oysters from the Washington coast have also been collected and analyzed. Observations have shown that, with few exceptions, the population has not received radionuclide concentrations above natural or fallout levels. Most exceptions resulted from operation of the once-through cooling production reactors, the last of which was deactivated during January 1971. Highlights of all observations follows:

- Milk--Naturally-occurring ^{40}K was observed most frequently, and from the available data, a median value of about 1000 pCi/l was obtained. A median value of ^{90}Sr was observed between 2 pCi/l and 4 pCi/l and attributed to fallout. Iodine-131 was observed occasionally with the higher concentrations generally following an atmospheric nuclear detonation by the Peoples Republic of China. The appearance of ^{65}Zn was attributed to past operation of the once-through cooling production reactors. During 1971, the 50-year whole body dose commitment potentially received by a person consuming 365 liters of milk containing 100 pCi/l of ^{65}Zn was 0.1 mrem. (See pages 6-9.)
- Beef--Potassium-40 was observed in the highest concentrations and a median value of 2 pCi/g was observed. Strontium-90 and ^{137}Cs were observed occasionally, and attributed to worldwide fallout. (See pages 10-12.)
- Chickens and Eggs--Potassium-40 was the only radionuclide observed consistently. A median value for chicken and eggs of 1.8 pCi/g and 0.9 pCi/g, respectively, was observed. (See pages 12-15.)
- Green Leafy Vegetables--A median value for ^{40}K of 3 pCi/g was observed in samples of spinach, leaf lettuce, turnip greens and mustard greens. Strontium-90, observed in most samples, was attributed to fallout and showed a median concentration of

0.01 pCi/g. Only one analysis of ^{137}Cs was above the detection level. (See pages 15-17.)

- Whitefish--Potassium-40 from natural causes as well as ^{90}Sr and ^{137}Cs attributed to fallout were observed. Median concentrations for ^{40}K and ^{137}Cs were 3.2 pCi/g and 0.17 pCi/g, respectively. The majority of whitefish analyzed for ^{90}Sr yielded less than detectible results. However, a median concentration between 0.001 and 0.01 pCi/g is estimated. Phosphorus-32 and ^{65}Zn were observed and attributed to operation of the once-through cooling reactors. Following deactivation of the last of these reactors during January 1971, ^{32}P with a half-life of 14 days showed rapid decline. Zinc-65 concentrations gradually declined and were less than detectible by 1973. Assuming that during the year 1971, a local person consumed 18 kg of fish containing the average quantity of ^{32}P and ^{65}Zn observed that year, he would have incurred a 50-year whole body dose commitment of 0.4 mrem and 0.3 mrem, respectively. (See pages 18-22.)
- Deer--Potassium-40 was observed most frequently and in the greatest concentrations with a median observed concentration of about 2.5 pCi/g. Cesium-137 was detected in a few deer samples, but it is difficult to determine whether Hanford operations have contributed to those levels. Strontium-90 was less than detectible in all but one sample. (See pages 22-24.)
- Willapa Bay Oysters--Potassium-40 was detected in all samples and a median concentration of about 2 pCi/g was observed. For ^{137}Cs , 8 of the 35 samples analyzed yielded slightly positive results which could be attributed to fallout. During the 5-year period, a dramatic decrease in ^{65}Zn concentrations in oysters was observed with an approximate 100-fold decrease between 1971 and 1975. For 1971, dose calculations for a person consuming 9 kg of oyster meat containing the average concentration of ^{65}Zn observed (4.6 pCi/g) result in a potential 50-year dose commitment of 0.3 mrem to the whole body and 0.2 mrem to the bone. (See pages 24-26.)

The preceding dose estimates may be compared to the approximate 100 mrem/yr received from naturally-occurring radionuclides or a dose accumulation of 5000 mrem (50 x 100) during 50 years. Potassium-40 contributes, internally, a whole body dose of about 20 mrem per/year and is included in the 100 mrem per/year natural background dose.

FOODSTUFF DATA ANALYSIS

To assess the public's potential exposure to radionuclides from Hanford operations, a variety of foodstuffs including milk, meat, chickens, eggs and leafy vegetables have routinely been collected from the Hanford environs. Radionuclides observed included naturally-occurring ^{40}K , as well as the radionuclides ^{90}Sr and ^{137}Cs contributed by worldwide fallout. Radionuclides of Hanford origin would be similar to those from fallout and must necessarily be present in greater levels than the fallout nuclides to be detectible. The following sections examine the data for each foodstuff category separately. Figure 1 shows sampling locations of all foodstuffs.

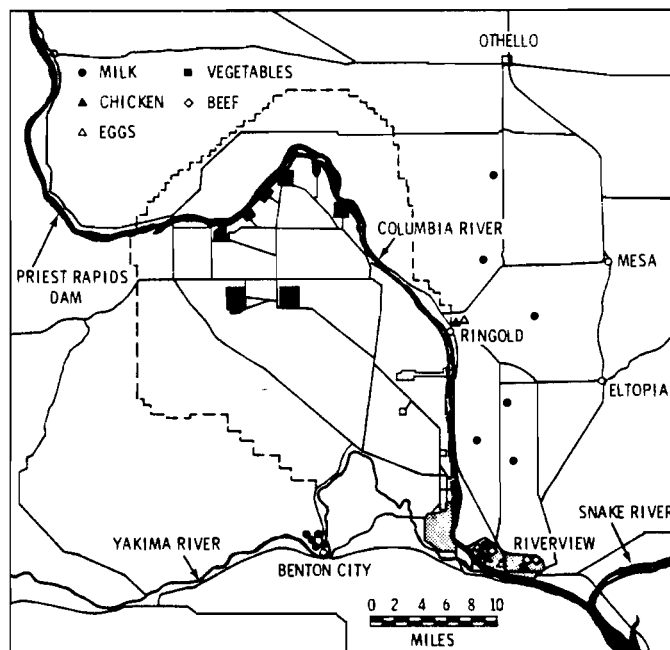


FIGURE 1. Foodstuff Sampling Locations from Local Farms in the Hanford Environs, 1971-1975. Samples were also obtained from Retail Outlets

MILK

Milk has been sampled from local farms near the Hanford Site, from the Pasco Riverview Area (which is irrigated with Columbia River water) and from two commercial sources (which obtain milk principally from either side of the Cascade mountain range). It has routinely been analyzed for gamma-emitting radionuclides, ^{90}Sr and ^{131}I . The results of these analyses are summarized in Table 1.

