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Baseline Measurements of Terrestrial Gamma Radioactivity at the CEBAF Site

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Introduction

A survey of the gamma radiation background from terrestrial sources was conducted at the CEBAF site, Newport News, Va, on November 12-16, 1990, to provide a gamma radiation baseline for the site prior to the startup of the accelerator. The concentrations and distributions of the natural radioelements in exposed soil were measured, and the results of the measurements were converted into gamma-ray exposure rates. Concurrently, samples were collected for laboratory gamma spectral analyses.

The principal terrestrial sources of gamma radiation are uranium-238, thorium-232, their decay products, and potassium-40 (Wollenberg and Smith, 1990). Fission-product fallout, primarily from nuclear bomb tests in the atmosphere in the 1950s and 1960s, presently contributes less than 5% of the terrestrial gamma radioactivity. The gamma-ray field from radioelements in rock and soil is superimposed on a nearly constant field from cosmic radiation, ~3 micro R/h in the CEBAF area (EG&G, 1975).

The geologic setting of CEBAF is dominated by the soft sediments of the Atlantic coastal plain. The surficial soils, generally sandy loam with some calcareous clayey horizons, were developed from terrace deposits of Quaternary age (Spangler and Peterson, 1950; Avon Burke and Root, 1907). In a preliminary geotechnical exploration report, the upper stratum of soil at CEBAF is described as "...loose to firm clayey sands, silty sands, sandy to silty clays, and silts of the Norfolk Formation" (Law, 1985). Underlying the Norfolk Formation, and exposed in the lower portion of the end station excavation at the time of our survey, is firm silty sand, containing shell fragments, of the Yorktown Formation.

Procedures

Field Activities:

Field activities consisted of a survey by a portable gamma-ray spectrometer system, the Geometrics GR 410, incorporating a 3-inch - diameter by 3-inch - thick NaI(Tl) detector, accompanied by collection of soil samples from most of the field measurement locations for subsequent laboratory gamma spectral analyses. Between measurement sites, the gamma detector was carried ~3 ft. above the ground with the attached pulse height analyzer in the rate-meter mode. At measurement locations with the detector also at ~3 ft. above the ground,

counts in 4 channels were recorded: total counts in the energy region from 0.5 to 3 MeV; and counts in 3 regions encompassing the 1.46 MeV peak of ^{40}K, the 1.76 MeV peak of ^{214}Bi of the U decay series, and the 2.62 MeV peak of ^{208}Tl of the Th decay series. K, U, and Th concentrations were calculated from the count rate data using calibration equations derived from measurements by the GR 410 system over planar sources of known radioelement concentration. In these calculations it is assumed that members of the U and Th decay series are in secular equilibrium with their parents. Concentration data were converted into gamma-ray exposure rates by applying equations determined by Beck and dePlanque (1968) for the exposure rate 3 ft. above the ground from evenly distributed radioelement sources. By operating the portable gamma spectrometer in the rate-meter mode while traversing the site on foot, we were able to determine anomalous areas and to also determine the relative uniformity of locations selected for gamma spectral measurements and accompanying soil sample collection. At most measurement sites surficial soil was collected by scraping away the leaf and pine needle cover, and troweling the top 2 to 3 cm of the soil from several points over a ~20 ft. diameter area into a plastic bag. Concurrently, counts in the aforementioned gamma spectral intervals were accumulated for 4 minutes while the operator walked slowly with the detector over the ~20 ft. diameter area. This procedure provided counting statistics to better than 10% in the consistently least populous of the intervals, that encompassing the 2.62 MeV peak of ^{208} Tl. Subsequent to the field survey, follow-up samples were collected in the vicinities of sites S18, S19, S20, and the "boneyard", and additional sites S50 (in a small ground depression), S51 (under tree cover), and S52 (in a nearby open undisturbed setting), were also sampled.

Laboratory Activities:

Laboratory gamma spectral analyses of CEBAF soils were performed at the LBL low background facility, employing both a NaI(Tl) scintillation crystal detector system and a high resolution Ge semiconductor detector system. Absolute radioelement concentrations were obtained from gamma spectra through calibrations based on asayed U-ore and Th-ore materials obtained in the 1960s from the New Brunswick laboratory of the (then) USAEC, and on CP-grade KCl.

