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USE OF TOTAL BETA COUNTS TO ESTIMATE GI TRACT DOSE RATES

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By

R. B. Hall

Environmental Studies & Evaluation
Radiation Protection Department

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It was the practice for several years to estimate the potential dose rate to the gastrointestinal (GI tract) from sanitary water sources by evaluating the results of radiochemical analysis of individual nuclides. The proposed method estimates the GI tract dose from Pasco and Richland domestic water from measurements of the total beta activity, and permits more frequent and more economical evaluation of a variable source of radiation exposure.

Beginning with 1964 data, the GI tract dose rate (in mrem/wk) for Richland and Pasco sanitary water has been obtained by multiplying the total beta count (in c/m per ml) by a conversion factor derived from the historical relationship between the radiochemical analyses and the total beta counts. Either the accumulation of more data or changes in the relative abundance of the more significant nuclides in the water may result in changes in this factor.

Discussion

There were three reasons behind the adoption of a new method to estimate the GI dose rate received from drinking water. First, it was known that regulation of the flow rate of the Columbia River by Priest Rapids Dam caused wide fluctuations in the concentrations of radionuclides in river water and in drinking water derived from the river. Dose estimates based on weekly and monthly radionuclide determinations could not properly take these fluctuations into account. Daily measurements of the total beta activity were being made on drinking water samples only as an indicator measurement. The fact that these measurements fluctuated by factors of two during many weeks and, occasionally by factors of 3 and 4 clearly indicated the need for a better measurement. Secondly, it appeared that since exposure to the GI tract was largely due to beta particles, a measurement of the beta activity should in some way be relatable to the GI dose rate. The third reason was an economic one. Radiochemical analyses for several nuclides are quite time consuming. Although the number of measurements being made were not adequate to take into account the fluctuations which were occurring, there was a strong economic incentive to reduce the number of measurements even further.

In the past, radiochemical analyses of drinking water samples were compared to the MPC values to obtain GI dose rate estimates. Samples were taken weekly at Pasco, biweekly at Richland and monthly at Kennewick. In addition, daily samples on which only a total beta activity measurement was made were taken at all three cities. The beta count rate was converted to picocuries by a tedious process relating the count rate to the relative abundance of individual nuclides present.

The method adopted as a result of this study estimates the GI dose rate from the daily total beta count rate measurements. Monthly measurements of the abundance of individual nuclides are made to maintain a check on the continued validity of the method.

Total beta determinations are made on evaporated samples counted in a proportional counter. The count rate from this instrument depends upon the relative abundance of the several nuclides present, weighted according to the energy of the beta particles emitted and the number of beta emissions per disintegration. The weighting of each nuclide that inherently occurs during the beta proportional count resembles the weighting given mathematically in the calculation of the MPC. For this reason, it was felt that the raw count would be more apt to be proportional to the GI tract dose rate than a count corrected to represent the total activity present. To test this proportionality, the counting efficiency of the proportional counter for the nuclides of greatest significance was compared to the GI dose rate per unit concentration derived from the MPC. The results of this comparison are shown in Table 1. It is apparent that the weighting listed in the right hand column is not uniform for all nuclides present, especially zinc-65 and arsenic-76. The relative abundance of the several nuclides is shown in Figure 1 where it can be seen that the amounts of those nuclides which have dose rate to count rate ratios greatly different from 0.1 (Zn-65, As-76, and RE + Y) is less than 10% of the total activity.

TABLE 1

CALCULATED RELATIONSHIP BETWEEN BETA COUNTS AND DOSE RATES

Nuclide	MPC GI (pc/ml)	Dose Rate per Unit Concentration (1) (mrem/wk)/(pc/ml)	Counter Efficiency Factor (2) (d/m)/(c/m)	Ratio of Dose Rate to Count Rate (mrem/wk)/(c/m/ml)
RE + Y	400	0.4	2.00	0.36
Na-24	2,000	0.8	1.74	0.063
P-32	900	0.18	1.79	0.14
Cr-51	20,000	0.008	28.0	0.10
Cr-64	3,000	0.053	4.38	0.10
Zn-65	2,000	0.080	20.8	0.75
As-76	200	0.8	1.81	0.65
Np-239	1,000	0.16	1.75	0.13

(1) Assumes a dose rate of 160 mrem/wk would result from consumption of 1.2 liters per day of water containing a MPC concentration of the nuclide listed in column 1.