TABLE 1. Radiochemical Analyses of Milk Samples

Units of pCi/l

Year	^{40}K				^{90}Sr				^{131}I			
	No. of Samples	Max.	Min.	Avg ^(a)	No. of Samples	Max.	Min.	Avg.	No. of Samples	Max.	Min.	Avg.
<u>Local Farms</u>												
1971	104	1900	*	<1140	8	3.3	*	<2.0	105	24.7	*	<4.3
1972	104	1600	*	<1130	8	3.9	*	<2.0	103	5.4	*	<2.0
1973	127	1400	*	<1110	11	3.5	*	<2.0	127	5.4	*	<2.0
1974	70	1300	*	<1030	10	4.6	*	<2.7	70	*	*	<0.5
1975	79	1300	*	< 920	12	6.1	*	<2.4	79	0.4	*	<0.4
<u>Riverview Farms</u>												
1971	32	1500	*	<1120	4	3.4	0.7	2.3	21	2.3	*	<2.0
1972	26	1900	740	1160	4	4.4	1.1	2.7	28	*	*	<2.0
1973	26	1300	700	1150	4	1.5	0.7	1.1	28	*	*	<2.0
1974	26	1400	710	1000	4	2.6	*	<1.8	25	3.0	*	<0.5
1975	26	1200	720	830	4	3.2	*	<1.5	26	0.4	*	<0.4
<u>Eastern Watershed</u>												
1971	0				3	3.7	0.5	2.1	21	3.1	*	<2.0
1972	21	1700	870	1200	4	3.7	1.5	2.5	25	*	*	<2.0
1973	24	1400	820	1080	3	2.4	0.8	1.7	24	*	*	<2.0
1974	13	1200	*	< 950	7	3.2	*	<1.4	13	*	*	<0.5
1975	14	1200	730	970	4	5.5	0.6	2.6	14	0.8	*	<0.5
<u>Western Watershed</u>												
1971	12	1500	930	870	4	6.5	3.9	5.2	10	*	*	<2.0
1972	12	1700	980	1260	4	7.1	0.8	6.4	12	*	*	<2.0
1973	12	1400	820	1120	4	7.6	1.0	3.0	12	*	*	<2.0
1974	11	1300	820	1050	4	5.5	*	<2.3	11	*	*	<0.5
1975	14	1300	820	1040	3	5.0	*	<2.6	14	*	*	<0.4

* Less than detectible. Approximate detection levels are ^{40}K , ~600-, ^{90}Sr , 0.5-, and ^{131}I , 2- pCi/l during 1971-1973, 0.5 pCi/l during 1974, and 0.4 pCi/l during 1975.

(a) Average for data containing less-than values was calculated by assuming all less-than values are equal to the detection level and showing the average as a less-than number.

Before February 1971, routine analysis was made for ^{32}P . Following the January 1971 deactivation of the last once-through cooling reactor, this analysis was stopped (^{32}P - 14 day half-life).

Potassium-40 is a naturally-occurring radionuclide and is present in the greatest concentrations. Figure 2 is a log-normal probability plot of the ^{40}K and ^{90}Sr data for each of the commercial sources of milk, one from each side of the Cascades. The figure shows that the ^{40}K concentrations are identical. Strontium-90 is present in the environment from worldwide fallout. Figure 2 shows that generally the concentrations in milk are slightly higher west of the Cascades than east of the mountains. This can be attributed to the higher rainfall west of the mountains. From Figure 2 a median value of approximately 1000 pCi/l for ^{40}K and between 2 and 4 pCi/l for ^{90}Sr would be expected.

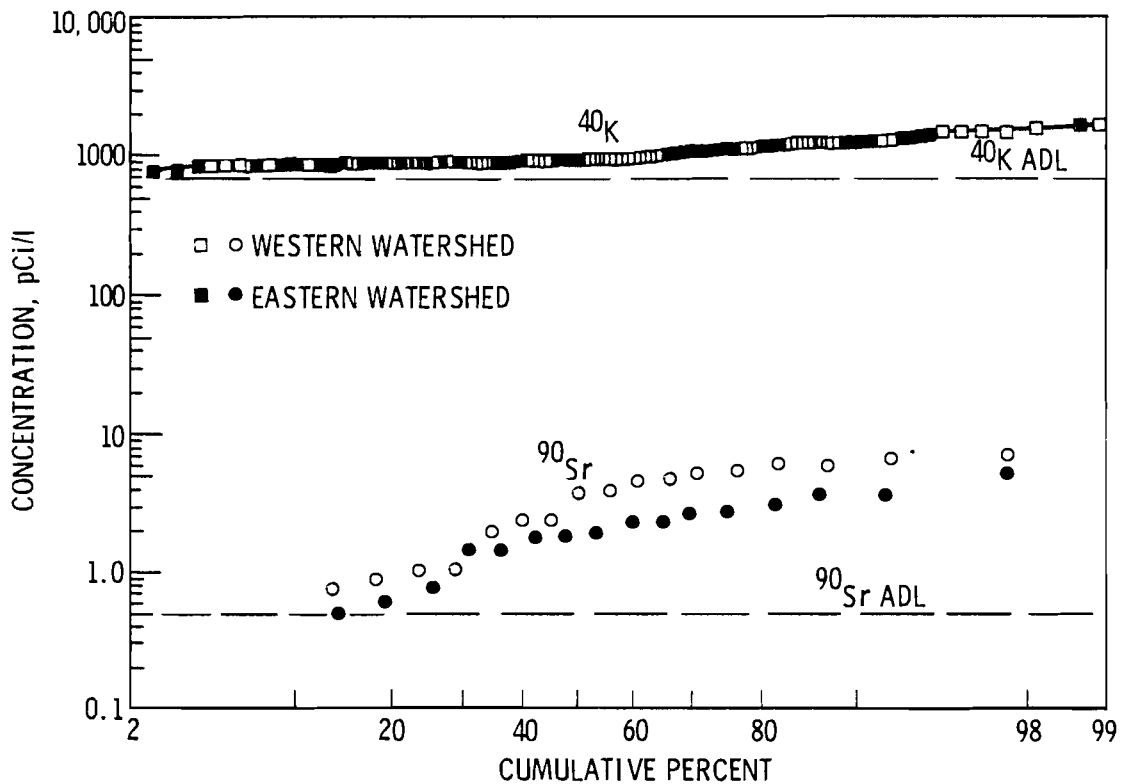


FIGURE 2. Probability Plot of Milk Samples Obtained from Commercial Sources Representing Watersheds East and West of the Cascades

Figure 3 is a log-normal probability plot of the ^{90}Sr data for local farms, Riverview farms, and commercial sources from the Eastern watershed. Apparently, there is no obvious difference in the concentrations observed in milk from the different sources. This indicates that any Hanford contributions to the levels at local or Riverview farms are indistinguishable from the levels in commercial milk for the region. From Figure 3, a median value of 2 pCi/l of ^{90}Sr would be expected for all milk produced in the Hanford region.