The laboratory analyses reported here were obtained through use of a low-background scintillation crystal gamma spectrometer based on an 8-inch diameter by 4-inch thick NaI(Tl) crystal detector. U, Th, and K concentrations were derived from 400-channel spectra which covered the gamma-ray energy range from 0.04-4.0 MeV, using the three energy intervals centered at 1.46 MeV for K, 1.76 MeV for U, and 2.62 MeV for Th. Emanation of ^{222}Rn was determined by a charcoal absorption method: the ^{222}Rn adsorbed onto charcoal in a canister sealed in a container with the emanating soil, was measured by detection of gamma rays emitted by Rn daughters.

All samples were processed alike, as described by the following steps:

1) NaI detector analysis, in plastic bags as received, in "wet" condition;

2) samples then air-dried, spread in thin layer to ensure free ^{222}Rn emanation;

3) NaI analysis in standard container, immediately after packing from step 2;

4) Samples then sealed in container with charcoal canister for measured time;

5) NaI analysis of charcoal canister immediately after step 4;

6) Ge(Li) analysis of soil in standard container, following a period of "free" Rn emanation.

Step 3 provides dry-weight values for total K in %, total Th in ppm, and that fraction of U in ppm which does not contribute to Rn emanation. Steps 4 and 5 provide a measure of Rn emanation, and also permit calculation of total U in ppm. Step 6 provides values for all of the above quantities, although the values for Rn emanation are considerably less precise than are those obtained from the NaI charcoal canister method. The main purpose of the Ge(Li) high-resolution spectrometry was to search for the presence of any gamma-emitting radionuclides besides the U-series, Th-series or K, to establish baseline levels against which to evaluate surveys taken after the CEBAF accelerator comes into operation. Another purpose was to determine if members of the U decay series were in secular equilibrium. Evaluation of high-resolution analyses are not yet complete, and will be included in a subsequent detailed report.

Results

Surface:

The locations of measurement and sampling sites are shown in Fig. 1, and results are listed in Table 1. Anomalously high exposure rates occur at 2 locations: "driveway" near site S6 and the "boneyard" east of the old accelerator building. As with many of the other road surfaces, "driveway" is paved with crushed granitic rock which contains relatively high concentrations of radioelements; a sample of this rock was obtained from a stockpile for laboratory gamma analysis. The high field measurement value at "boneyard" was obtained near an old stockpiled shielding block. However, laboratory measurement of the radioelement concentrations in the corresponding soil sample shows a value about average for the CEBAF site. With the exception of these two high values, field measurements of surface sites are relatively uniform, averaging 4.8 micro R/h, while laboratory measurements of corresponding soil samples (the soils dried, and the U contribution corrected for Rn emanation) average 5.2 micro R/h (Table 1). This ~5 micro R/h average for the CEBAF site is higher than the 2 to 4 micro R/h range of terrestrial exposure rates measured in 1973 ~5 miles north of the present CEBAF site by the EG&G aerial gamma survey (EG&G, 1975). Slightly elevated radioactivities occur in soils in a relatively small zone near the south boundary of the CEBAF site (locations S2, S27, S28, and S29; Fig. 1, Table 1). The relatively high concentration of Th in these samples, especially those with high Th/U ratios (S27 and S28) suggests that an abundance of the mineral monazite (a rare earth - Th- phosphate - silicate) might be responsible for their high radioactivities. Monazite in discrete concentrations has been noted in the Yorktown Formation in North Carolina (Dryden,

