GLOBAL JOURNAL OF PURE AND APPLIED SCIENCES VOL. 8, NO. 4, SEPTEMBER 2002: 505 - 509
COPYRIGHT(C) BACHUDO SCIENCE CO. LTD. PRINTED IN NIGERIA. ISSN 1118-0579

COMPARISON OF *IN SITU* AND LABORATORY GAMMA-RAY SPECTROSCOPY OF TERRESTRIAL GAMMA RADIATION IN IBADAN, SOUTH WESTERN NIGERIA

A. M. AROGUNJO, I. P. FARAI and N. N. JIBIRI

(Received 3 December 2001; Revision accepted 28 June 2002)

ABSTRACT

In situ γ- ray spectroscopic method of measeruments, using the calibration factor by Zombori et al, and laboratory method for soil samples were carried out in Ibadan, SW Nigeria. The average specific activities of ^{40}K, ^{238}U and ^{232}Th in the soil were 299.0 ± 16.5 $Bqkg^{-1}$, 40.0 ± 5.8 $Bqkg^{-1}$ and 95.0 ± 7.8 $Bqkg^{-1}$, respectively, by *in situ* measurements, while for the laboratory measurements, the specific activities were found to be 355.0 ± 19.7 $Bqkg^{-1}$ for ^{40}K, 31.0 ± 5.9 $Bqkg^{-1}$ for ^{238}U and 63.0 ± 7.5 $Bqkg^{-1}$ for ^{232}Th. Statistical analysis using F- hypothesis test of microsoft excel 5.0 analysis toolpak gave F-values to be 0.32, 0.52 and 0.00, respectively, which indicated that the radionuclides were not site dependent. The comparison shows a correlation of 0.65, 0.59 and 0.63 respectively, for ^{40}K, ^{238}U and ^{232}Th.

Key words : gamma - ray; calibration; soil; activity; radionuclide

INTRODUCTION

Collection of soil samples for laboratory radioactivity analysis using gamma - ray spectroscopy has been employed by many researchers for environmental radioactivity monitoring(Alberto et al.,1997; Ibrahiem et al.,1993; Jaworowski,1982). The reliability and simplicity of this method have been made possible by counting a spiked sample of known activity and the samples with unknown activities of the same geometry. Unlike the laboratory method, *in situ* gamma - ray spectroscopy identifies the contributions of individual radionuclides but without the drawbacks of a size restricted characterisation area and long processing and counting times(Benke and Kearfott,1997). This method has been used by many environmentalist in their works (Murith et al.,1988; Miller and Shebell,1993; Miller et al.,1994) and has been found to be a good tool for constant environmental monitoring, if properly calibrated, since it can quantify a large volume of soil(Miller et al.,1994).

However, the reliability and accuracy of *in situ* method have to be ascertained to a reasonable level of confidence, particularly as the calibration factors used in the method were determined using different detectors. *In situ* γ - ray spectroscopy has been used world-wide and various calibration factors have been employed by many researchers. *In situ* method, using the infered calibration factor by Zombori et al(1983) and laboratory method by direct soil sampling were carried out in Ibadan, SW Nigeria in order to ascertain whether the infered calibration factors would yield good results in the qualitative determination of natural radionuclides using our detector. This study is also desired to determine the sensitivity of the radiation monitoring equipment under tropical conditions. Measurement and analysis for both the laboratory sgamma - ray spectroscopy and the *in situ* gamma - ray spectroscopy were carried out at the Federal Radiation Protection Service(FRPS), University of Ibadan.

MATERIALS AND METHODS

Soil samples were collected from fourteen locations in Ibadan metropolis, as shown in Fig.1, for the laboratory and *in situ* gamma - ray spectroscopy. The samples for laboratory analysis were homogenised, air dried and sieved through a 2mm mesh. The samples were carefully packed in thick plastic containers and kept for four weeks to ensure secular equilibrium between the natural radionuclides and their respective progeny(Ibrahiem et al.,1993). A 7.6cm x 7.6cm detector with a resolution of about 8.0% at 662Kev γ - ray energy from ^{137}Cs was coupled to a multi-channel analyser(MCA).