(2) Applicable only to the particular counting equipment and procedures used by Battelle-Northwest and United States Testing Company laboratory at Hanford for counting beta activity in water samples. Assumes 10 mg precipitate weight.

A determination of a factor to convert the beta count rate to a dose rate was made for each sample for which both the beta count rate and individual nuclide determinations had been made. The results are summarized in Tables 2, 3, and 4.

The randomness of the ratios of dose rate to beta count rate can be affected in two ways. Statistical errors in both beta counting and the determination of the concentrations of individual nuclides become greater as the total count becomes low. Inspection of the data doesn't indicate that this is a major factor. The more important influence seems to be variation in the relative isotopic abundance. Some variation occurs in the reactor effluent water at the time of release of these nuclides to the river. In addition, the half-lives of most of the nuclides are short which means that the amount each nuclide contributes to the beta count varies with changes in decay time (the number of hours between the time of release to the river and the time of delivery to the drinking water system). Variations in elapsed time result from varying river flow rates and differing residence times within the water treatment plants.

A geographic separation of about 12 river miles between Richland and Pasco is at least partially responsible for the differences in activity which can be seen in Figure 1.

The assumptions used by the ICRP [1] in the derivation of MPC values did not justify expression of the MPC's to more than one digit. The same

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(1) "Report of ICRP Committee II on Permissible Dose for Internal Radiation (1959), with Bibliography for Biological Mathematical and Physical Data," Health Physics. Vol. 3, pp 1-380. 1960.

applies to the derivation of the MPC value for the RE + Y mixture which was derived at Hanford.(2) Although two digits were used throughout this evaluation, probably only one was justified.

TABLE 2

PASCO SANITARY WATER

Date		Total Beta c/m/ml	GI Dose Rate * mrem/wk	Ratio of GI Dose Rate to Total Beta
Jan.	7	3.7	0.63	0.17
	13	3.9	0.38	0.10
	20	3.4	0.47	0.14
	27	2.6	0.38	0.15
Feb.	3	4.3	0.54	0.13
	10	3.1	0.43	0.14
	17	4.1	0.44	0.11
	24	2.2	0.30	0.14
March	9	2.9	0.49	0.17
	23	3.1	0.38	0.12
April	13	8.8	0.80	0.09
	27	5.9	0.62	0.11
May	11	6.3	0.84	0.13
	25	1.9	0.35	0.18
June	8	2.3	0.27	0.12
	22	1.8	0.16	0.09
July	13	1.8	0.16	0.09
	27	1.7	0.17	0.10
August	10	3.7	0.43	0.12
	24	3.3	0.63	0.19
Sept.	28	5.1	0.45	0.09
Oct.	26	2.3	0.32	0.14
Nov.	2	2.3	0.15	0.07
	30	1.8	0.16	0.09

* Based on determination of the concentration of individual nuclides.

(2) M. W. McConiga, Unpublished Data, General Electric Company, Richland, Washington, September 1, 1960 (Internal Report, Confidential).

TABLE 3

RICHLAND SANITARY WATER

Date		Total Beta c/m/ml	GI Dose Rate * mrem/wk	Ratio of GI Dose Rate to Total Beta
Jan.	6	14	1.8	0.13
Feb.	3	13	1.5	0.12
March	2	10	1.0	0.10
	16	9.5	0.98	0.10
April	20	14	1.6	0.11
May	4	15	1.4	0.09
	18	8.8	0.96	0.11
June	1	6.7	0.63	0.09
	15	3.8	0.27	0.07
July	6	4.0	0.35	0.09
	20	3.0	0.24	0.08
August	3	6.1	0.48	0.08
	17	8.1	0.77	0.10
Sept.	21	10	1.2	0.12
Oct.	19	6.0	0.69	0.12
Nov.	2	6.9	0.75	0.11
	30	15	1.4	0.09

* Based on the determination of the concentration of individual nuclides.