Iodine-131 concentrations were generally less than detectible, as shown in Table 1, with a few occasional positive measurements. Figure 4 is a sequential plot of the positive ^{131}I data from 1971 through 1975. Included in Figure 4 is an indication of the occurrence of atmospheric nuclear detonations in the Northern Hemisphere by the Peoples Republic of China, which generally preceded the higher observed concentrations. This was particularly true during the latter part of 1971, the early part of 1972, middle of 1973, and the middle of 1974. The concentrations observed at other times to be slightly above the detection level are attributed to the statistical uncertainty in performing low-level radiochemical analyses.

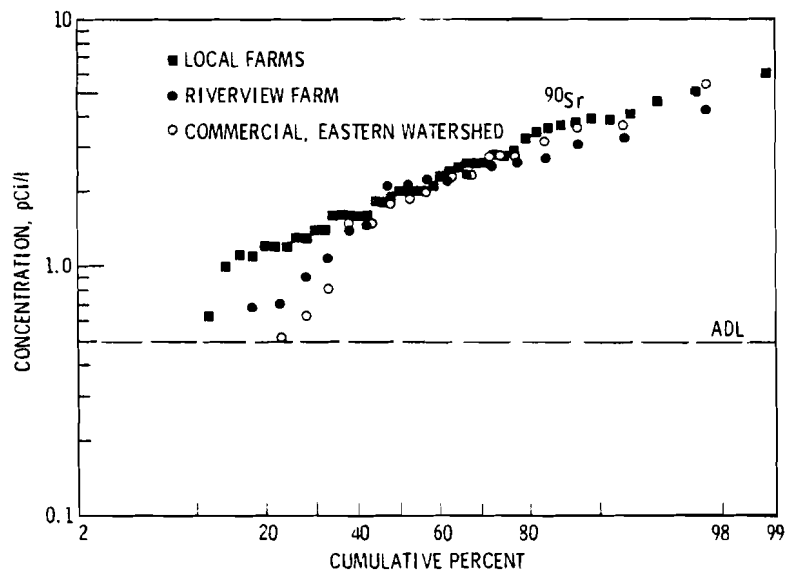


FIGURE 3. Probability Plot of ^{90}Sr Concentrations in Milk from Hanford Vicinity Farms

BEEF

Samples were taken of beef grown in Pasco's Riverview area and from a local slaughtering and packing plant. The samples were routinely collected to assess the potential presence of radionuclides attributable to Hanford operations. The packing plant receives cattle from local farms throughout the entire region whereas the Riverview area is directly downstream and downwind of the Hanford Site, as shown in Figure 1.

Table 2 summarizes the maximum, minimum, and average concentration observed for ^{40}K , ^{90}Sr and ^{137}Cs for samples from local and Riverview farms for each of the years 1971 through 1975. The tabled data indicates no apparent increase in levels for the Riverview samples. There is an apparent slight decrease in ^{90}Sr and ^{137}Cs concentrations from 1971 through 1975 that is likely attributable to the gradual decline of atmospheric fallout activity, the major source of ^{90}Sr and ^{137}Cs in the environment. No other radionuclides were observed except naturally-occurring ^{40}K .

Figure 5 is a log-normal probability plot of the ^{40}K , ^{90}Sr and ^{137}Cs data greater than the detection level for all of the beef samples. Potassium-40, a naturally-occurring radionuclide, was observed most frequently and in the greatest concentration. From the data in Figure 5, a median concentration for ^{40}K in beef of about 2 pCi/g would be expected. The ^{90}Sr and ^{137}Cs shown in Figure 5 are attributed to worldwide fallout. Although the majority of the ^{90}Sr and ^{137}Cs data are less than detectible, one can estimate an expected median value by extrapolation from the plotted data. From Figure 5, the median value for ^{90}Sr would be between 0.0002 and 0.002 pCi/g; for ^{137}Cs the median would lie between 0.05 and 0.5 pCi/g. The broad range for these estimates is due to the rather large statistical uncertainty associated with the slightly positive data.

TABLE 2. Radiochemical Analyses of Beef Samples Obtained from Local Farms and the Riverview Farming Area

Units of pCi/g (Wet Weight)

Year	<u>Riverview</u>				No. of Samples	<u>Local Farms</u>			
	<u>No. of Samples</u>	<u>Concentration</u> (a)				<u>Max</u>	<u>Min</u>	<u>Avg</u>	
		<u>Max</u>	<u>Min</u>	<u>Avg</u>		<u>Max</u>	<u>Min</u>	<u>Avg</u>	
<u>⁴⁰K</u>									
1971	2	2.3	1.7	2.0	11	2.5	1.1	1.9	
1972	0	--	--	--	12	2.8	1.5	2.3	
1973	1	--	--	2.2	13	2.7	1.9	2.3	
1974	1	--	--	1.7	11	2.6	1.8	2.1	
1975	1	--	--	1.9	13	2.4	1.6	2.0	
<u>⁹⁰Sr</u>									
1971	0	--	--	--	12	0.013	*	<0.003	
1972	0	--	--	--	12	0.006	*	<0.007	
1973	1	--	--	0.003	13	0.005	*	<0.002	
1974	1	--	--	<0.002	11	*	*	<0.002	
1975	1	--	--	0.002	13	0.007	*	<0.003	
<u>¹³⁷Cs</u>									
1971	2	*	*	<0.04	11	0.19	*	<0.06	
1972	0	--	--	--	12	0.08	*	<0.05	
1973	1	--	--	<0.04	13	0.06	*	<0.04	
1974	1	--	--	<0.04	11	*	*	<0.04	
1975	1	--	--	<0.04	13	*	*	<0.04	

* Less than detectible. Detection levels are approximately: ⁴⁰K, 0.6-; ⁹⁰Sr, 0.002-; and ¹³⁷Cs, 0.04-pCi/g.

(a) Average for data containing less-than values was calculated by assuming all less-than values are equal to the detection level and showing the average as a less-than number.

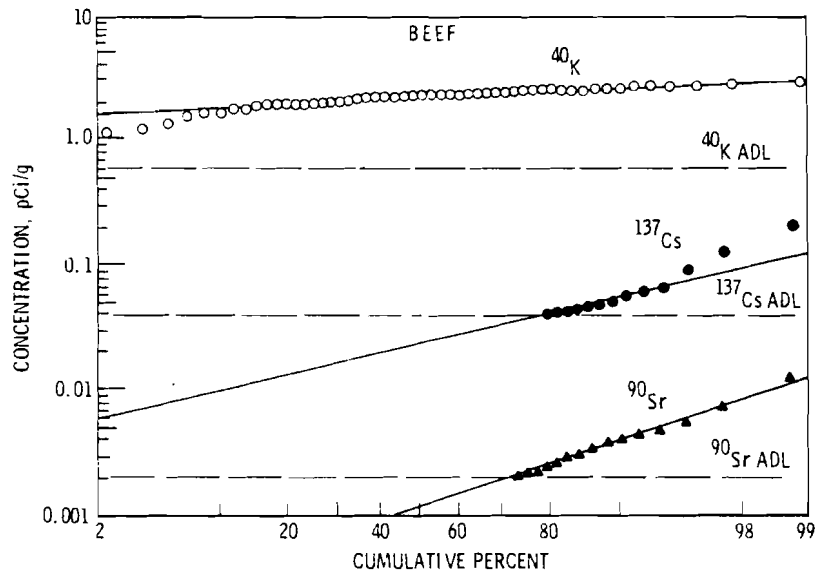


FIGURE 5. Probability Plot of ^{40}K , ^{90}Sr and ^{137}Cs Activity in Beef Samples

CHICKENS AND EGGS

Each year a few chickens and eggs have been collected from local farms near the Hanford Site and from chain grocery stores for gamma spectral and ^{90}Sr analysis. Generally, the chain grocery stores have carried products which are not locally grown. Any increase in radionuclide concentrations observed for local samples compared to the chain store samples would indicate an apparent impact from Hanford operations.

