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Studies of Long-Term Ecological Effects of Exposure to Uranium IV

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Studies of Long-Term Ecological Effects of Exposure to Uranium IV

Gary C. White
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Wayne C. Hanson*

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Research performed by the Los Alamos Scientific Laboratory for the Air Force Armament Laboratory, Eglin Air Force Base, Florida, is reported. The phoswich portable survey instrument was evaluated as a uranium field-survey instrument and seems to be useful for double sampling as well as for the quick field surveys for which it was originally designed.

Three methods used to measure uranium concentrations in soils were also compared. Eglin personnel have determined approximate concentrations by

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CONTENTS

ABSTRACT 1

I. INTRODUCTION 1

II. EVALUATION OF THE PHOSWICH PORTABLE SURVEY INSTRUMENT . . . 2

III. ANALYTICAL PROCEDURES DEVELOPMENT FOR DETERMINATION OF URANIUM IN SOILS 3
- A. Analytical Procedures 3
- B. January 5, 1978, EAFB Soil Samples 4
- C. May 5, 1978, EAFB Soil Samples 4
- D. August 21, 1978, EAFB Soil Samples 6

IV. SUMMARY AND CONCLUSIONS 6

ACKNOWLEDGMENTS 7

REFERENCES 9

APPENDIX 10

DISTRIBUTION 13

STUDIES OF LONG-TERM ECOLOGICAL EFFECTS OF EXPOSURE TO URANIUM IV

by

Gary C. White, Ernest S. Gladney,
Kenneth V. Bostick, and Wayne C. Hanson

ABSTRACT

Research performed by the Los Alamos Scientific Laboratory for the Air Force Armament Laboratory, Eglin Air Force Base, Florida, is reported. The phoswich portable survey instrument was evaluated as a uranium field-survey instrument and seems to be useful for double sampling as well as for the quick field surveys for which it was originally designed.

Three methods used to measure uranium concentrations in soils were also compared. Eglin personnel have determined approximate concentrations by analyzing soils in an ND-100 gamma counter. Thermal-neutron-induced delayed neutron activation and instrumental epithermal neutron activation analysis are the methods used at the Los Alamos Scientific Laboratory. Comparison of the three analytical techniques indicates differences; only part of the lack of agreement is explainable by the heterogeneity of aliquots taken from the same soil sample. There seems to be a basic difference in what each of the three techniques measures.

I. INTRODUCTION

This report summarizes results from October 1, 1977, through September 30, 1978, of research performed by the Los Alamos Scientific Laboratory (LASL) for the Air Force Armament Laboratory, Eglin Air Force Base (EAFB), Florida. Included are (1) an evaluation of the phoswich portable survey instrument as a uranium field-survey instrument, (2) analytical results from three sets of soil samples from test ranges at EAFB; and (3) a comparison of three different analytical techniques used for uranium determinations.

The general scope and objectives of this study and the site descriptions were presented in the 1976 and 1977 completion reports.[1-5] Objectives of the research efforts reported here were:

(1) to determine if the phoswich portable survey instrument is useful for *in situ* measurement of uranium in soil, and
(2) to evaluate three analytical techniques currently used to determine uranium concentrations in soil.

This research has application to field situations where substantial amounts of uranium have been released to the environs.

II. EVALUATION OF THE PHOSWICH PORTABLE SURVEY INSTRUMENT

The standard instrument for the field detection of low-energy photons such as those emitted from uranium has been the FIDLER (Field Instrument for the Detection of Low-Energy Radiation).[4] However, Compton events from high-energy photons are a major source of detector background and place relatively high limits on the detectability of low-energy events.

We are pursuing a possible solution to this problem by using a phoswich low-energy photon detector, which is designed to compensate for high-energy photon interference (Fig. 1). The phoswich detector is composed of a sandwich of two different scintillator crystals coupled to a single photomultiplier tube.[5] Because of differences in the absorption characteristics of the two crystals, it is possible to differentiate between desired low-energy events that stop only in the front thin crystal and those events, though similar in energy, that arise through other processes (such as Compton scattering) and deposit energy in both crystals. The detector used in this work has a NaI(Tl) crystal face, 1 mm thick, and a CsI(Na) back, 38 mm thick. The detector has a face surface area of 9216 mm^2, and thus integrates over this area. The instrument emits an audible "beep" for each photon absorbed *only* in the NaI portion of the detector. The frequency, or pitch, of the beep is a function of the count rate, hence facilitating qualitative surveys without constant operator attention to the count-rate meter or digital readout.