TABLE 4

KENNEWICK SANITARY WATER

Date		Total Beta c/m/ml	GI Dose Rate * mrem/wk	Ratio of GI Dose Rate to Total Beta
Jan.	20	0.65	< 0.10	-
Feb.	24	0.59	< 0.15	-
March	30	0.48	< 0.09	-
April	27	0.95	0.16	0.17
May	25	0.64	< 0.09	-
June	29	0.14	< 0.06	-
July	27	0.31	< 0.06	-
August	31	0.37	< 0.07	-
Sept.	29	0.48	0.06	0.12
Oct.	26	0.46	< 0.07	-
Nov.	16	0.45	0.10	0.22

* Based on the determination of the concentration of individual nuclides.

Kennewick water is obtained from horizontal wells under the river bed. This system removes radionuclides so effectively that the concentrations of those nuclides which were important to the estimation of the GI tract dose rate were often below detection levels. No satisfactory evaluation was possible with available data and the low level of exposure estimated for Kennewick water users did not justify the additional effort to provide suitable data.

Analysis of Data

The relationship between the total beta measurement (c/m/ml) and the dose rate to the GI tract (mrem/wk) was analyzed. Linear coefficients were determined by the least squares method using a linear model, and Richland and Pasco data were treated separately. From that analysis it was found that at neither location did the 90 per cent confidence interval include the origin. Correlation coefficients were then determined using linear models which did pass through the origin. Since the range of overlap of the 90 per cent confidence intervals for the linear models for the two locations included most of the region of interest, the data were pooled. The model for the pooled data was found to pass through the origin, and this model was used although analysis of variance indicated that Pasco and Richland were different. Table 5 shows the factors and variance for the three cases, and Figure 2 shows the regression plots and the accepted conversion factor.

TABLE 5

CONVERSION FACTOR
BETA COUNT RATE TO GI DOSE RATE

Location	mrem/week / c/m per ml	
Richland	0.11 ± 0.01	(90% Confidence Interval)
Pasco	0.12 ± 0.01	(90% Confidence Interval)
Pooled Data	0.11 ± 0.01	(90% Confidence Interval)

In spite of all the possible reasons for error, the variance was found to be very small. Since the dose rates normally encountered averaged about 50 mrem per year at Richland, a precision of 25 per cent or 12.5 mrem per year at the 90 per cent confidence level would have been considered acceptable. The data proved to be in better agreement than required, (~10% precision) and the decision was made to use the factor of 0.11 with beta counts at all locations rather than individual nuclide determinations to estimate the GI tract dose rate.

Limitations

Two limitations are immediately apparent. The factor derived applies only to beta counts made by the same counting procedures used for this analysis since the conversion factor is dependent upon the detection efficiences for the several nuclides which contribute to GI dose. In addition, changes in relative abundance of nuclides, particularly an increase in zinc-65 or arsenic-76 would alter the conversion factor. Because changes in relative abundance occur frequently, Figures 3 and 4 were plotted to show that this influence is normally acceptably small.

Acknowledgement

The assistance of associates in Environmental Studies and Evaluation Section is gratefully acknowledged. The contribution of J. P. Corley to the statistical evaluation was especially helpful.