Tables 3 and 4 summarize the maximum, minimum, and average concentration of ^{40}K , ^{90}Sr and ^{137}Cs in local farm and store samples for each year, 1971 through 1975. The tabulated data indicates no distinguishable Hanford impact because the majority of the results, except for ^{40}K , were less than the detection level. Naturally-occurring ^{40}K was observed in the greatest concentration. Occasionally, ^{90}Sr levels were observed near the detection limit. Cesium-137 concentrations were less than detectible for all but one egg sample. The single positive measurement was taken in 1972 and was slightly above the detection limit of 0.04 pCi/l.

Figure 6 is a log-normal probability plot of naturally-occurring ^{40}K in chicken muscle tissue and eggs. From Figure 6, a median ^{40}K concentration in chickens and eggs of 1.8 pCi/g and 0.9 pCi/g, respectively, would be expected.

TABLE 3. Radiochemical Analyses of Chicken Muscle
Obtained from Local Farms and Commercial
Stores

Units of pCi/g (Wet Weight)

Year	<u>Local Farms</u>			<u>Commercial Sources</u>			
	<u>No. of Samples</u>	<u>Concentration</u>		<u>No. of Samples</u>	<u>Concentration</u>		
		<u>Max</u>	<u>Min</u>	<u>Avg</u> ^(a)	<u>Max</u>	<u>Min</u>	<u>Avg</u>
<u>⁴⁰K</u>							
1971	1	--	--	2.3	0	--	--
1972	4	2.8	2.0	2.4	0	--	--
1973	2	2.2	2.0	2.1	1	--	1.8
1974	4	2.0	1.1	1.8	2	1.6	1.6
1975	4	2.1	1.1	1.6	2	1.5	1.4
<u>⁹⁰Sr</u>							
1971	2	0.003	*	<0.003	0	--	--
1972	3	0.004	*	<0.003	0	--	--
1973	2	*	*	<0.002	1	*	<0.002
1974	4	*	*	<0.002	2	*	<0.002
1975	4	0.014	*	<0.006	2	0.006	<0.004
<u>¹³⁷Cs</u>							
1971	1	*	*	<0.04	0	--	--
1972	4	*	*	<0.04	0	--	--
1973	2	*	*	<0.04	1	*	<0.04
1974	4	*	*	<0.04	2	*	<0.04
1975	4	*	*	<0.04	2	*	<0.04

* Less than detectible. Detection limits are approximately: ⁴⁰K, 0.6-; ⁹⁰Sr, 0.002-; and ¹³⁷Cs, 0.04-pCi/g.

(a) Average for data containing less-than values was calculated by assuming all less-than values are equal to the detection level and showing the average as a less-than number.

TABLE 4. Radiochemical Analyses of Chicken Eggs Obtained from Local Farms and Commercial Stores

Units of pCi/g (Wet Weight)

Year	<u>Local Farms</u>				<u>Commercial Sources</u>			
	<u>No. of Samples</u>	<u>Concentration</u> ^(a)			<u>No. of Samples</u>	<u>Concentration</u>		
		<u>Max</u>	<u>Min</u>	<u>Avg</u>		<u>Max</u>	<u>Min</u>	<u>Avg</u>
<u>⁴⁰K</u>								
1971	10	1.6	0.7	1.0	0	--	--	--
1972	10	1.4	0.7	1.0	0	--	--	--
1973	12	1.2	0.7	0.9	1	--	--	1.2
1974	11	1.1	0.7	0.9	2	1.0	0.95	1.0
1975	13	1.1	0.6	0.9	2	0.8	0.8	0.8
<u>⁹⁰Sr</u>								
1971	3	0.012	0.003	0.007	0	--	--	--
1972	3	0.026	0.002	0.013	0	--	--	--
1973	3	0.004	*	<0.003	1	--	--	0.005
1974	4	0.004	*	<0.003	2	*	*	<0.002
1975	3	*	*	<0.002	2	0.003	*	<0.003
<u>¹³⁷Cs</u>								
1971	10	*	*	<0.04	0	--	--	--
1972	10	0.04	*	<0.04	0	--	--	--
1973	12	*	*	<0.04	1	*	*	<0.04
1974	11	*	*	<0.04	2	*	*	<0.04
1975	13	*	*	<0.04	2	*	*	<0.04

* Less than detectible. Detection levels are approximately: ⁴⁰K, 0.6-; ⁹⁰Sr, 0.002-; and ¹³⁷Cs, 0.04-pCi/g.

(a) Average for data containing less than values was calculated by assuming all less-than values are equal to the detection level and showing the average as a less-than number.

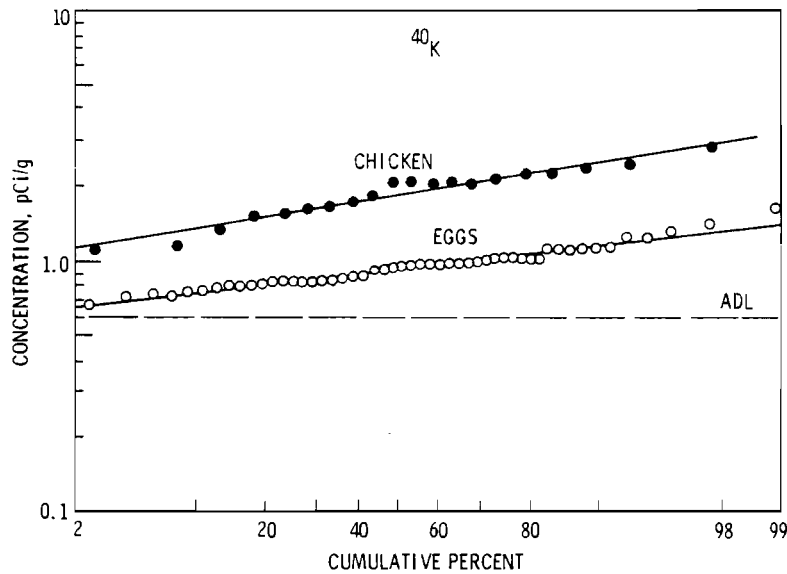


FIGURE 6. Probability Plot of Naturally-Occurring ^{40}K Concentrations in Chicken and Egg Samples

GREEN LEAFY VEGETABLES

A few samples of green leafy vegetables such as spinach, leaf lettuce, turnip greens and mustard greens have been collected each year during the summer growing season from local farms and commercial stores for analysis. Local farms sampled always included the Riverview area as shown in Figure 1. Because the commercial produce samples are generally not locally grown, they reflect levels of radionuclides due to fallout.