SITE PLAN CEBAF

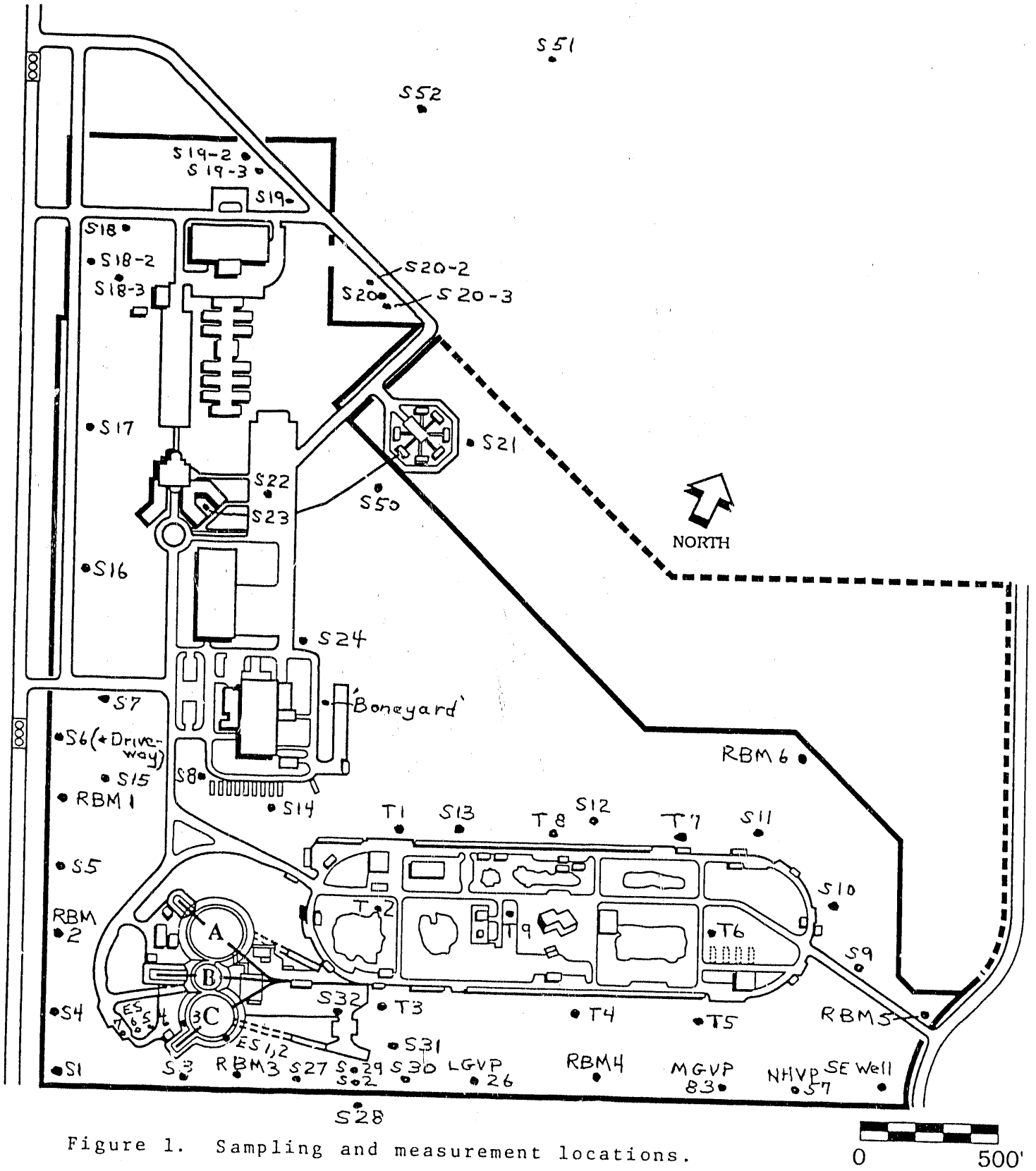

Figure 1. Sampling and measurement locations.

Table 1. CEBAF Field and Lab. Gamma Exposure Rates

Location	Field Exp.Rate (uR/h)	Lab. Exp. Rate (uR/h)
S 1	3.9	5.8
RBM 3	4.9	
RBM 4	5.1	6.4
SE Well	4.6	5.1
NHVP57	4.8	4.7
MGVP83	4.5	5.4
S 2	7.5	7.1
LGVP26	5.8	5.9
S 3	4.4	5.8
S 4	4.2	4.3
RBM 2	3.8	4.9
S 5	4.5	5.4
RBM 1	4.6	
S 6	4.7	4.7
Driveway	23	25
S 7	4.8	5.6
S 8	3.3	3.1
RBM 5	3.8	4.6
RBM 6	4.2	4.7
S 9	4.5	4.9
S 10	4.5	5.5
S 11	4.9	4.5
S 12	4.4	4.8
S 13	4.1	4.9
S 14	5.1	5.3
S 15	4.2	4.7
T 1	5.2	5.4
T 2	5.4	6.1
T 3	4.7	4.9
T 4	4.7	5.1
T 5	5	5.3
T 6	4.7	4.4
T 7	4.8	5.3
T 8	4.6	5.6
T 9	4.6	4.2
S 16	4.6	5.05
S 17	4.4	4.9
S 18	4.6	
S 18-2		4.8
S 18-3		4.6
S 19	4.6	
S 19-2		4.3
S 19-3		6.6
S 20	5.2	
S 20-2		5.5
S 20-3		5.3
S-21	5.5	5.7
S 22	4.5	
S 23	4.5	4.1
S 24	4.9	
S 25	4.5	
S 26	5.2	
S 27	5.7	8.2
S 28	6.2	8.1
S 29	5.3	6.4
S 30	5.2	
S 31	5.1	
S 32	4.7	4.4
S 50		3.9
S 51		5.1
S 52		5.7
"Boneyard"	13.7	5.2
Mean*	4.8	5.2
Std. Dev.	0.8	0.95
*excl.boneyard and driveway		