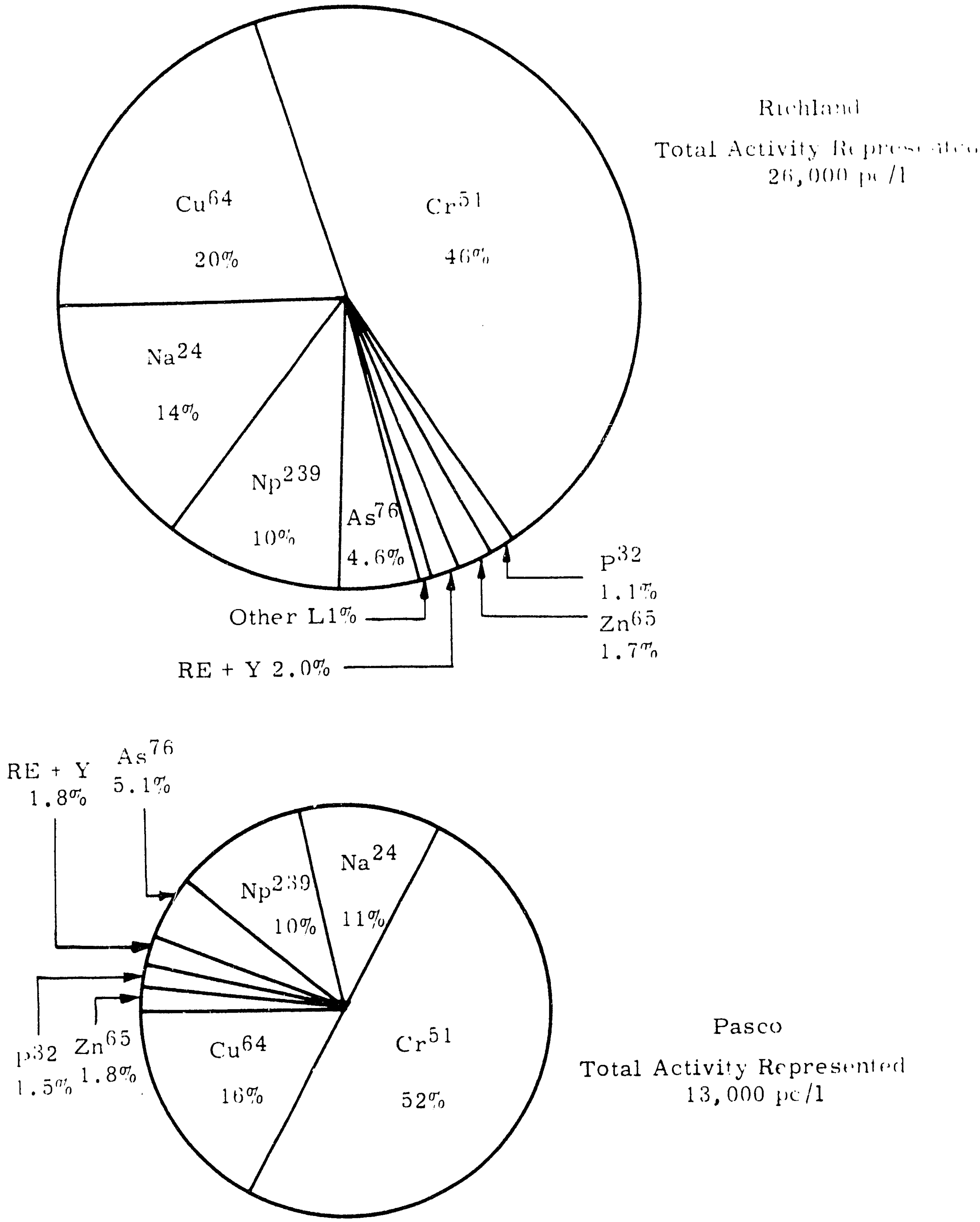


FIGURE 1

Relative Abundance