Table 5 summarizes the maximum, minimum, and average concentration observed for ^{40}K , ^{90}Sr and ^{137}Cs for samples from local farms and grocery stores for each of the years, 1971 through 1975. There is no apparent difference between concentrations for samples from local farms and commercial stores. Naturally-occurring ^{40}K was observed in the highest concentrations. Strontium-90 measurements were generally positive and the levels observed are attributed to worldwide fallout. Cesium-137 results were less than detectible with one exception for a sample collected from a store in 1971.

TABLE 5. Radiochemical Analyses of Green Leafy Vegetables
Obtained from Local Farms and Commercial Stores

Units of pCi/g (Wet Weight)

Year	No. of Samples	<u>Local Farms</u>			No. of Samples	<u>Commercial Stores</u>		
		Concentration (a)				Concentration		
		Max	Min	Avg		Max	Min	Avg
<u>⁴⁰K</u>								
1971	3	3.0	2.0	2.6	5	4.7	0.9	2.9
1972	3	4.5	2.7	3.6	5	5.6	2.4	4.0
1973	3	4.9	2.0	3.0	5	4.0	2.2	3.3
1974	5	3.6	1.7	2.4	6	3.2	1.2	2.1
1975	4	3.3	2.1	2.6	6	5.1	2.1	3.3
<u>⁹⁰Sr</u>								
1971	0	--	--	--	1	--	--	0.039
1972	1	--	--	0.030	2	0.010	0.009	0.009
1973	1	--	--	0.005	1	--	--	0.009
1974	3	0.016	0.011	0.014	2	0.011	0.009	0.010
1975	2	0.055	0.025	0.040	2	0.027	0.004	0.015
<u>¹³⁷Cs</u>								
1971	3	*	*	<0.1	5	0.2	*	<0.1
1972	3	*	*	<0.1	5	*	*	<0.1
1973	3	*	*	<0.1	5	*	*	<0.1
1974	5	*	*	<0.1	6	*	*	<0.1
1975	4	*	*	<0.1	6	*	*	<0.1

* Less than detectible. Detection levels are approximately: ⁴⁰K, 0.8-; ⁹⁰Sr, 0.003-; and ¹³⁷Cs, 0.1-pCi/g.

(a) Average for data containing less-than values was calculated by assuming all less-than values are equal to the detection level and showing the average as a less-than number.

Figure 7 is a log-normal probability plot of the ^{40}K and ^{90}Sr data. Based on the data shown, a median ^{40}K concentration of about 3 pCi/g would be expected. The ^{90}Sr plot illustrates the similarity of the local farm and grocery store concentrations. The expected median concentration for ^{90}Sr would be about 0.01 pCi/g.

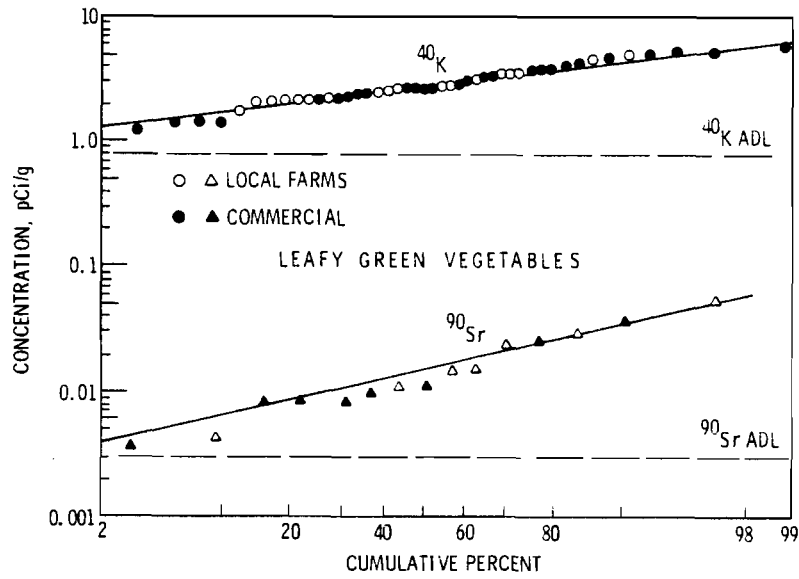


FIGURE 7. Probability Plot of ^{40}K and ^{90}Sr Concentrations in Leafy Green Vegetables

WILDLIFE DATA ANALYSIS

A few wildlife species play an important role in assessing the potential dose to people from Hanford operations. The routinely collected species include game birds, fish and deer in the Hanford environs as well as oysters from Willapa Bay along the Pacific Coast. The game bird data for 1971 through 1975 have been evaluated in another report.⁽¹⁾ The species of Columbia River fish collected was whitefish because they are prominent and are caught throughout the year. Generally, deer samples were obtained from road accidents on the Hanford Site. The locations of the samples analyzed are shown in Figure 8. Oysters were obtained from a commercial supplier who farms in Willapa Bay. Radionuclides observed included naturally-occurring ^{40}K , as well as the worldwide fallout radionuclides, ^{90}Sr and ^{137}Cs . Radionuclides of Hanford origin observed included ^{32}P and ^{65}Zn from operation of the once-through cooling production reactors and possibly ^{137}Cs at near fallout levels. The following sections examine the data for each wildlife species, separately. Figure 8 shows the location of all fish and deer samples.

WHITEFISH

Each year for five years, quarterly samples of whitefish from the Columbia River have been routinely collected adjacent to and immediately downstream of the Hanford Site. The samples were taken to assess the concentration of radionuclides potentially attributable to Hanford operations.

Table 6 summarizes the maximum, minimum and average concentrations observed for ^{40}K , ^{32}P , ^{65}Zn , ^{90}Sr and ^{137}Cs for each of the years 1971 through 1975. The tabled data shows that following the January 1971 shutdown of the last once-through cooling production reactor, the ^{32}P and ^{65}Zn concentrations showed a rapid decrease. Because of the approximate 14 day half-life for ^{32}P , this particular analysis was stopped as a routine analyses after March 1971. Occasional analyses were done after this date to insure that continuing reactor operations did not contribute significant quantities of ^{32}P to the river. Observed levels of ^{90}Sr and ^{137}Cs show no obvious pattern and can be attributed to worldwide fallout.

