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GAMMA SPECTRUM, COUNT RATE, AND DOSE RATE
MEASUREMENTS ON THE COLUMBIA RIVERBANK
FROM VERNITA TO SACAJAWEA

BY

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INTRODUCTION

The purpose of this study was to evaluate radiological conditions that exist on the riverbank. Included was a comparative study of the suitability of three instruments to measure the dose rates. These instruments were a NaI (Tl) scintillation counter normally used for aerial monitoring, a bioplastic scintillation counter normally used as a road monitor, and a portable 40 liter ionization chamber normally used to measure very low gamma dose rates. The selection of representative sites for the comparative study was based on an initial GM survey of the general areas in question. Seven sites were studied--from Vernita Ferry Landing above the Hanford project to Sacajawea Park below Pasco.

SUMMARY AND CONCLUSIONS

The major contributor to the dose rates measured at the Hanford town-site location and locations downstream was Zn-65. Small additional contributions from Na-24 and Cr-51 were noted at the Hanford site. Accumulations of radionuclides were found mainly in algae, among the rocks and from native vegetation growing along the riverbank. Where the river shoreline was swept by swift current, deposition was at a minimum.

For measurement of the low dose rates encountered in this study, the NaI (Tl) scintillation counter proved to be a more practical instrument than either of the other two instruments. In addition to being more reliable and faster to read than the 40 liter ion chamber instrument, the NaI (Tl) system had a more constant dose rate conversion factor than the bioplastic crystal.

Dose rate conversion factors were calculated by comparing the readings obtained three feet above the shoreline for each of the three instruments. The average conversion factor calculated from the comparative study was 2.3×10^{-4} μ R/hr per count/minute for the NaI (Tl) scintillation counter. This factor did not vary significantly for the shoreline locations surveyed between White Bluffs and Sacajawea Park. The factor calculated for the bioplastic crystal scintillation counter varied significantly between locations surveyed.

DISCUSSION

Gamma Spectrum Measurements

Gamma spectra were measured at several locations along the riverbank to evaluate the influence of changing radionuclide composition on the dose rate. It was anticipated that the spectra would change with the distance downstream from the reactors because of decay of short-lived

radionuclides. To determine the distribution and variation in gamma activity, spectra were measured at Vernita Ferry Landing, Columbia side of Hanford Slough, Hanford Ferry Landing, Boundary Island at Ringold, Byers Landing, PRTR Inlet, Richland boat landing, across from Richland boat landing, Sacajawea boat landing, and Finley Lagoon. Nine spectrum measurements were made at each of seven sites. Spectra were taken at the surface level of the beach, three feet above the beach, and five feet above the beach at each level of wetting, in order to approximate the elevation of feet, gonads, and thyroid, respectively, of a person standing on the beach. Three locations on the beach were chosen at each site: near the maximum flood level, the maximum weekly flow level, and at the water line existing at the time of measurement. The equipment used to obtain these spectra included a Nuclear Data 256 channel analyzer, the NaI (Tl) crystal (normally a part of the Aerial Monitor), an oscilloscope, a preamplifier, a gain control box, a 900 Volt high-voltage power supply, an automatic readout typewriter, and a generator. The gain control was set to (10^{-1}) and the gain on the analyzer was set to read from 0-3 MeV over the 256 channels. Sources of monoenergetic gamma rays (Cr-51 and Zn-65) were used in the field to approximate the calibration. In most of the spectra, Cr-51 fell in channels 20-30 and Zn-65 in channels 90-100. An analysis of the spectrum of the Columbia side of Hanford Slough (Figure 1) shows a small amount of Cr-51, the positron annihilation peak for Zn-65, a wide band of low energy emitters (probably Mn-54, Mn-65, etc.), the large peak of Zn-65, (a shoulder peak to this may be Na-24 with a 1.4 MeV gamma), other background peaks of uranium and its daughters, and the Na-24 peak at 2.76 MeV. Further downstream, (Figure 2) the spectrum changes slightly. Zn-65 is still the major contributor, but the contribution of the short-lived nuclides is small.