A. M. AROGUNJO, Department of Physics, Federal University of Technology, Akure, Nigeria
I. P. FARAI, Department of Physics, University of Ibadan, Ibadan, Nigeria
N. N. JIBIRI, Department of Physics, Ogun State University, Ogun State, Nigeria

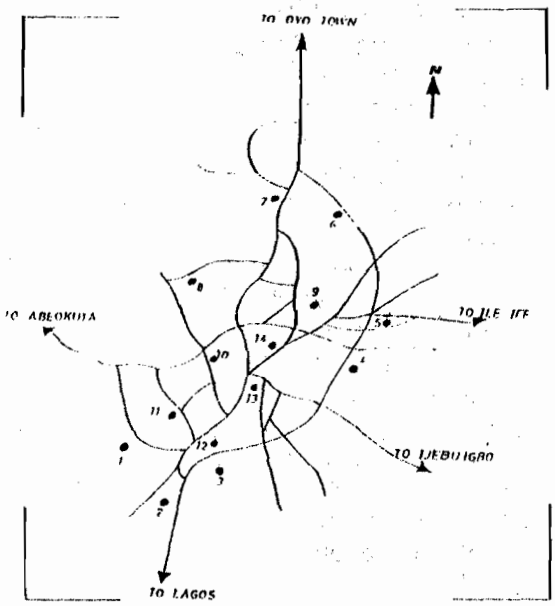

FIG 1. MAP OF IBADAN SHOWING THE LOCATIONS OF SOIL SAMPLES (SEE TABLE 1).

However, a good resolution was observed at photopeaks with energies 1460KeV, 1760KeV and 2615KeV from ^{40}K, ^{238}U and ^{232}Th, respectively, in the mixed γ field, typical of the type of environment considered.

The *in situ* γ - ray spectroscopy measurement was carried out using the portable MCA equipment operating on battery packs each of which runs continuously for about 8hrs. The complete spectroscopic system in one compact package was taken to the various locations shown in Fig.1. The detector was placed at 1.0m above the ground at each location(Beck et al.,1972) and the peak count rate was recorded. The specific activities of natural radionuclides in the soil samples analysed in the laboratory were estimated from the photopeak count rate for each radionuclides of the standard soil sample and the collected soil samples. A uniform distribution of

$$\text{Percentage difference \%} = \frac{(A_i - A_l)}{A_l} x100$$

where A_i is the mean specific activity for the *in situ* method and A_l is the mean specific activity for the laboratory method.

RESULTS

The specific activities for the natural radionuclides are presented in Table 2 for both the *in situ* and the laboratory methods. The mean specific activity of ^{40}K, ^{238}U and ^{232}Th are 355.0 ± 19.7 $Bqkg^{-1}$, 31.0 ± 5.9 Bqkg and 63.0 ± 7.5 $Bqkg^{-1}$, respectively, for the Laboratory method. Specific activity of the natural radionuclides estimated from the factors given by Zombori et al(1983) for gamma flux intensity at 1.0m above the ground are presented in Table 2. The mean specific activity for ^{40}K, ^{238}U and ^{232}Th are 299.0 ± 16.5 $Bqkg^{-1}$, 40.0 ± 5.8 $Bqkg^{-1}$ and 95.0 ± 7.8 $Bqkg^{-1}$, respectively, for the *in situ* method. Figure 2 shows that the highest values of ^{40}K for both the *in situ* and the Laboratory methods occur at location 8 with the lowest values of ^{40}K occuring at location 5 and 11 for the *in situ* and laboratory methods respectively. Figure 3 reveals highest values of ^{238}U at different locations for both the *in situ* and Laboratory methods. The highest value

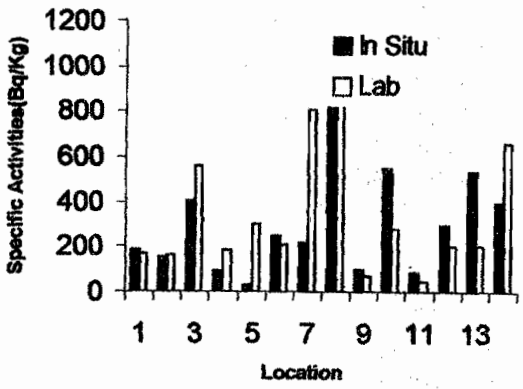

Fig. 2. Comparison of In Situ and Laboratory specific activities for Potassium-40