Fig. 1.
The phoswich portable survey instrument, which measures 30 by 8 by 8 cm and weighs 3 kg.

The E-F Firing Site at LASL was resampled with the phoswich survey instrument at the same locations that were sampled in the 1976 soil uranium field survey.[2] The initial sampling grid was systematically placed on a polar coordinate system radiating from the detonation point every 45°, with concentric circles at 10, 20, 30, 40, and 50 m from the detonation point. Count time for the phoswich was 500 s, and background was determined from an uncontaminated soil sample from the same soil type.

Soil samples collected on the grid system during the 1976 uranium survey at E-F Site were obtained with a polyvinylchloride coring tube with a 2.5-cm inside diameter. Uranium concentrations were determined by fluorometric analysis.[6-8]

The correlation between the phoswich measurements and the uranium concentrations in the 0- to 2.5-cm-depth soil samples taken in 1976 was excellent (Fig. 2), with $r = 0.95$ ($P < 0.0001$) even though the respective measurements were taken 2 years apart. Changes in the distribution of uranium during the interval between samplings must have been minor relative to the total inventory of uranium in the soil.

One practical application of the relationship between the phoswich counts and the uranium concentration in the soil cores is in double sampling[9] to reduce the cost of a field survey. Field measurements of uranium with the phoswich survey instrument are less expensive than those obtained by the collection and subsequent analysis of samples by chemical methods. Thus, a less expensive and labor intensive sampling scheme can be developed by taking a large number (n') of phoswich counts (x_i, with mean $\overline{X}$) along with a much smaller number of samples (n) where both soil cores (y_i) and phoswich

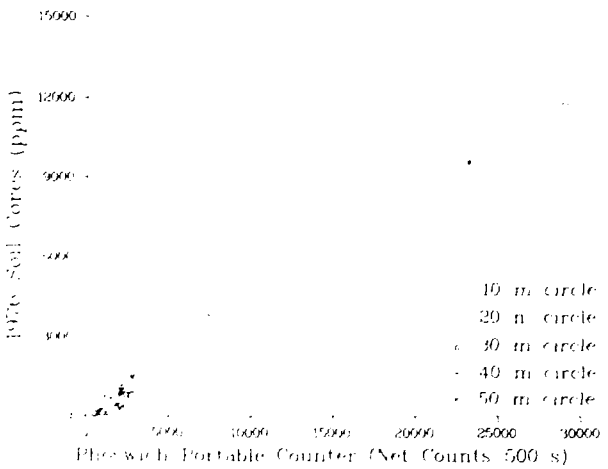

Fig. 2.
Uranium concentrations in the 0- to 2.5-cm-depth segment from the 1976 E-F Site soil survey plotted with the 1978 phoswich portable survey instrument results.

counts are made. (The phoswich counts are termed an auxiliary variable, because they are less expensive to acquire.) The phoswich counts are then used to make a regression estimate of $\overline{Y}$, or the mean uranium concentration, with regression coefficient B.

Assume as a model,

$$y_i = \overline{Y} + B(x_i - \overline{X}) + e_i \ ,$$

where, for fixed x_i, the random variate e_i follows a frequency distribution with mean 0 and variance $S_e^2 = S_y^2 (1 - \rho^2)$. Here, S_e^2 is the variance of e_i, S_y^2 is the variance of y_i, and ρ^2 is the squared correlation coefficient of the y_i and x_i.

In the above equation, a nonzero intercept was assumed because the phoswich instrument may measure other radionuclides present at background levels. Thus, we do not want to assume that a plot of uranium concentration versus phoswich counts passes through the origin until this assumption has been tested with the data. Additionally, we assumed that a linear relation exists over the range of soil concentrations encountered. At very high uranium concentrations, the phoswich counter may not record counts fast enough to provide an accurate reading. Such concentrations are not expected in soil samples.

