EFFECT OF A REACTOR FUEL ELEMENT FAILURE
ON THE COLUMBIA RIVER RADIONUCLIDE CONCENTRATIONS
AT PASCO, WASHINGTON

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The failure of a fuel element cladding in one of the water-cooled plutonium production reactors permits the erosion of irradiated uranium metal by the cooling water which is normally disposed to the Columbia River. Monitoring systems at both the reactors and at their effluent basin outlets to the river continuously monitor these streams, and if a major fission-products release occurs the coolant can be held in retention basins. In addition to these monitoring systems, a river monitor is located at the 300 area ⁽¹⁾ which continuously monitors the gross gamma activity of the Columbia river; however, its sensitivity to rupture debris is limited because of the relatively high "background" from the short-lived (n, γ) produced radionuclides in the river.

In making hazard assessments and in providing adequate monitoring techniques and equipment at down-river locations, it is essential to know what changes occur in fission and (n, γ) produced radionuclides following release of rupture products to the river.

It is also important to determine actual travel times required for rupture debris to reach the municipal water intake station at Pasco, Washington.

On August 13, 1962, a minor fuel element failure did occur at B reactor (about 53 miles upstream from Pasco), and this was used as an opportunity to measure the changes in radionuclide content of the Columbia river resulting at Pasco, Washington. The continuous monitor of the effluent water basin outlet to the river showed an increase in activity at 8:15 p.m. which continued to 8:50 p.m., then dropped off until about 11:30 p.m. The reactor shut down at 8:00 p.m. to remove the damaged

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element.

The continuous monitor at the 300 area did not give a definite indication of the failure; however, water samples collected below the new Pasco-Kennewick bridge did show the arrival of fission products.

Radionuclide Measurements

Sampling was started at 7:30 a.m. on August 14, 1962 and continued for about 12 hours. The samples were filtered, immediately after collection, through a membrane filter (Gelman Instrument Company AM-3, pore size 2.0 microns) and the radionuclides measured by gamma-ray spectrometric analysis. The activities measured in the filtrates and on the filters are presented graphically in Figures 1 and 2, respectively, while the actual values are tabulated in Tables 1 and 2. As would be expected, the (n, γ) induced radionuclides (Na^{24} , Cu^{64} , Cr^{51}) did not show a significant increase in either the particulate or the soluble fraction. The fission products Ru^{103} , Zr^{95} - Nb^{95} and Np^{239} (an (n, γ) product of uranium) did show an erratic but substantial increase in the particulate fraction (see Figure 2). The fission product La^{140} did not show a significant increase; however, it is also formed from stable lanthanum by the reaction La^{139} (n, γ) La^{140} and is normally present in a relatively high concentration. I^{131} was not measured in the particulate fractions. In the soluble fractions, the I^{131} measurements which were made showed about a 10-fold increase in activity (see Figure 1). Of the other fission products measured in the filtrate, only Ru^{103} showed an increase (about a factor of 2).

Travel Time Measurements

The release rate of radioactivity to the Columbia River during the rupture as recorded by the effluent water basin outlet monitor is shown in Figure 3. Also included in this figure are the observed river water concentrations at Pasco of I^{131} and Ru^{103} . From these data, it is evident that the time required for the activity peak to travel from the basin outlet at B reactor to Pasco was about

21 hours.

The river flow during the period of this rupture, as measured at the Priest Rapids gauge (10 miles above B reactor), is presented in Figure 4. At the river flow rates at which the rupture occurred, it requires 2 to 3 hours for water to move from Priest Rapids to 100 B. The flow rate at B at the time the rupture occurred was, therefore, about equivalent to that observed at Priest Rapids at 6:00 p.m., or about 135,000 CFS (see Figure 4). If a travel time to Pasco is calculated on the basis of a flow rate of 135,000 CFS, using the equations based on float measurements⁽²⁾, a period of 18 hours is obtained. This is significantly shorter than the observed flow time and may be partly due to the decreased flow over Priest Rapids Dam during travel of the activity peak between B area and Pasco. Recent flow time determinations, based on measurements of the activity changes at Pasco when all of the reactors went down at once, indicated that float measurement equations give too short a travel time. The investigator of the float test measurements has concluded that his measurements actually provide a measure of the time required for the leading edge, rather than the peak, of the activity to reach downstream locations⁽³⁾.

DISCUSSION

Measurements of the radionuclide concentrations in river water at Pasco following a fuel element rupture in one of the plutonium production reactors indicate that I^{131} in solution provides the most sensitive indicator of the arrival of fission products. The Ru^{103} also showed a definite rise. The particulate fraction of the radionuclides Zr^{95} - Nb^{95} , Ru^{103} and Np^{239} showed large but more erratic increases on arrival of the rupture debris.

The travel time between the reactors and Pasco is about 15% ^{longer} ~~shorter~~ than that calculated by the float test equations⁽²⁾; however, the float test equations give a good value for the arrival of the leading edge of the activity.

A similar set of measurements should be made during some future fuel element rupture to determine if these observations are actually typical and also to measure the concentration changes of the more potentially hazardous fission radionuclides Sr^{89} and Sr^{90} .