1958), and in crystalline bedrock of the Piedmont along the James River west of Richmond (Mertie, 1953), indicating the possibility of concentrations in sediments downstream.

Field and laboratory measurements of radioelement concentrations are summarized in Table 2. Exposure rates are compared in Fig. 2, showing good agreement between field and laboratory measurements. The y-intercept of 0.52 micro R/h is attributed to the situation that the exposure rates measured in the laboratory are for dried samples, while field soil moisture averaged ~10%.

Subsurface:

Excavation of the end station site provided access for sampling of subsurface beds. Results of laboratory gamma spectral analyses of these samples (ES 1 through 7, Table 3) indicate that, not surprisingly, radioelement concentrations similar to those measured the surface soil occur in the uppermost of the subsurface beds. The suite of samples included those from the bottom of the exposed cut, then sequentially upward and out of the excavation along the haulage ramp. The samples are briefly described, and their radioelement concentrations listed in Table 3, and plotted in Figure 3. Primarily Th, but also U and K to some extent, are in substantially higher concentrations in the upper beds than in the lowermost unit sampled, the Yorktown Formation. The preponderance of Th in the upper beds suggests that, as with the zone near the south boundary described above, monazite is principally responsible for their relatively high radioactivity.

Conclusion

Whether field measurement or sampling sites are under tree cover or on disturbed or undisturbed open areas, the terrestrial component of the natural gamma ray exposure rate at the CEBAF site is relatively uniform, averaging ~5 micro R/h. Exceptions are roadways paved with crushed granitic rock where exposure rates are several times those on natural or disturbed soil surfaces. Radioelement concentrations in the lower portion of the end station excavation, in the Yorktown Formation, are significantly lower than those in the upper portion of the excavation or in surficial soils. The average terrestrial gamma exposure rate at CEBAF is higher than exposure rates measured over land areas north and west of the site by aerial radiometric surveys in the 1970s.

Acknowledgements

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Table 2: Summary, Radioelements and Exposure Rates

	U (ppm)	Emanation (%)	Th (ppm)	K (%)	Exp. Rate (uR/h)
Lab. measurements	2.7, s.d. 0.6	19, s.d. 4.4	7.4, s.d. 1.7	0.72, s.d. 0.17	5.2, s.d. 0.95
Field measurements	2.1, s.d. 0.5		7.7, s.d. 1.5	0.6, s.d. 0.2	4.8, s.d. 0.8

Table 3. Radioelements, End Station Excavation

Sample, Description	U (ppm)	Th (ppm)	K (%)
ES1: Dark gray, fine to medium-grained sandstone	1.88	4.04	0.76
ES2: Reddish, ~1 ft. thick iron oxide band	1.85	2.93	0.51
ES3: Buff, fine-to-medium grained sand with shell fragments	1.93	2.64	0.38
ES4: Buff fine sand w/ thin (<1/8 in.) horiz. black stringers, ~4 ft.thick	1.22	3.79	1.23
ES5: Dark clay band, ~1.5 ft. thick	3.76	8.85	1.82
ES6: Red-orange mottled and dark brown Fe-stained silty sand, w/ some clay	3.06	8.94	1.25
ES7: Gray-orange mottled sandy clay, upper layer and surficial soil	3.31	8.78	0.83