The regression estimate of mean uranium concentration is

$$\bar{y}_e = \bar{y} + b(\bar{x}' - \bar{x}) \ ,$$

where $\bar{x}'$ and $\bar{x}$ are the means of x_i in the first and second samples, respectively, and b is the least squares regression coefficient of y_i on x_i, computed from the second sample. We are interested here in assessing the validity of the linear regression relating uranium concentration to the phoswich counts. The regression line fitted to the data in Fig. 2 is

$$y_i = -71.57 + 0.3963x_i + e_i \ .$$

The intercept in the above equation is not significantly different from zero (P = 0.33), indicating that a regression through the origin is adequate.

An important question is whether the data from E-F Site used to construct this regression equation are adequate for EAFB uranium contamination areas. Soil uranium concentrations at EAFB are much lower than those observed at E-F Site and are mostly due to depleted uranium on those test ranges of greatest interest. Also much of the observed correlation of the phoswich counts and soil cores in Fig. 2 is due to the four samples with high uranium concentrations. The rest of the samples seem to have much more scatter relative to the range in concentrations. Thus, more data need to be collected at the concentration levels observed at EAFB.

A possible drawback of the phoswich field instrument is that its response seems to be a function of air temperature; that is, the counting efficiency of the instrument is slightly affected by the ambient air temperature. We have initiated studies in an environmental chamber to calibrate the instrument's counts as a function of ambient temperature.

III. ANALYTICAL PROCEDURES DEVELOPMENT FOR DETERMINATION OF URANIUM IN SOILS

A. Analytical Procedures

Analytical results for three sets of EAFB soil samples are presented in the Appendix as Tables A-I, A-II, and A-III. The samples were collected by EAFB

personnel as a part of test range cleanup operations or other activities. Our interpretation is limited to the analytical characteristics of the data.

Three methods have been used to measure uranium concentration in soil. EAFB personnel have determined approximate concentrations by analysis in an ND-100 gamma counter* (denoted as "EAFB method" in this report). Thermal-neutron-induced delayed neutron activation (DNA) and instrumental epithermal neutron activation analysis (IENA) were the methods used at LASL. Two-gram aliquots of EAFB soil samples were randomly selected and submitted for IENA and DNA analyses.[4,10] We have taken the following brief descriptions of these methods from Hanson and Miera.[8]

In the IENA analysis, samples were first irradiated for 2 min with epithermal neutrons in the energy range 280 to 1000 eV. After a decay time of 2 to 4 days, each sample was counted for 5 min on a large Ge(Li) detector. The 228- and 278-keV transitions from the decay of ^{239}Np (half-life 2.35 days) were observed and used for quantitative analysis. The gamma-ray spectra were accumulated on a pulse-height analyzer and output on computer-compatible magnetic tape for off-line data reduction. International Atomic Energy Agency (IAEA) soils with certified uranium concentrations were used to standardize the analyses.

DNA measurements were performed on each sample by irradiating the sample for 20 s in a thermal-neutron flux. Irradiations were made at different reactor power levels, but for each, the thermal-neutron flux was monitored during the exposure by a fission ion chamber. The sample was pneumatically transferred to a neutron counter of 27% efficiency and counted for 20 s following a 10-s delay. The neutron data were normalized to a constant flux. The system was calibrated to samples of NBS SRM-1633 (fly ash) of certified uranium concentration. Uranium concentrations were calculated with the assumption that the ^{238}U was in normal crustal abundance.

IENA measured only ^{238}U. However, for uranium occurring in crustal abundance, ^{238}U makes up 99.3% of the total uranium present. In contrast, DNA measures only ^{235}U, which makes up 0.7% of crustal abundance. Therefore, when measuring uranium depleted in ^{235}U, the DNA method seriously underestimates the total uranium in the sample. However, the ratio of the uranium concentrations obtained by the two methods (DNA/IENA) is useful to indicate the presence of depleted or enriched uranium. This ratio should equal 1 if no depleted or enriched uranium is present.

*Nuclear Data, Inc., Schaumberg, IL 60172.

B. January 5, 1978, EAFB Soil Samples

The data in Table A-I were obtained from seven soil samples collected on the Air Force Development and Test Center (ADTC) Range 74-L on 5 January 1978, and two control samples collected off the Range. LASL analyses were conducted on three 2-g aliquots taken from each sample. Control samples were analyzed by DNA and agree well with the Eglin gamma-counting method. The samples from ADTC Range 74-L were analyzed for uranium by IENA and the data agreement between laboratories is only fair. The instances of wide differences (samples 1-1, 1-7, and 2-2) probably reflect aliquoting problems in a sample where the uranium is not well mixed.