Conversion of Count Rate to Dose Rate

The relative response of the three instruments available for measuring the low gamma dose rates occurring along the Columbia's riverbank was investigated. The 40 liter ion chamber with a portable electrometer was used to measure dose rates directly at three feet above the shoreline at seven locations. These dose rates were compared with gross gamma counting rates obtained with both the NaI (Tl) and bioplastic scintillation counters at the same positions. The relative response is illustrated in Figures 3, 4, and 5. The dose rate factor and the ratio of dose rate to counting rate for the two scintillation systems are summarized in Table I.

The average dose rate factor for the NaI (Tl) scintillation counter was 2.3×10^{-4} $\mu\text{R/hr}$ per count/minute for the six locations below the reactors. The factor obtained at Vernita Ferry was 6.2×10^{-4} $\mu\text{R/hr}$ per count/minute for this instrument. This difference in response was expected since the gamma spectrum measured above the project was that of uranium and its daughters. Since the dose rate factor is dependent upon the gamma spectrum, new factors must be determined for different

FIGURE 1

Gamma Spectrum of the Columbia Side of Hanford Slough at Three Foot Elevation

FIGURE 2

Spectrum of Sacajawea Park at Three Foot Elevation

FIGURE 3

40 ℓ Chamber Readings vs. Road Monitor Readings

FIGURE 4

40 Chamber Readings vs. Aerial Monitor Readings

FIGURE 5

Road Monitor vs. Aerial Monitor

TABLE I

RATIO OF GAMMA DOSE RATE MEASUREMENTS TO SCINTILLATION COUNTER
READINGS OBTAINED 3 FEET ABOVE THE COLUMBIA RIVER SHORELINE

<u>Location</u>	<u>40 Liter Chamber $\mu\text{R/hr}$</u>	<u>NaI Scintillation Counter</u>		<u>Bioplastic Scintillation Counter</u>	
		<u>c/m</u>	<u>$\mu\text{R/hr}$ c/m</u>	<u>c/m</u>	<u>$\mu\text{R/hr}$ c/m</u>
Vernita Ferry Landing (South Side)	15.5	2.5×10^4	6.2×10^{-4}	8.0×10^3	19.4×10^{-4}
White Bluffs Ferry Landing (South Side)	56.	2.4×10^5	2.3×10^{-4}	7.8×10^4	7.2×10^{-4}
River Side of Hanford Slough	185.	9.0×10^5	2.0×10^{-4}	3.4×10^5	5.4×10^{-4}
Hanford Ferry Landing	115.	4.9×10^5	2.3×10^{-4}	1.85×10^5	6.2×10^{-4}
Ringold	60.	2.8×10^5	2.1×10^{-4}	9.2×10^4	6.5×10^{-4}
Byers Landing	36.	1.5×10^5	2.4×10^{-4}	3.6×10^4	10×10^{-4}
Sacajawea Park	21.5	8.2×10^4	2.6×10^{-4}	2.7×10^4	8.0×10^{-4}

gamma spectra before the NaI (Tl) scintillation counter can be used. Because of the constancy of the dose rate factor below the Hanford reactors, the NaI (Tl) scintillation counter can be used for dose rate surveys between White Bluffs and Sacajawea Park.

The factors calculated for the bioplastic scintillation counter varied significantly between the locations surveyed as shown in Table I. The factor obtained at Vernita Ferry Landing was 19.0×10^{-4} $\mu\text{R/hr}$ per count/minute and varied from 5.4×10^{-4} to 10×10^{-4} $\mu\text{R/hr}$ per count/minute at downstream locations. The variance of the dose rate factor shows the bioplastic scintillation counter to be unreliable for dose rate surveys, but can be used in emergencies for a knowledge of magnitude.

Dose Rate Vs Gamma Energy

One of the objectives of this study was to determine the relative contribution of the several radionuclides on the beach to the dose rate. It proved to be impractical and unnecessary to determine the relative contribution of individual radionuclides. Instead, the gamma photon energy spectrum was converted to a dose rate-energy curve which indicated that gamma photons of about 1 MeV (most probably from Zn-65) were responsible for a large fraction of the dose rate. This observation was made for only one gamma spectrum obtained at the Columbia side of Hanford Slough.