Table 1 : Gamma flux intensity by Zombori et al(1983) at 1m above the ground using 7.6cm x 7.6cm NaI(Tl) Scintillation detector

Energy (Kev)	N_p/D (cps/nGyh^{-1})	N_p/S (cps/BqKg^{-1})	D/S (nGyh^{-1}/BqKg^{-1})
1460 (^{40}K)	0.2400 ± 0.0070	0.0101 ± 0.0005	0.042
1760 (^{238}U)	0.0245 ± 0.0012	0.0105 ± 0.0005	0.429
2614 (^{232}Th)	0.0308 ± 0.0008	0.0205 ± 0.0010	0.666

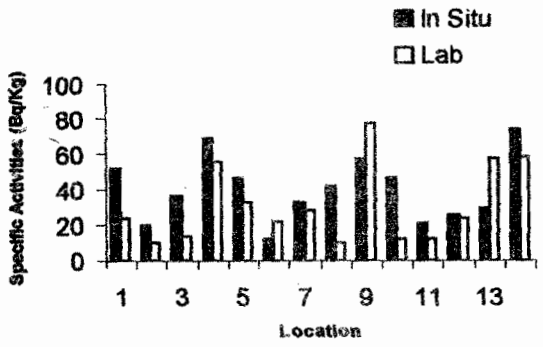

Fig. 3. Comparison of In Situ and Laboratory specific activities for for Uranium-238

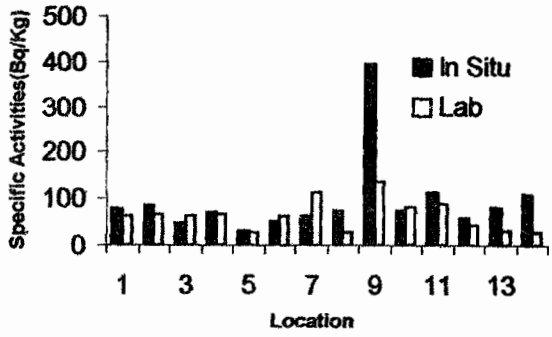

Fig. 4. Comparison of In Situ and Laboratory specific activities for Thorium-232

for the *in situ* method was found at location 14 while the Laboratory method has its value at location 9. The lowest value was found at location 6 with the Laboratory method having its value at locations 2 and 8. Figure 4 shows that the two methods have the highest and the lowest values at locations 9 and 5, respectively, in the determination of ^{232}Th.

Significance test was done using the statistical F-test calculations of the Microsoft excel 5.0 analysis toolpak for radionuclide site dependency of the natural radionuclides. Good radionuclides was assumed for the *in situ* method, therefore, the daughters were considered to be in equilibrium with their respective parent including gaseous ^{222}Rn and ^{220}Rn from ^{238}U and ^{232}Th, respectively. Under this assumption, the crucial factors in *In situ* γ - ray spectrometry reduce to peak count rate Np(cps) per dose D(nGyh^{-1}) and Np per specific activity

Table 2 : The Laboratory and the In-situ specific activities of the natural radionuclides in the *soil at various locations at* Ibadan, SW, Nigeria.