C. May 5, 1978, EAFB Soil Samples

The data in Table A-II are from 34 soil samples collected 5 May 1978 on Range 74-L. LASL DNA analyses were conducted on three 2-g aliquots taken from each sample, but IENA analyses were conducted on only one 2-g aliquot. Summary statistics and correlations between the three different analyses are presented in Table I, and the data are plotted in Figs. 3-5.

The correlations in Table I are highly significant but do not test the hypothesis that any two methods are actually measuring the same thing. For example, suppose method y and method x are related by $y = bx$. If both x and y are observed without error, then the correlation between them is 1. Likewise, suppose $y = a + x$. Again the correlation between y and x is 1. In both cases, however, method y and method x are not measuring the same quantities, because the two concentrations differ by a constant multiplier or an additive constant.

All three figures suggest that the linear function relating the two plotted variables passes through the origin, and this was further verified by linear regression tests for nonzero intercepts. (That is, all three

TABLE I

SUMMARY STATISTICS AND CORRELATION MATRIX FOR THREE METHODS OF MEASURING URANIUM CONCENTRATION IN SOIL FROM 5 MAY 1978, RANGE 74-L SAMPLES

Statistic	EAFB	IENA	DNA
n	34	34	34
Mean, x	80.7	55.4	12.2
Standard Deviation, s	126.6	89.0	21.2
Coefficient of Variation, s/x̄	1.6	1.6	1.7
Median	22.0	10.1	2.2
Minimum	0.5	0.0	0.7
Maximum	443	370	99
Range	42.5	370	98.3

Methods	Correlation	Significance
EAFB with IENA	0.90	<0.001
EAFB with DNA	0.94	<0.001
IENA with DNA	0.92	<0.001

tests accepted the null hypothesis of zero intercepts.)

Note in Figs. 3-5 that the three methods appear to be measuring different quantities because the slope of a linear function through the origin is not 1. We have compared the three sets of ratios (IENA/EAFB, DNA/EAFB, and IENA/DNA) against 1 with the Wilcoxon signed rank test[11] as a means of statistically testing for differences in the three analytical methods. If each technique is measuring the same quantity, then the ratio of the two analyses for a particular sample should be close to 1; that is, $y_i = x_i$, or $y_i/x_i = 1$. Because of randomness, the ratio will not be exactly 1, and thus a statistical procedure is required to determine if the ratio differs significantly from 1. The Wilcoxon signed rank test provides the probability of observing a sample with as many values less than (or greater than) 1, giving each value a weight based on its rank. For example, in Table II we see that for the ratio IENA/EAFB, 26 of the 34 samples were less than 1. If the expected ratio was really 1, the probability of observing this many values less than 1 is 0.008. Thus, we conclude that IENA and EAFB procedures are not measuring the same quantities.

Similar results (but not statistically significant at P = 0.05) are observed for DNA and EAFB. We expected this because DNA measures only ^{235}U and the Range 74-L soils are contaminated with depleted uranium.

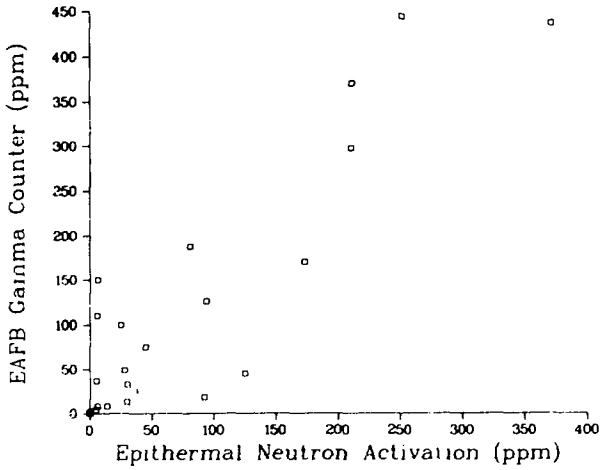

Fig. 3.
Results of the EAFB and IENA analytical techniques for determining uranium concentration in soil from the 5 May 1978, Range 74-L samples.