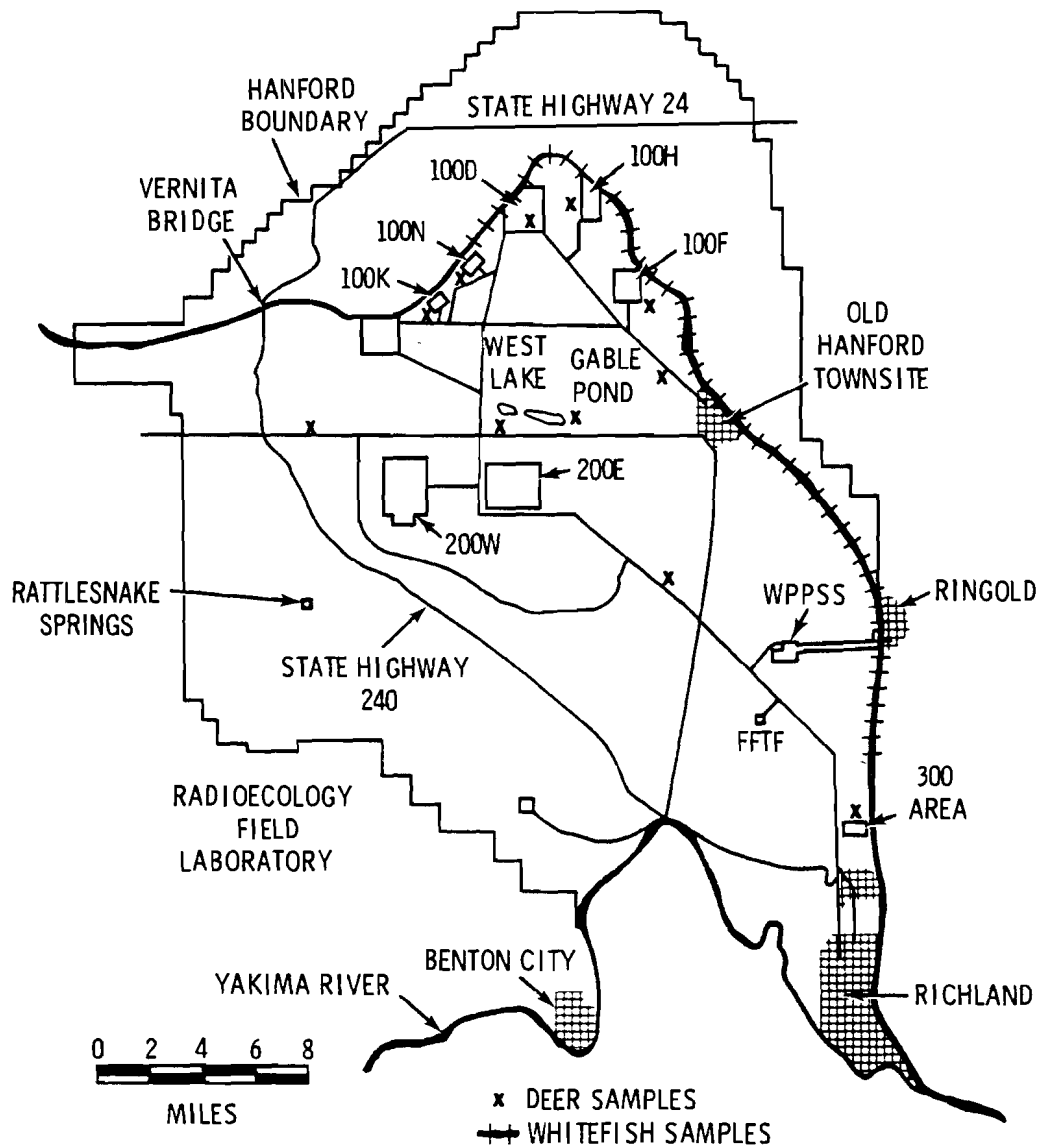


FIGURE 8. Deer and Whitefish Sample Collection Locations from 1971-1975

Figure 9 is a sequential time plot of the ^{40}K and ^{65}Zn data obtained from 1971 through 1975. The plotted data illustrate the consistency of the naturally-occurring ^{40}K concentrations observed throughout the 5-year period. Figure 9 shows the rapid decline of ^{65}Zn concentrations in whitefish following shutdown of the last of these reactors. Zinc-65 had been released to the river by the once-through cooling production reactors.

TABLE 6. Radiochemical Analysis of Whitefish

Units of pCi/g (Wet Weight)

Year	No. of Samples	⁴⁰ K			³² P(a)		
		Max	Min	Avg ^(b)	Max	Min	Avg
1971	20	6.9	2.8	3.8	36	*	<3
1972	21	4.9	2.6	3.4	*	*	*
1973	22	4.1	2.8	3.4	*	*	*
1974	10	3.9	2.1	3.0	*	*	*
1975	9	10.0	2.8	4.0	*	*	*

Year	No. of Samples	⁶⁵ Zn			¹³⁷ Cs		
		Max	Min	Avg	Max	Min	Avg
1971	20	5.6	0.7	2.2	0.5	0.2	0.3
1972	21	0.9	*	<0.4	0.3	*	<0.2
1973	22	0.3	*	<0.1	0.2	*	<0.1
1974	10	0.2	*	<0.1	0.1	*	<0.1
1975	9	*	*	<0.1	0.4	*	<0.2

Year	No. of Samples	⁹⁰ Sr		
		Max	Min	Avg
1971	0			--
1972	7	*	*	<0.005
1973	22	0.035	*	<0.008
1974	10	0.007	*	<0.005
1975	9	0.180	*	<0.027

* Less than detectible. Detection levels are approximately: ⁴⁰K, 1; ³²P, 1; ⁶⁵Zn, 0.1; ⁹⁰Sr, 0.005; and ¹³⁷Cs, 0.1 pCi/g.

- (a) Routine low-level ³²P analyses stopped after March 1971 following shutdown of KE. A few analyses were done each year after 1971.
- (b) Average for data containing less-than values was calculated by assuming all less-than values are equal to the detection level and showing the average as a less-than number.