of Radionuclides in Richland and Pasco Drinking Water - 1964

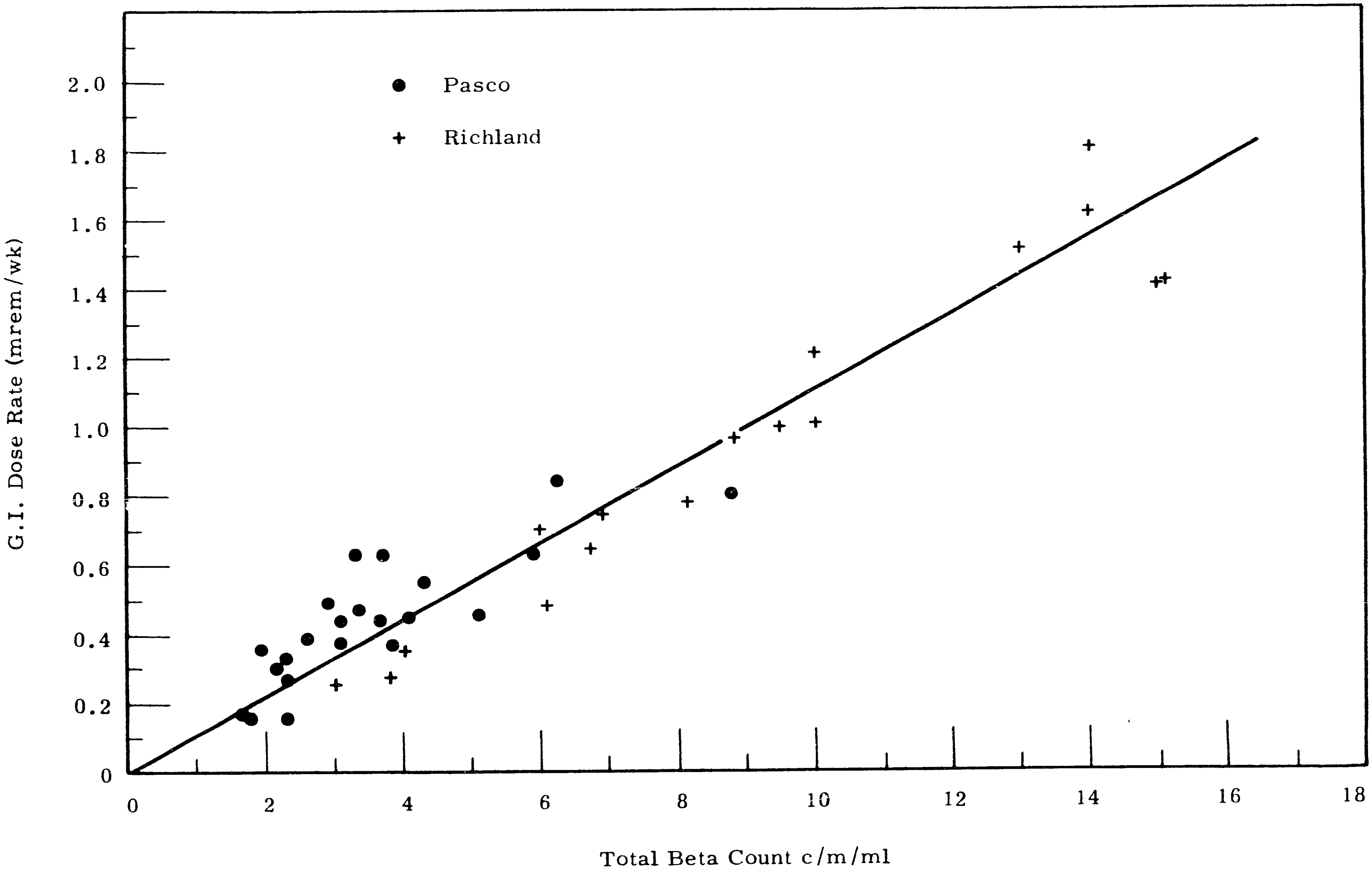
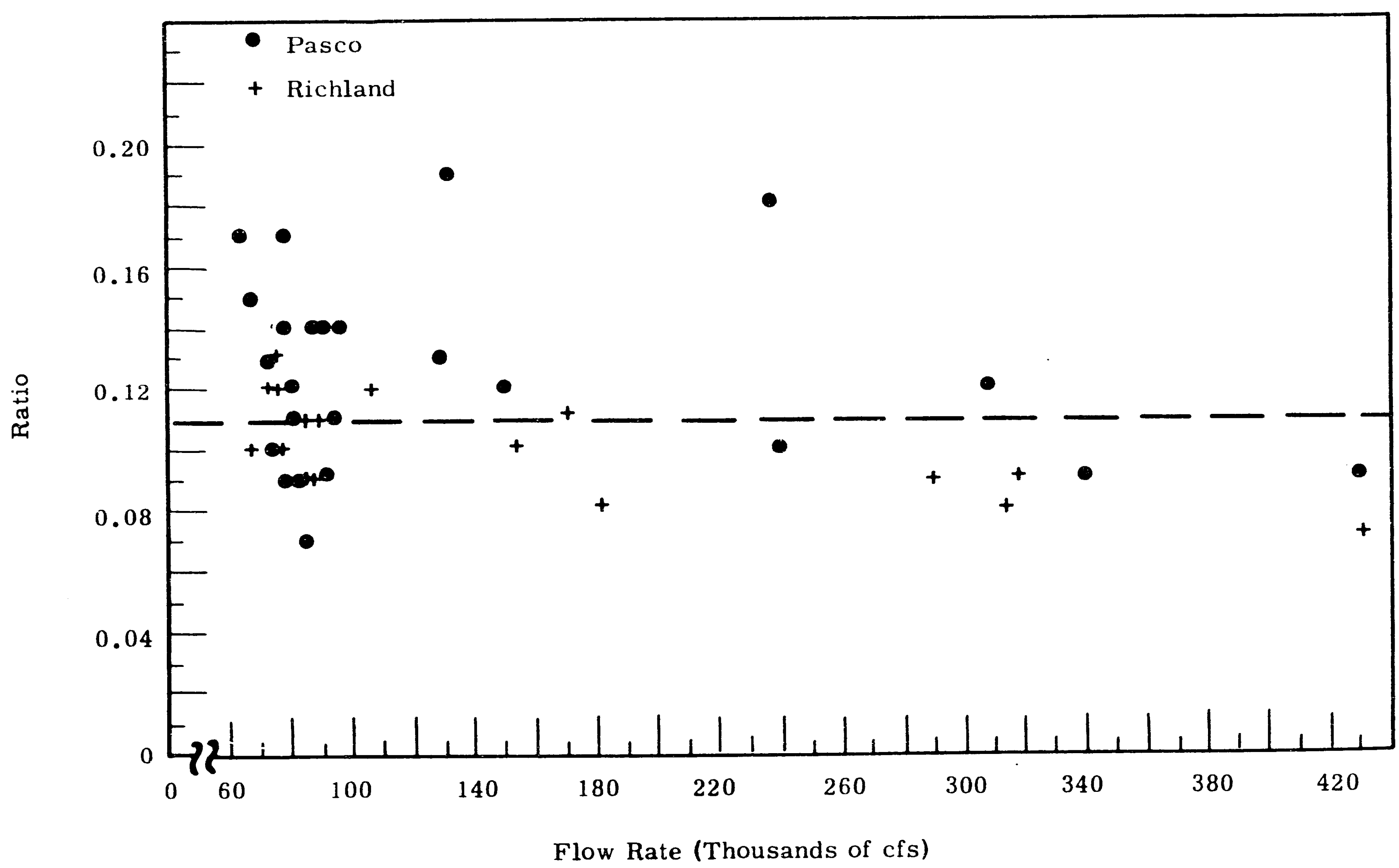