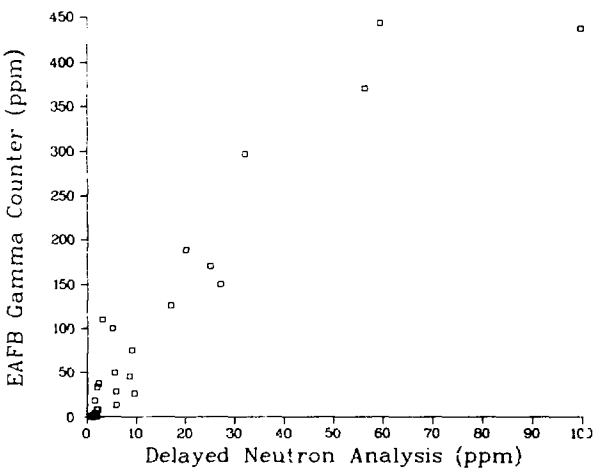

Fig. 4.
Results of the EAFB and DNA analytical techniques for determining uranium concentration in soil from the 5 May 1978, Range 74-L samples.

The test also significantly rejected (P = 0.001) the null hypothesis for the IENA-DNA ratios. The mean of the IENA-DNA ratios was 5.1 (s = 10.6), indicating that several of the samples had ratios much

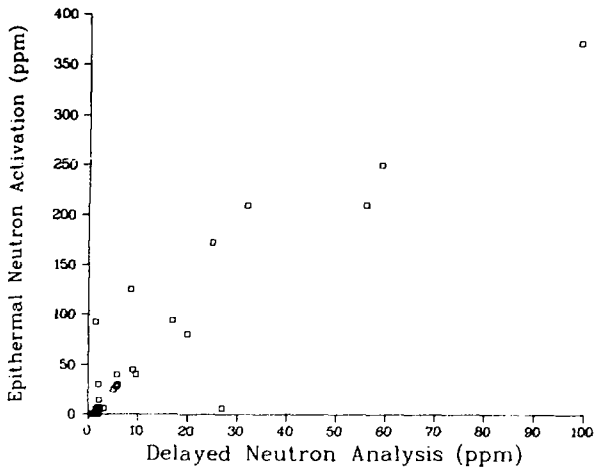

Fig. 5.
Results of the IENA and DNA analytical techniques for determining uranium concentrations in soil from the 5 May 1978, Range 74-L samples.

greater than 1. As discussed above, the mean of the ratios of IENA to DNA should differ from 1 because DNA results are highly dependent on the isotopic ratio of ^{235}U to ^{238}U. The data in Table A-II are for depleted uranium, and thus assuming an isotopic ratio of 0.0072 for the DNA method is not valid.

In an attempt to substantiate the heterogeneity of soil sample aliquots, we completely analyzed three samples (78.00854, -855, and -856) by the DNA method. These results are presented in Tables III and IV for ease in comparing the results. The wide range of aliquot concentrations indicates the great deal of variability between aliquots. LASL sample 78.00854 has a particularly wide range (6.3-1600), although the other two samples have ranges of 161 and 194. The poor agreement between the EAFB procedure and the weighted average of the DNA analyses is due to the samples' containing depleted uranium. Thus, we would expect the DNA analysis to give much lower concentrations than are actually present.

D. August 21, 1978, EAFB Soil Samples

The data in Table A-III are analyses of 52 soil samples collected 21 August 1978 on ADTC Test Area C-64 to establish a base-line uranium concentration for the area before its first use. EAFB samples 1-17, 2-16, and 3-17 were controls. DNA and IENA analyses were conducted on different 2-g aliquots taken from each soil sample. The uncertainties listed in Table A-III represent the counting errors.

TABLE II

RESULTS OF THE WILCOXON SIGNED RANK TEST OF THE RATIOS OF THE THREE ANALYTICAL METHODS FROM THE 5 MAY 1978 SOIL DATA

Ratio	Observations Less Than 1	Observations Greater Than 1	Test Significance
IENA/EAFB	26	8	0.008
DNA/EAFB	24	10	0.146
IENA/DNA	13	21	0.001

The IENA technique varies greatly at the 1-ppm concentration level, and thus the DNA analysis should be considered the more reliable of the two presented. The means and standard deviations of the samples in Table A-III are: IENA, 0.88 ± 0.45; DNA, 0.64 ± 0.17.