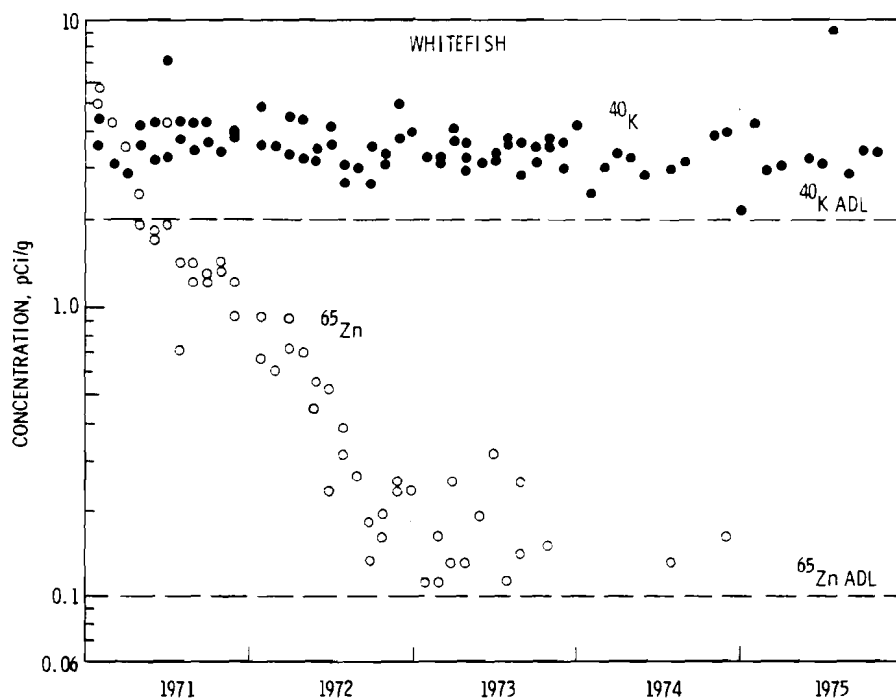


FIGURE 9. Potassium-40 and ^{65}Zn Levels in Whitefish Obtained from 1971 Through 1975

Figure 10 is a log-normal plot of the ^{40}K , ^{90}Sr and ^{137}Cs data. It is apparent that naturally-occurring ^{40}K is present in the largest concentrations and, from the data in Figure 10, a median value of about 3.2 pCi/g would be expected. The ^{90}Sr and ^{137}Cs concentrations shown in Figure 10 are attributed to worldwide fallout. Based on the data shown, the expected median concentration of ^{137}Cs would be about 0.17 pCi/g. Strontium-90 in most of the whitefish was less than detectible. However, from the plotted data, a median concentration between 0.001 and 0.01 pCi/g would be expected.

The dose implication to a person eating whitefish varied greatly from 1971 through 1975 because of the rapid decline in ^{32}P and ^{65}Zn concentrations following shutdown of the last once-through production reactor during January 1971. Assuming during 1971 an individual consumed 18 kg* of fish which contained the average quantity of ^{32}P and ^{65}Zn (3 pCi/g and 2.2 pCi/g) that

* Consumption value obtained from ERDA 77-24 for the maximum individual dosage. (Reference 2)

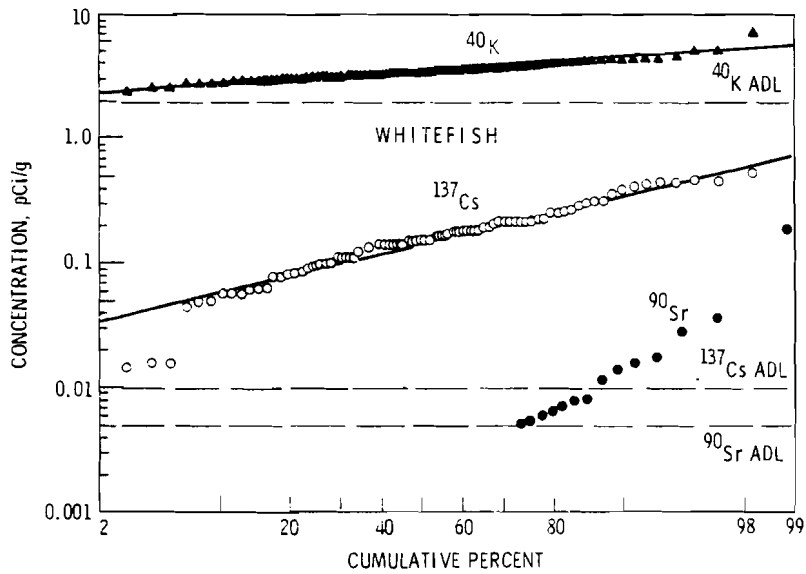


FIGURE 10. Data Collected from 1971 Through 1975 Showing the Levels of ^{40}K , ^{90}Sr and ^{137}Cs in Whitefish

individual would incur a 50-year whole body dose commitment of 0.4 mrem and 0.3 mrem, respectively. The 50-year respective dose commitment to the bone would be 10.3 mrem and 0.2 mrem.

DEER

Each year a few deer are collected on the Hanford Site to assess the radionuclide concentrations in edible muscle tissue. The deer are generally "road kills". Table 7 shows the maximum, minimum, and average concentrations of ^{40}K and ^{137}Cs observed during each of the years 1971 through 1975. Deer were also analyzed for Strontium-90. Except for one positive result (0.008 ± 0.005) during 1974, ^{90}Sr was not detectible.

Figure 11 is a log-normal plot of the ^{40}K and ^{137}Cs data. Naturally-occurring ^{40}K was observed at a similar concentration for all of the deer samples and from the plotted data a median concentration of about 2.5 pCi/g would be expected. Only 5 of the 14 deer samples showed positive ^{137}Cs results. Although the observed ^{137}Cs concentrations are similar to the levels observed in beef (see Figure 5) which were attributed to fallout, it is

TABLE 7. Radiochemical Analyses of Deer Muscle Samples

Units in pCi/g (Wet Weight)

Year	No. of Samples	⁴⁰ K			¹³⁷ Cs		
		Max	Min	Avg ^(a)	Max	Min	Avg
1971	2	2.9	2.9	2.9	*	*	<0.1
1972	3	2.7	2.5	2.6	0.2	*	<0.1
1973	2	2.4	2.3	2.3	0.5	*	<0.3
1974	3	2.3	2.2	2.2	1.8	*	<1.0
1975	4	2.8	*	<2.3	0.2	*	<0.1

* Less than detectible. Detection levels are approximately: ⁴⁰K, 2 pCi/g and ¹³⁷Cs, 0.1 pCi/g.

(a) Averages for data containing less-than values was calculated by assuming all less-than values are equal to the detection level and showing the average as a less-than number.