FIGURE 2

Regression Plot
Beta Count vs G.I. Dose Rate



<u>FIGURE 3</u>

Ratio $\frac{\text{G.I. Dose Rate}}{\text{Total Beta}}$ vs River Flow Rate

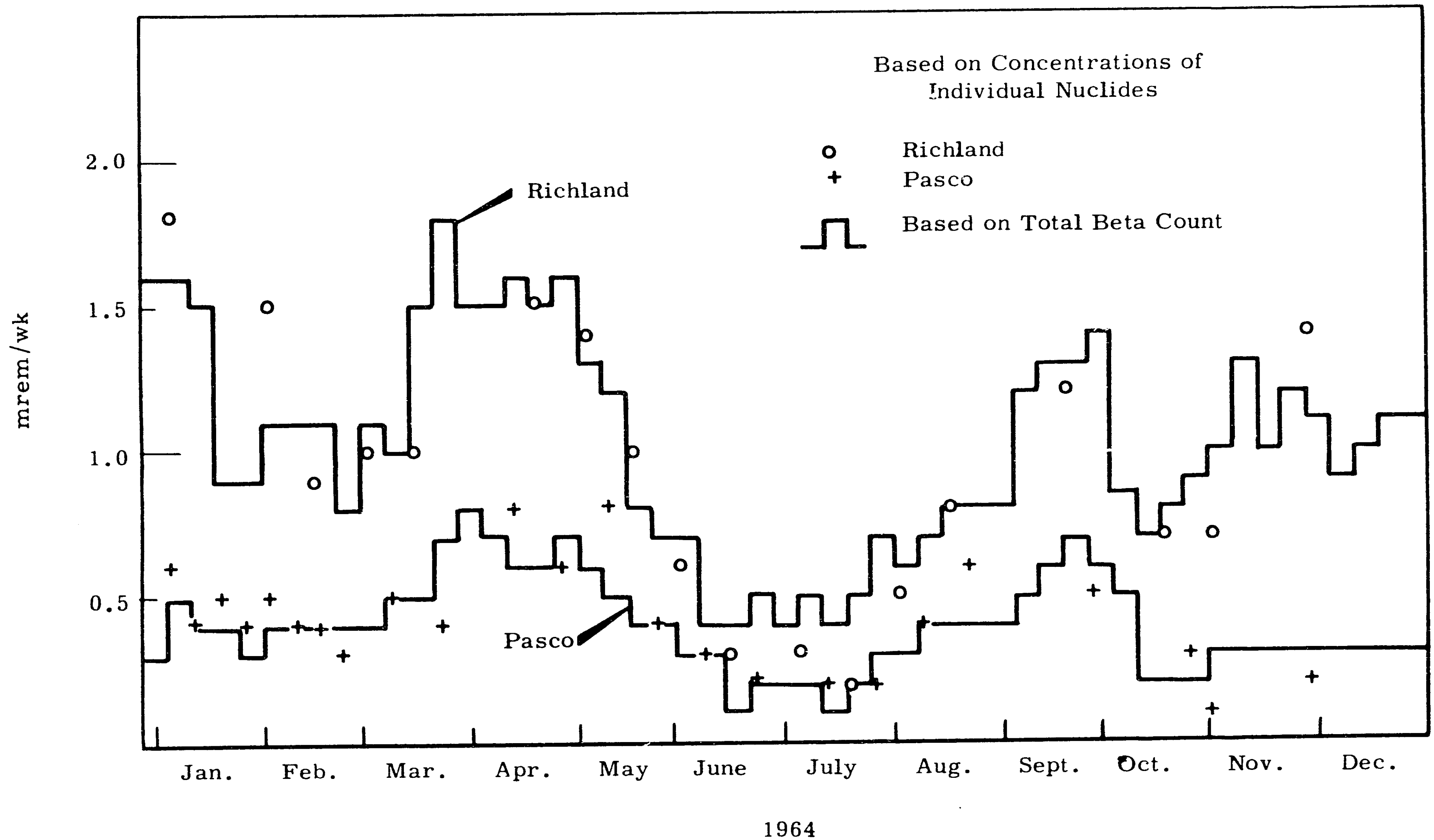


FIGURE 4

Dose to G.I. Tract from Drinking Water

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