The conversion of observed count rate to photon incidence rate is variable with energy. Conversion was made by constructing a calibration curve for the instrument using monoenergetic sources with known emission rates.

The observed count rate to photon incidence rate curve and the gamma spectrum obtained by measurement were divided into equal increments for ease of calculation. The rate of incidence of photons with the detecting crystal was used instead of actual flux per unit area, since the effective area of the crystal was unknown. The histogram showing photon incidence vs. energy was converted to the relative dose rate histogram shown in Figure 6 by dividing the photon incidence indicated for each energy band by the flux to dose rate relationship for that energy.* It is apparent from Figure 6 that no single gamma energy completely dominates the dose rate, but that gamma photons with energies over 1 MeV are far more significant than lower energy photons.

From analyses of river mud and silt and from routine analyses of river water, it can be inferred that the peak in the neighborhood of 1 MeV is due to Zn-65 which emits a 1.11 MeV photon. Some contribution was probably also made by Na-24 which emits photons of 1.37 MeV and 1.39 MeV which gives a sum peak of 2.76 MeV.

* P.H.S. Department of HEW., Radiological Health Handbook, September, 1960, pp 140.

FIGURE 6

Percentage of Total Dose Rate

SURVEYS

The following information was obtained from the initial GM survey data. The two areas where the highest counting rates were obtained with the GM meter were the river side of Hanford Slough, and the north shore at the old Hanford Ferry Landing. Readings obtained on the mossy rocks at these locations were 1000 to 3000 counts/minute with a maximum of 15000 counts/minute. Counting rates normally decreased rapidly with increasing distance and height from the shoreline. An exception was noted at Columbia side of Hanford Slough 20 yards from the shoreline. The activity level increased from 150 counts/minute at the surface to 400 counts/minute at heights of three to five feet. This increase was due to improved geometry for the gamma radiation originating at the shoreline and river. This was the only location where the activity increased with height above the surface.

Vegetation which was irrigated by the river at least once per year or which obtained water and minerals from the ground close to the river, showed a significant concentration of radionuclides. Such high concentrations were noted between Hanford and Ringold and at Ringold where activity levels ranged from 200 to 1000 counts/minute. Readings at the water's edge at Ringold varied from 1000 to 3500 counts/minute, except where a very swift current washes against the rocks. The reading at this point was approximately 600 counts/minute.

The activity level at the water's edge remained fairly constant at 1000 to 3000 counts/minute from Hanford to the 300 Area. Between the 300 Area and Richland the activity showed a steady decrease to 250 counts/minute. From Richland to Finley Lagoon the level was essentially background at 150 counts/minute.

TABLE II

Location	Waters Edge G.M. Reading in c/m			Maximum Weekly Flow Level			Maximum Flood Level		
	Surface	3 Feet	5 Feet	Surface	3 Feet	5 Feet	Surface	3 Feet	5 Feet
Hanford	3000	1000	400	800	500	400	150-200	200	300
	1000	500	500	800	400	400	200	100	100
	2000	1000	600	360	200	100	150	150	150
	2000	400	300	600	400	400	300	300	150
	2000	600	600	600	250	150	1000	500	500
	1500	400	200	1000	500	400	300	250	250
	1500	700	550	500	400	300	600	400	400
	2000	800	600	1000	400	300	300	200	150
Ringold	1000	600	500	600	250	250	300	200	200
	3000	600	500	300	300	300	200	200	200
Swift Current	600	400	300	300	200	200	250	200	200
	3500	600	400	500	300	300	200	200	200
	2500	500	400	300	300	300	200	200	200
	700	500	400	300	400	300	300	200	200
	700	400	400	400	300	250			
300 Area	1000	300	250	300	200	200	300	200	200
	800	500	400				300	200	200
Richland	250	200	150	200	150	150	150	150	150
Bateman Island	200	150	150						
Finley Lagoon	175	150	150	150	150	150	150	150	150

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