REFERENCES

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2. Soldat, J. K., Columbia River Flow - Time Calculations, HW-58312, November 1958.
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TABLE I

RADIONUCLIDE CONCENTRATIONS IN FILTERED
COLUMBIA RIVER WATER (8/14/62)

Time Sampled	R A D I O N U C L I D E S (d/m/ml)									
	Na ²⁴	Sc ⁴⁶	Cr ⁵¹	Cu ⁶⁴	Zn ⁶⁵	ZrNb ⁹⁵	RuRh ¹⁰³	I ¹³¹	La ¹⁴⁰	Np ²³⁹
1400	7.56	0.0125	8.05	4.69	0.182	0.0120	0.0138	0.0031	0.380	1.91
1420	7.64	0.0123	8.19	4.95	0.183	0.0100	0.0136	0.0130	0.192	1.88
1440	7.04	0.0112	8.00	5.54	0.172	0.0104	0.0143	0.0020	0.211	2.00
1500	7.19	0.0130	8.17	5.49	0.193	0.0110	0.0127	0.0012	0.167	1.89
1520	7.55	0.0061	8.23	5.20	0.091	0.0087	0.0124	--	0.145	1.83
1540	7.91	0.0102	8.66	5.04	0.058	0.0097	0.0132	0.0152	0.154	1.94
1600	7.31	0.0075	8.22	4.76	0.047	0.0093	0.0175	0.0078	0.185	1.88
1620	6.88	0.0127	8.57	4.57	0.054	0.0113	0.0157	0.0199	0.171	2.00
1640	6.96	0.0107	8.91	6.08	0.072	0.0128	0.0239	0.0262	0.170	2.10
1700	6.90	0.0071	7.88	4.45	0.074	0.0107	0.0233	0.0477	0.163	1.88
1720	7.42	0.0137	8.49	4.91	0.085	0.0137	0.0312	0.0494	0.207	2.18
1740	7.33	0.0148	8.48	5.45	0.048	0.0136	0.0312	0.0256	0.197	2.16
1800	6.76	0.0124	8.54	5.21	0.049	0.0137	0.0322	0.0561	0.213	2.25
1820	6.66	0.0119	8.57	4.98	0.057	0.0112	0.0336	0.0549	0.202	2.29
1840	6.52	0.0144	8.37	5.02	0.053	0.0121	0.0291	0.0448	0.202	2.18
1900	6.39	0.0081	8.34	4.86	0.041	0.0097	0.0307	0.0577	0.174	2.21
1920	6.75	0.0152	8.74	4.55	0.054	0.0111	0.0322	0.0130	0.220	2.20

TABLE II

RADIONUCLIDE CONCENTRATIONS ON
PARTICULATES FROM COLUMBIA RIVER WATER
(8/14/62)

Time Sampled	R A D I O N U C L I D E S (d/m/ml)									
	Sc ⁴⁶	Cr ⁵¹	Cu ⁶⁴	Zn ⁶⁵	ZrNb ⁹⁵	Ru ¹⁰³	Ba ¹⁴⁰	La ¹⁴⁰	Ce ¹⁴¹	Np ²³⁹
1400	0.088	1.10	1.36	0.075	0.017	0.0070		0.471		0.282
1420	0.111	1.50	1.51	0.108	0.024	0.0071		0.565	0.024	0.302
1440	0.078	0.83	1.33	0.083	0.021	0.0064		0.472	0.017	0.213
1500	0.117	1.47	1.56	0.113	0.024	0.0109		0.550	0.021	0.311
1520	0.086	1.04	1.65	0.141	0.046	0.0088		0.529	0.028	0.338
1540	0.067	0.80	0.98	0.128	0.025	0.0086		0.482	0.022	0.279
1600	0.090	1.15	1.63	0.145	0.047	0.0184	0.0066	0.433	0.041	0.556
1620	0.081	1.05	1.59	0.142	0.109	0.0698	0.158	0.483	0.941	1.58
1640	0.081	1.06	1.44	0.136	0.042	0.0183	0.065	0.469	0.041	0.577
1700	0.063	0.75	1.38	0.111	0.135	0.0896	0.169	0.447	0.116	1.62
1720	0.094	1.17	1.53	0.147	0.109	0.0723	0.119	0.525	0.101	1.52
1740	0.076	0.94	1.39	0.133	0.069	0.0367	0.093	0.449	0.061	0.886
1800	0.054	0.58	1.28	0.115	0.051	0.0269	0.065	0.350	0.040	0.492
1820	0.051	0.57	1.56	0.110	0.178	0.140	0.201	0.449	0.086	5.91
1840	0.075	0.75	1.70	0.136	0.159	0.0444	0.069	0.513	0.070	1.09
1900	0.064	0.73	1.77	0.137	0.187	0.126	0.237	0.499	0.125	2.49
1920	0.059	0.82	1.28	0.117	0.075	0.0585	0.050	0.381	0.070	1.07

FIGURE 1

Observed Concentrations of Soluble Radionuclides in the Columbia River at Pasco Following a Fuel Element Rupture at B Reactor

FIGURE 2

Observed Concentrations of Radionuclides Associated with Particulate Material in the Columbia River at Pasco Following a Fuel Element Rupture at B Reactor

FIGURE 3

Changes in the Radioactivity Entering the Columbia River at B Reactor and Radionuclide Concentrations Arriving at Pasco, Wn. Following a Fuel Element Rupture

FIGURE 4

Columbia River Flow Rate Measured at the Priest Rapids Gauge