These data are plotted in Fig. 6. Except for three high values of IENA, the plot suggests good agreement between the DNA and IENA results, but the values vary greatly from sample to sample. The plotted data suggest that the expected ratio of the two analysis techniques is close to 1, but after we tested the ratio statistically with the Wilcoxon signed rank test, we rejected the hypothesis that it was equal to 1 ($P = 0.0002$). Of the 52 values, only 19 were less than 1. The mean of the ratios is 1.44, with standard deviation 0.87. Thus, we conclude that IENA and DNA are not measuring the same quantities at these low background concentrations.

IV. SUMMARY AND CONCLUSIONS

Comparison of the instrumental measurements of LASL E-F Site soil uranium obtained by the portable phoswich detector with the 1976 results of soil uranium measured by chemical analytical methods indicates good agreement between the two surveys. We believe the phoswich instrument may be good for field use to survey soil uranium concentrations. Further studies will be required at sites where the

TABLE III

TOTAL ANALYSIS OF THREE SAMPLES OF EAFB SOIL BY THE DNA METHOD

	78.00854		78.00855		78.00856	
	U (ppm)	Sample Weight (g)	U (ppm)	Sample Weight (g)	U (ppm)	Sample Weight (g)
	6.3	2.00	210	2.00	250	2.00
	85	2.00	62[a]	3.99	61[a]	5.04
	28[a]	4.34	49[a]	4.61	59[a]	4.83
	26[a]	4.30	56[a]	5.06	56[a]	4.32
	26[a]	4.47	124	6.10	131	5.94
	56	5.88	124	5.88	141	5.39
	51	5.97	80	6.24	111	5.83
	51	6.12	109	6.12	150	4.83
	63	5.97	113	6.03	112	5.84
	48	5.75	96	6.20	105	6.27
	1600	5.94	121	6.06	154	6.13
	54	5.94	130	6.48	119	5.94
	50	5.79	159	2.79	117	5.96
	60	5.33	---	---	---	---
Total Weight		67.80		67.56		68.32
Weighted Av U Conc	221		118		131	
EAFB U Conc	153		390		461	

[a]DNA values not used in computation of weighted average.

concentrations are as low as those observed at EAFB.

Comparisons of three different analytical techniques to measure uranium concentrations in soil indicate differences in the methods. Part of the lack of agreement between methods is explainable by the heterogeneity of aliquots taken from the same soil sample. However, there seems to be a basic difference in what each of the three techniques measures.

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TABLE IV

STEM AND LEAF DISPLAYS OF THE THREE SOIL SAMPLES COMPLETELY ANALYZED BY DNA*

78.00854		78.00855		78.00856	
Stem	Leaf	Stem	Leaf	Stem	Leaf
0	6	0		0	
10		10		10	
20	668	20		20	
30		30		30	
40	8	40	9	40	
50	01146	50	6	50	69
60	03	60	2	60	1
70		70		70	
80	5	80	0	80	
90		90	6	90	
100		100	9	100	5
110		110	3	110	1279
120		120	144	120	
130		130	0	130	1
140		140		140	1
150		150	9	150	04
160		160		160	
170		170		170	
180		180		180	
190		190		190	
200		200		200	
210		210	0	210	
220		220		220	
230		230		230	
240		240		240	
250		250		250	0
↓		↓		↓	
1600	0	1600		1600	

Statistic	78.00854	78.00855	78.00856
n	14	13	13
Median	51	113	117
Mean, $\bar{x}$	157.45	110.23	120.46
Standard Deviation, s	415.65	44.12	50.98
Coefficient of Variation, $s/\bar{x}$	2.64	0.40	0.42

*Example of how to read: the row 120|144 in the 78.00855 column represents three concentrations whose leaf digits are 1, 4, and 4; that is, the three concentrations are 121, 124, and 124.