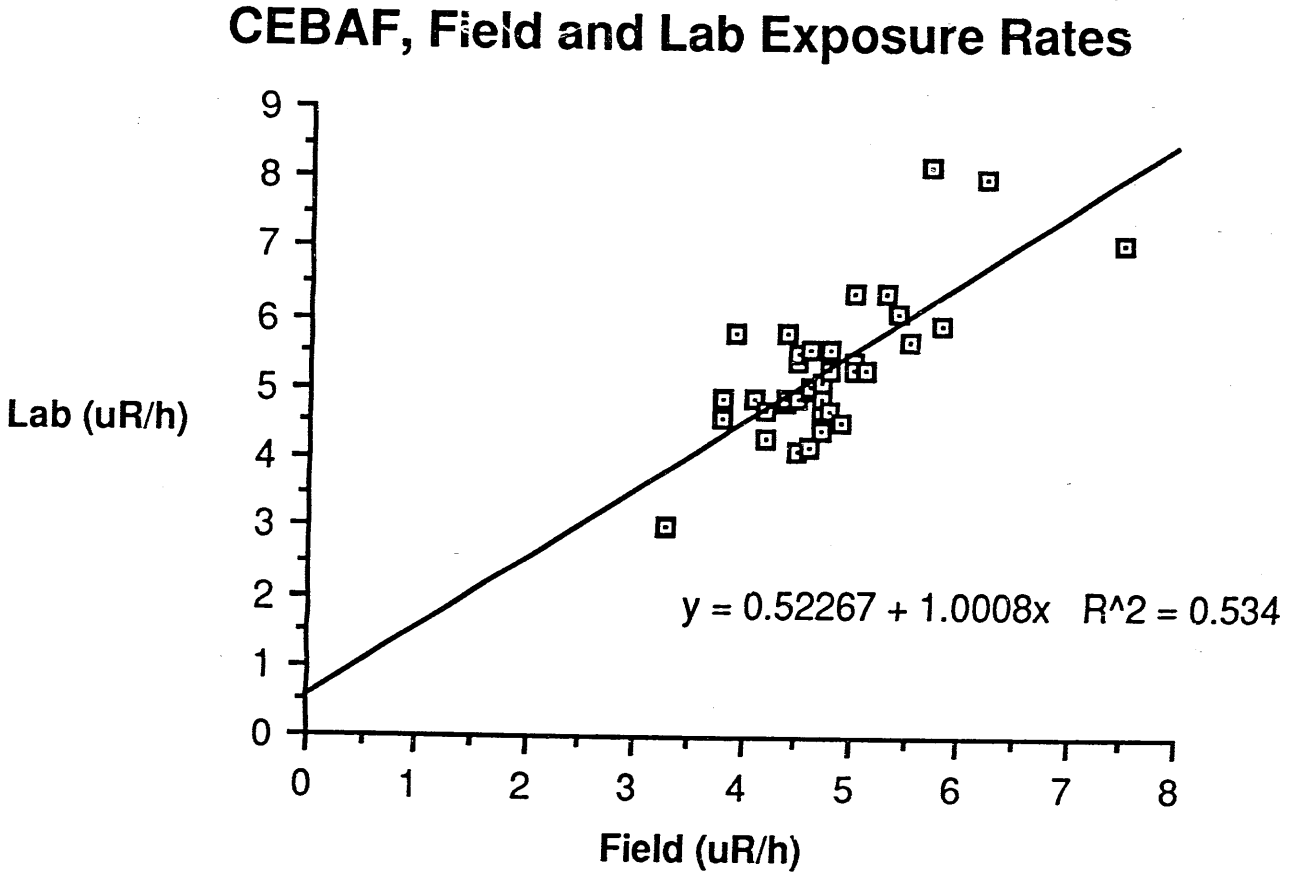
CEBAF, Field and Lab Exposure Rates
Lab (uR/h)
Field (uR/h)
y = 0.52267 + 1.0008x R^2 = 0.534
0
1
2
3
4
5
6
7
8
9

Figure 2.

