

Determination of the Gross Gamma Radioactivity of Indiana Soils by Large Volume Liquid Scintillation Counting

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Introduction

A portion of the normal background radiation dose to which man is exposed is due to radioactivity in the earth's crust. This radioactivity is due in part to the presence of natural radioactive substances of the uranium and thorium series and in some cases carbon-14 and potassium-40 (2). Atmospheric testing of nuclear weapons over the past decade has resulted in the deposition of fallout fission products in soils. Of particular concern in the latter case has been the possible entrance of these radioactive materials into the food cycle and eventually into man.

Previous studies (1) have shown that typical Indiana soils (Plainfield sand, Clearmont silt loam, Crosby silt loam and Zanesville silt loam) contain an average of 2.73×10^{-3} g uranium per kg soil, 6.2×10^{-3} g thorium per kg soil, and 14.0 g potassium per kg soil (of which about 1.7×10^{-3} g is the potassium-40 isotope). In addition to these natural constituents, the long-lived gamma emitters cesium-137, ruthenium-106, and cerium-144 have been identified in amounts of the order of 10^{-10} to 10^{-9} curies per kg (1).

The increased use of power reactors with the potential of accidental release of radionuclides to the environment, together with the possibility of future resumption of nuclear weapons testing, suggest that it would be prudent to develop methods for rapidly measuring large numbers of soil samples for gross activity. This would be particularly important in our nation's farmlands and agricultural areas. Furthermore, it is desirable to know the extent of natural radioactivity in soils so as to provide a reference point for evaluating increases.

In this study, samples of Indiana soil, collected prior to resumption of weapons testing in 1961, were examined for gross gamma radioactivity by means of a large volume liquid scintillation counter. The technique is both rapid and sensitive, and would lend itself quite well to a large scale monitoring program.

Method of Sample Collection

The samples studied represented soils submitted from 2153 farm fields in 63 counties throughout the State of Indiana.¹ Samples were collected by the individual farmers who were instructed to sample as follows:

1. Use a sampling tube, auger, or spade.
2. Get 10 or more equal sized cores or slices from the surface to plow depth (6-8 inches) except permanent pastures (2-3 inches).

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3. Place cores or slices in a clean pail and mix thoroughly.
4. Spread mixture on a clean paper to air dry. Do not heat.
5. Fill sample carton (supplied) with the air-dried mixture.
6. Number the sample and mark its location on the field map.

The samples from each field, which averaged about 200 g each, were pooled by counties and thoroughly mixed. From the mixed sample, a representative 1000 gram portion was taken for the gross activity determination.

Instrumentation

The 1000-gram samples from the various counties were placed in quart size ice cream cartons² and introduced into the 8 inch long by 4 inch diameter sample chamber of the Purdue Small Animal Counter (PUSAC). This counter, a large volume liquid scintillation counter, has been described in detail by Dunavant and Christian (3). Briefly, PUSAC was a 4 pi system consisting of an annular tank 8 inches long and 16 inches in diameter with a central sample chamber. The tank was filled with approximately 23 liters of a scintillator solution (p-terphenyl and POPOP in toluene). Four 5-inch Dumont 6364 photo-multipliers were mounted symmetrically about one end of the tank. Shielding was accomplished by means of a cylindrical rolled iron shield 5 inches thick completely surrounding the scintillator tank.

A voltage distribution panel permitted separate adjustment of the individual high voltages on each photo tube. The tube anodes were connected in parallel and the output pulse fed to a preamplifier, an amplifier, a single channel analyzer, and a scaler respectively.

The instrument was operated in the integral counting mode with the base discriminator set at zero and the gain at 1/16. These settings permitted spanning essentially the full energy spectrum giving maximum counting efficiency.

All samples were counted for 4 minutes (four 1-minute counts) preceded and followed by two 1-minutes background counts. The backgrounds were obtained by using a mock soil blank of pure sugar in the chamber so as to eliminate any need to consider background reduction corrections due to sample mass.