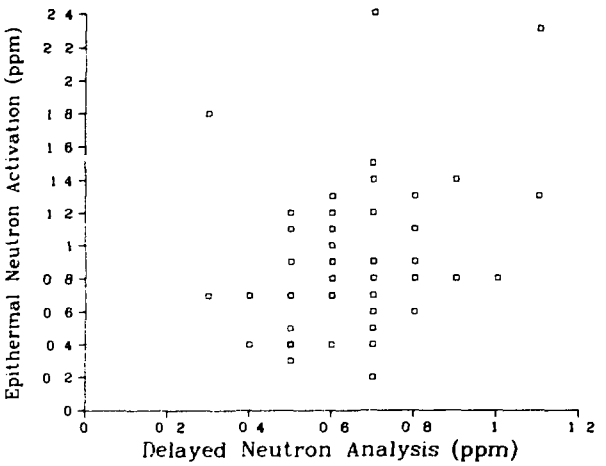

Fig. 6.

Comparison of the results of the IENA and DNA analytical techniques for determining uranium concentration in 21 August 1978, ADTC Test Area C-64, base-line soil samples.

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APPENDIX

DETERMINATION OF URANIUM IN SOILS

TABLE A-1

ANALYTICAL RESULTS FOR EAFB SOIL SAMPLES COLLECTED 5 JANUARY 1978

EAFB No.	EAFB Result (ppm = μg/g)	LASL Result* (ppm = μg/g)
0-0 top	6000	5800 ± 1600
0-0	4400	4300 ± 940
1-7	702	1400 ± 390
1-9	329	312 ± 45
2-2	97	35 ± 5
1-1	32	17 ± 1
3-15	16	14 ± 1
Range Control 1	0	0.9 ± 0.3
Range Control 2	0	0.8 ± 0.3

*Uncertainty represents the standard deviation of three analyses.

TABLE A-II

ANALYTICAL RESULTS FOR EAFB SOIL SAMPLES COLLECTED 5 MAY 1978

EAFB No.	LASL No.	EAFB Result (μg/g)	LASL Results DNA (μg/g)	LASL Results IENA (μg/g)
0-0	78.00868	170	25 ± 1[a]	173
1-1	78.00853	188 ± 15	20 ± 4	81
1-3	78.00854	150 ± 4	27 ± 1	6.3
1-5	78.00855	370 ± 28	56 ± 6	210
1-7	78.00856	443 ± 25	59 ± 2	250
1-9	78.00857	26	9.6 ± 0.4	40
1-11	78.00858	100	5.1 ± 0.1	25
1-13	78.00859	13	5.9 ± 0.1	30
1-15	78.00860	297	32 ± 2	210
1-17 (control)	78.00861	1	0.87 ± 0.12	ND[b]
1-19 (control)	78.00862	<1	0.72 ± 0.02	ND
2-0	78.00863	435	99 ± 13	370
2-2	78.00864	126	17 ± 2	94
2-4	78.00865	45	8.6 ± 0.5	125
2-6	78.00866	49	5.6 ± 1.1	28
2-8	78.00867	8	2.0 ± 0.5	6.3
2-10	78.00869	1	1.3 ± 0.4	ND
2-12	78.00870	33	2.0 ± 0.2	30
2-16 (control)	78.00871	2	1.2 ± 0.2	ND
3-1	78.00872	1	1.8 ± 0.1	ND
3-3	78.00873	75	9.0 ± 0.8	45
3-5	78.00874	<1	1.6 ± 0.1	ND
3-7	78.00875	18	1.5 ± 0.2	92
3-9	78.00876	1	1.4 ± 0.1	ND
3-11	78.00877	<1	1.3 ± 0.1	ND
3-13	78.00878	4	1.6 ± 0.2	4.8
3-15	78.00879	28	5.8 ± 0.5	40
4-0	78.00880	8	2.2 ± 0.5	14
4-2	78.00881	<1	2.0 ± 0.1	ND
4-4	78.00882	110	3.1 ± 0.7	6
4-6	78.00883	<1	1.2 ± 0.1	ND
4-8	78.00884	37	2.3 ± 0.2	5
4-10	78.00885	<1	1.3 ± 0.3	ND
4-12	78.00886	<1	1.4 ± 0.1	ND

[a]Uncertainty represents the standard deviation of two analyses for EAFB results and three analyses for DNA results.

[b]ND means nondetected.