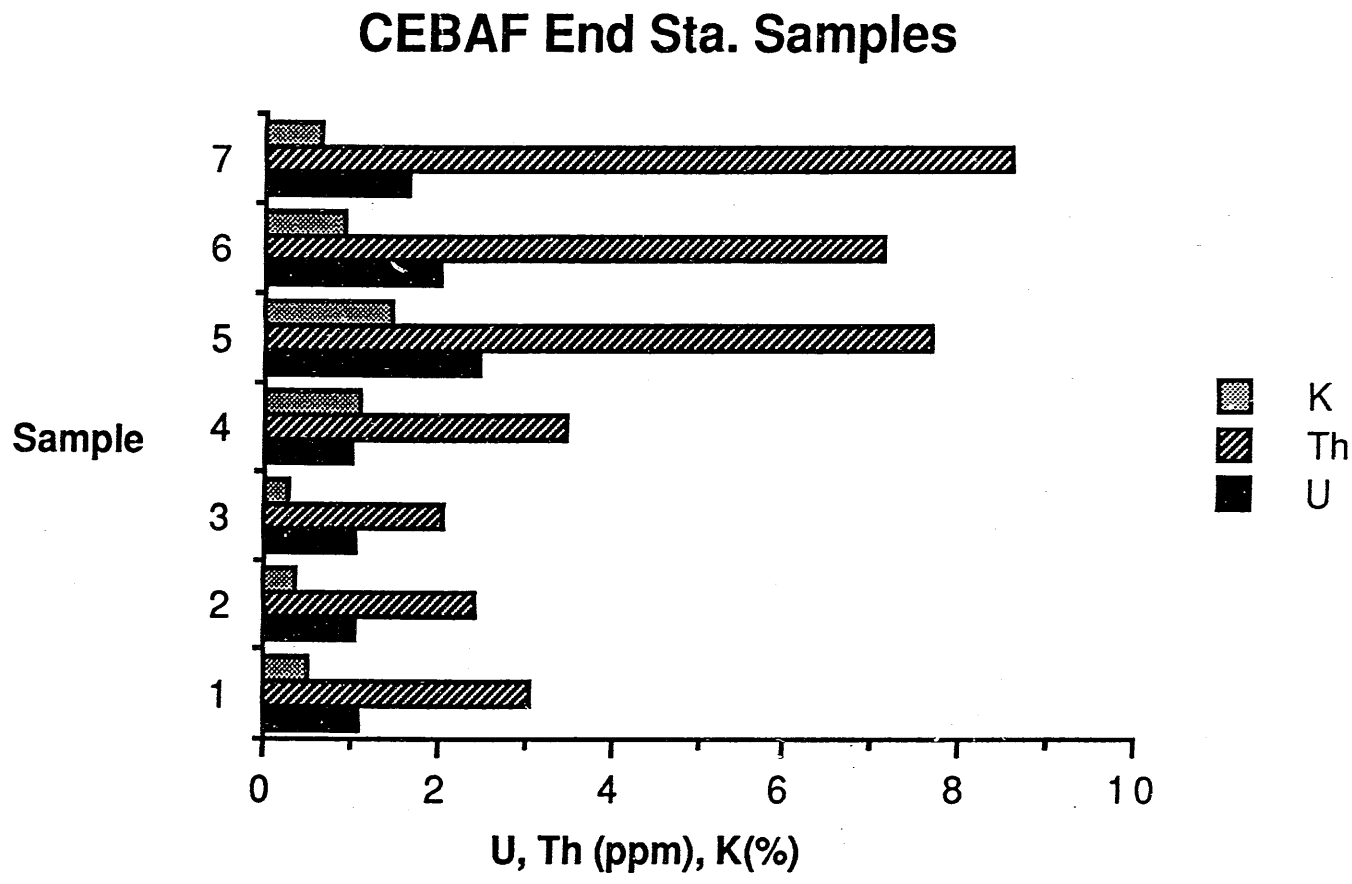

Figure 3.

References

Avon Burke, R.T., and Root, A.S., Soil survey of the Yorktown area, Virginia. U.S. Dept. of Agriculture, Bur. of Soils, Seventh Rept., p. 247-270, 1907.

Beck, H. and dePlanque, G., The radiation field in air due to distributed gamma-ray sources in the ground. U.S. Atomic Energy Commission Health and Safety Laboratory Rept. HASL 195, 1968.

Dryden, L., Monazite in part of the South Atlantic Coastal Plain. U.S. Geol. Survey Bulletin 1042L, p.393-429, 1958.

EG&G, Radiological survey of the area surrounding the Surry Power Station, Gravel Neck, Va. EGG-1183-1645, 1975.

Law Engineering Testing Co., Report of preliminary geotechnical exploration, Continuous Electron Beam Facility, Newport, Virginia. Rept. dated Oct. 3, 1985.

Mertie, J.B. Jr., Monazite deposits of the southeastern Atlantic states. U. S. Geol. Survey Circular 237, 1953.

Spangler, W.B., and Peterson, J.J., Geology of the Atlantic coastal plain in New Jersey, Delaware, Maryland, and Virginia. Amer. Assoc. Petroleum Geologists Bull., 34, 1, p. 1-99, 1950.

Wollenberg, H.A. and Smith A.R., A geochemical asessment of terrestrial Gamma-ray absorbed dose rates. *Health Physics*, 58, 183-189, 1990.

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