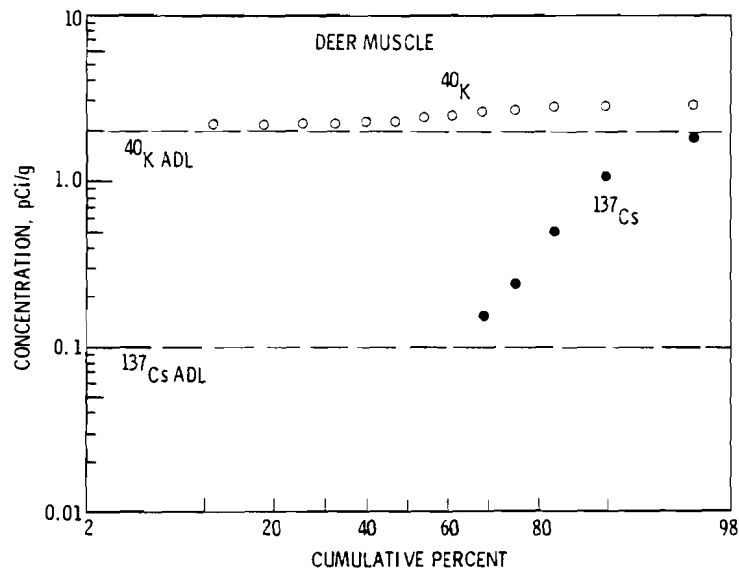


FIGURE 11. Levels of ⁴⁰K and ¹³⁷Cs Shown in Deer Muscle Samples Collected Over the Period, 1971 Through 1975

possible that Hanford operations have contributed to the observed levels. Assuming an individual were to consume 50 kg of deer meat which contained the maximum concentration observed (1.8 pCi/g) he would incur a 50-year whole body dose commitment of about 5 mrem.

WILLAPA BAY OYSTERS

For many years, oysters have been collected from Willapa Bay along the coast of Washington to assess the significance of Hanford-originated radionuclides (primarily ^{65}Zn) accumulated by the oysters. Table 8 summarizes the maximum, minimum, and average concentrations of ^{40}K , ^{65}Zn , and ^{137}Cs observed during each of the years 1971 through 1975. Naturally-occurring ^{40}K was observed in all samples. For ^{137}Cs , only 8 of the 35 oyster samples analyzed were greater than the approximate analytical detection level of 0.04 pCi/g. These results, with a maximum of 0.06 pCi/g, were only slightly greater than the detection limit and are attributed to either the statistical variability of low level counting or to the presence of ^{137}Cs activity from fallout.

Zinc-65 concentrations observed have shown a significant decline from 1971 to 1975 as shown by the average concentrations in Table 8. Figure 12 is a sequential plot of the ^{40}K and ^{65}Zn results from 1971 through 1975. The decline in ^{65}Zn activity is quite evident following shutdown of the last once-through cooling production reactor in January 1971. During the 5-year period, an approximate 100-fold decrease in ^{65}Zn concentrations was observed. All analyses for ^{65}Zn during 1975 were below the detection limit. The average concentration of ^{40}K observed during the 5 years is about 2 pCi/g.

Fifty-year internal dose commitment calculations were made using dose factors of 7 mrem for total body and 4.8 mrem for bone per μCi of ^{65}Zn activity ingested. During 1971 with an average ^{65}Zn concentration of 4.6 pCi/g, a person ingesting 9 kg* of oyster meat would have incurred a

* Consumption value obtained from ERDA 77-24 for the maximum individual dosage. (Reference #2)

TABLE 8. Radionuclides Observed in
Willapa Oysters

Concentration, pCi/g (Wet Weight)

<u>Year</u>	<u>No. of Samples</u>	⁴⁰ K			⁶⁵ Zn		
		<u>Max.</u>	<u>Min.</u>	<u>Avg.</u> (b)	<u>Max.</u>	<u>Min.</u>	<u>Avg.</u>
1971	12	2.6	0.9	1.8	7.1	2.4	4.6
1972	9	2.1	1.3	1.7	2.5	0.9	1.7
1973	10	2.1	1.4	1.7	0.9	0.2	0.6
1974	1	1.6	1.6	1.6	0.1	0.1	0.1
1975 ^(a)	3	1.7	1.7	1.7	*	*	*

<u>Year</u>	<u>No. of Samples</u>	¹³⁷ Cs		
		<u>Max.</u>	<u>Min.</u>	<u>Avg.</u>
1971	12	0.06	*	0.03 - 0.05
1972	9	0.05	*	0.01 - 0.04
1973	16	*	*	*
1974	1	*	*	*
1975	3	*	*	*

* Less-than-detectible. Approximate detection levels are 0.08 pCi/g for ⁶⁵Zn and 0.04 for ¹³⁷Cs.

(a) ⁴⁰K results for only one of the three samples analyzed was reported.

(b) Range of arithmetic average shown by assuming all less-than results are alternatively equal to zero and then equal to the detection level.

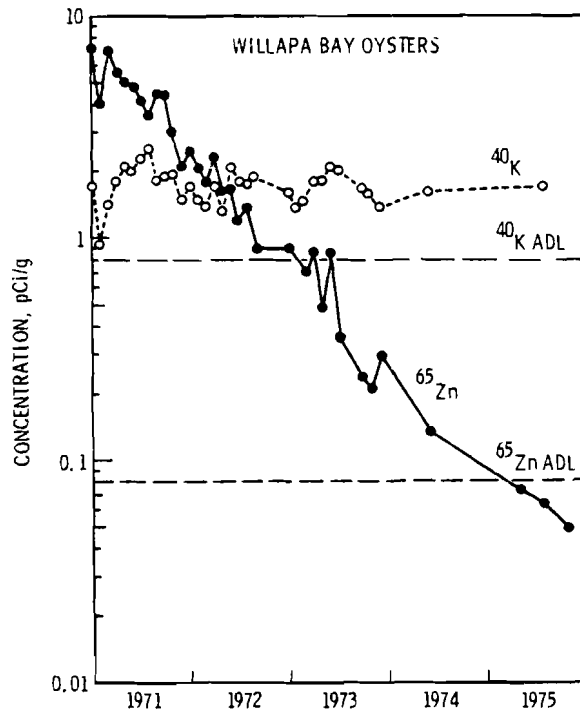


FIGURE 12. Plot of ^{40}K and ^{65}Zn Concentrations in Willapa Bay Oysters

dose commitment to the total body and bone of 0.3 mrem and 0.2 mrem, respectively. During 1975, the ^{65}Zn concentration is about a 100-fold less, implying dose commitments much less than 0.01 mrem.

The above dose estimates may be compared to the approximate 100 mrem/yr received from natural background radiation (a dose accumulation over 50 years of 5000 mrem). Naturally-occurring ^{40}K contributes, internally, a whole body dose of about 20 mrem/year and is included in the 100 mrem/year natural background dose.

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REFERENCES

1. J. J. Fix and P. J. Blumer Radiochemical Analyses of Game Birds Collected from the Hanford Environs 1971-1975. BNWL-2089, Battelle, Pacific Northwest Laboratories, Richland, WA 99352, July 1977.
2. J. P. Corley, et al., A Guide for Environmental Radiological Surveillance at ERDA Installations, ERDA 77-24, Energy Research and Development Administration, Division of Safety, Standards, and Compliance, Washington, DC 20545, March 1977.

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