For purposes of calibration, a vial containing 1 ml of a 920 gamma/sec/ml standard cesium-137 solution³ was imbedded in the center of one of the cylindrical cartons filled with pure sugar as an absorbing medium. Gross gamma counting efficiency was determined by comparing the observed count rate with the known disintegration rate of the standard. For the system as described, the counting efficiency for gammas was 33.4%.

Results and Discussion

Results for the samples studied are tabulated in Table 1 by counties. The average gross gamma activity for all counties was 4.6 picocuries per gram. The highest individual sample observed was 5.9

² Standard Package Corporation, Serial FC-1.

³ Prepared from Nuclear Chicago Model RS-137 radioactive standard solution.

TABLE 1
Gross Gamma Activity of Indiana Soils

County	Sample Wt. (grams)	Net Counts/min	pc/g
Adams	1000.00	4174	5.6
Allen	1012.50	3869	5.2
Bartholomew	1055.70	3039	3.9
Benton	971.37	3512	4.9
Blackford	1017.60	4218	5.6
Carroll	1111.22	3988	4.8
Cass	1000.00	3114	4.2
Clinton	1033.20	4044	5.3
Davies	1000.00	2673	3.6
Decatur	1034.00	3751	4.9
Dekalb	1000.00	3473	4.7
Delaware	1057.60	3965	5.1
Elkhart	1000.00	2679	3.6
Fayette	988.20	3675	5.0
Floyd	1000.00	3635	5.0
Fountain	1003.90	3879	5.2
Franklin	1000.00	3827	5.2
Fulton	1013.20	1974	2.6
Gibson	1000.00	3997	5.4
Grant	910.00	3908	5.8
Hamilton	1056.90	3565	4.5
Hancock	1035.70	3764	4.9
Henry	1000.00	3723	5.0
Howard	1124.52	4566	5.5
Huntington	1046.90	3972	5.1
Jackson	1038.00	3714	4.8
Jasper	1053.90	1970	2.5
Jay	1030.40	4510	5.9
Johnson	1000.00	3542	4.8
Knox	1000.00	2777	3.8
Kosciusko	1049.80	2483	3.2
Lake	1000.00	3408	4.6
LaPorte	1022.80	2571	3.4
Lawrence	1000.00	3703	5.0
Madison	1015.40	4105	5.5
Marion	1000.00	3552	4.8
Marshall	1123.60	2700	3.2
Miami	1044.40	3126	4.0
Montgomery	1000.00	3084	4.2
Morgan	1000.00	3464	4.7
Newton	1000.00	2668	3.6
Nobel	994.40	2738	3.7
Parke	1045.20	3717	4.8
Porter	1021.70	3296	4.4
Posey	1052.90	3925	5.0
Pulaski	1041.60	1906	2.5

County	Sample Wt. (grams)	Net Counts/min	pc/g
Putnam	1021.90	3841	5.1
Randolph	1032.50	4248	5.5
Ripley	1000.00	3699	5.0
Rush	1041.10	3879	5.0
Shelby	1005.50	3572	4.8
Steuben	1000.00	2049	2.8
Sullivan	1045.80	3730	4.8
Tippecanoe	1077.95	3357	4.2
Tipton	1102.88	4325	5.3
Vanderburg	1000.00	3782	5.1
Vermillion	1052.00	3335	4.3
Wabash	947.70	3444	4.9
Warren	1000.00	3898	5.3
Wayne	998.90	3600	4.9
Wells	1000.00	4157	5.6
White	1113.64	2778	3.4
Whitley	1000.00	3480	4.7
Average:			4.6

picocuries per gram for Jay County, while the lowest was 2.5 picocuries per gram for both Jasper and Pulaski Counties.

Based on the statistical counting errors for four-minute sample counts and four-minute backgrounds, the precision of the method was calculated to be ± 0.08 picocuries per gram.

The technique of determining the gross radioactivity in environmental samples by large volume liquid scintillation counting is both rapid and sensitive. Sample handling and processing is minimized, and no chemical treatment or manipulation is required. The method should prove useful for large scale environmental monitoring programs where rapid evaluation of gross activity is required.

Literature Cited

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