TABLE A-III

ANALYTICAL RESULTS FOR EAFB SOIL SAMPLES COLLECTED 21 AUGUST 1978 AT TEST AREA C-64

EAFB No.	LASL No.	IENA (ppm)	DNA (ppm)	EAFB No.	LASL No.	IENA (ppm)	DNA (ppm)
0-0	78.00754	0.7 ± 0.3	0.3 ± 0.2	3-15	78.00780	1.2 ± 0.2	0.7 ± 0.2
				3-17 (control)	78.00781	2.4 ± 0.3	0.7 ± 0.2
1-1	78.00755	1.3 ± 0.3	0.8 ± 0.2				
1-3	78.00756	0.7 ± 0.2	0.7 ± 0.2	4-0	78.00782	1.0 ± 0.2	0.6 ± 0.2
1-5	78.00757	0.4 ± 0.2	0.4 ± 0.2	4-2	78.00783	0.4 ± 0.1	0.6 ± 0.2
1-7	78.00758	0.8 ± 0.3	0.6 ± 0.2	4-4	78.00784	1.1 ± 0.2	0.8 ± 0.2
1-9	78.00759	1.4 ± 0.4	0.7 ± 0.2	4-6	78.00785	0.7 ± 0.1	0.6 ± 0.2
1-11	78.00760	0.4 ± 0.2	0.7 ± 0.2	4-8	78.00786	0.4 ± 0.1	0.5 ± 0.2
1-13	78.00761	1.2 ± 0.2	0.6 ± 0.2	4-10	78.00787	0.7 ± 0.1	0.6 ± 0.2
1-15	78.00762	1.4 ± 0.5	0.9 ± 0.2	4-12	78.00788	0.7 ± 0.1	0.5 ± 0.2
1-17 (control)	78.00763	1.1 ± 0.1	0.5 ± 0.2	4-14	78.00789	0.9 ± 0.1	0.5 ± 0.2
2-0	78.00764	1.3 ± 0.3	1.1 ± 0.2	5-1	78.00790	0.4 ± 0.1	0.5 ± 0.2
2-2	78.00765	0.9 ± 0.3	0.8 ± 0.2	5-3	78.00791	0.8 ± 0.2	0.8 ± 0.2
2-4	78.00766	1.5 ± 0.5	0.7 ± 0.2	5-5	78.00792	0.9 ± 0.2	0.6 ± 0.2
2-6	78.00767	0.8 ± 0.3	0.9 ± 0.2	5-7	78.00793	0.7 ± 0.1	0.4 ± 0.2
2-8	78.00768	1.8 ± 0.3	0.3 ± 0.2	5-9	78.00794	0.8 ± 0.2	0.7 ± 0.2
2-10	78.00769	1.3 ± 0.3	0.6 ± 0.2	5-11	78.00795	0.9 ± 0.2	0.6 ± 0.2
2-12	78.00770	0.4 ± 0.1	0.5 ± 0.2	5-13	78.00796	0.9 ± 0.2	0.7 ± 0.2
2-14	78.00771	0.8 ± 0.2	0.6 ± 0.2	5-15	78.00797	0.3 ± 0.1	0.5 ± 0.2
2-16 (control)	78.00772	0.8 ± 0.3	0.8 ± 0.2				
				6-0	78.00798	0.5 ± 0.1	0.7 ± 0.2
3-1	78.00773	2.3 ± 0.3	1.1 ± 0.2	6-2	78.00799	0.6 ± 0.1	0.7 ± 0.2
3-3	78.00774	0.4 ± 0.1	0.5 ± 0.2	6-4	78.00800	0.8 ± 0.2	1.0 ± 0.2
3-5	78.00775	0.9 ± 0.2	0.7 ± 0.2	6-6	78.00801	0.4 ± 0.1	0.5 ± 0.2
3-7	78.00776	0.7 ± 0.2	0.4 ± 0.2	6-8	78.00802	0.7 ± 0.1	0.5 ± 0.2
3-9	78.00777	1.2 ± 0.2	0.5 ± 0.2	6-10	78.00803	0.7 ± 0.1	0.6 ± 0.2
3-11	78.00778	0.2 ± 0.2	0.7 ± 0.2	6-12	78.00804	0.5 ± 0.1	0.5 ± 0.2
3-13	78.00779	1.1 ± 0.2	0.6 ± 0.2	6-14	78.00805	0.6 ± 0.1	0.8 ± 0.2

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