Location		Radioactivity concentration in topsoil (BqKg^{-1})					
		^{40}K		^{238}U		^{232}Th	
		In-situ	Lab	In-situ	Lab	In-situ	Lab
1	Orita Challenge	189.0±11.4	169.0±12.4	52.0±6.4	24.0±4.4	79.0±7.0	61.0±8.4
2	Ijebu Ode Road	156.0±10.7	164.0±14.2	20.0±4.4	10.0±6.5	85.0±7.9	65.0±5.8
3	Express Road	404.0±26.2	564.0±24.4	36.0±5.0	14.0±5.0	45.0±4.8	62.0±5.0
4	Yidi	96.0±8.3	183.0±27.3	69.0±8.9	55.0±9.5	70.0±6.0	64.0±7.6
5	New Gbagi Mkt.	28.0±6.4	305.0±25.1	46.0±6.6	33.0±7.4	31.0±1.9	27.0±1.3
6	Oke Imole Area	252.0±16.3	209.0±13.5	12.0±3.4	22.0±4.9	49.0±2.7	62.0±4.4
7	U.I. and Gate	217.0±14.4	810.0±24.8	33.0±4.8	28.0±6.6	61.0±4.8	113.0±22.0
8	Eleiyele	870.0±30.0	1096.0±36.4	42.0±7.4	10.0±6.2	75.0±5.8	28.0±2.4
9	Govt. House	102.0±10.7	68.0±18.0	57.0±7.6	77.0±8.4	395.0±24.0	135.0±24.8
10	UTC Stores	551.0±21.1	284.0±17.6	46.0±6.1	12.0±1.2	75.0±6.6	81.0±5.8
11	NTC	85.0±9.4	46.0±9.9	21.0±2.9	12.0±6.0	113.0±12.0	90.0±7.6
12	Children Home Sc.	299.0±16.6	199.0±14.6	25.0±3.4	24.0±3.3	59.0±5.4	41.0±1.8
13	Oja Oba Area	540.0±23.4	206.0±12.1	29.0±4.0	57.0±5.6	80.0±7.2	30.0±3.1
14	Adeoyo Hospital	398.0±26.0	661.0±25.6	74.0±9.7	58.0±8.0	110.0±12.8	28.0±4.6
	Mean	299.0±16.5	355.0±19.7	40.0±5.8	31.0±5.9	95.0±7.8	63.0±7.5

S($BqKg^{-1}$) which relate Np to the absorbed dose and soil concentration of each radionuclide, respectively. The values for these factors obtained by Zombori et al, (1983) for gamma flux intensity at 1.0m above the ground using 7.6cm x 7.6cm NaI(Tl) scintillation detector are given in Table 1.

The average percentage difference (%) between the *in situ* and the laboratory methods was computed using the relation:

rules of thumb for determining significance from calculated F-values are $F < 2$ implies site is not significant, $2 < F < 5$ implies site is significant and $F > 5$ implies site is very significant (Benke and Kearfott, 1997). The results obtained show that ^{40}K, ^{238}U and ^{232}Th F- values were 0.32, 0.57 and 0.00, respectively.

Correlation coefficient, r, between the laboratory and the *in situ* results was obtained using the statistical analysis toolpak of Microsoft excel 5.0. Using a good rule of $r \leq 0.2$ for slight correlation, $0.2 < r \leq 0.4$ for low correlation, $0.4 < r \leq 0.7$ for moderate correlation, $0.7 < r \leq 0.9$ for high correlation and $0.9 < r \leq 1.0$ for very high correlation; the results of 0.65 for ^{40}K, 0.59 for ^{238}U and 0.63 for ^{232}Th show a moderate correlation between the laboratory and the *in situ* methods.

DISCUSSION

Figures 2,3,4 show the comparison between the *in situ* and the Laboratory analysis. Except for ^{40}K (more than half of the locations), the *in situ* results obtained in this work is greater than the laboratory results for ^{238}U and ^{232}Th in most of the sites considered. The opposite correlation to this result was found in the *in situ* and the laboratory comparisons of Daling et al (1990). Daling et al (1990) *in situ* data compared much better to the laboratory data than this work. Large deviations recorded between the *in situ* and the laboratory measurements in this work may be due to the fact that the samples collected for the laboratory analysis only accounted for a very small volume of soil as against the *in situ* measurements with gamma contributions from soil surface area up to hundreds of m^3 (Daling et al., 1990). However, the correlation obtained between the *in situ* and laboratory comparisons agrees with a similar work done by Benke and Kearfott (1997) except for the higher percentage error recorded in this work. The average % difference of -15.8, 29.0 and 50.8 was obtained for ^{40}K, ^{238}U and ^{232}Th, respectively. The large average % difference obtained for ^{232}Th may be attributed to the fact that the *in situ* gamma spectroscopy system has an upper detection limit of 2MeV. Therefore, efficiency calibration for *in situ* measurements at the gamma ray energy may not be very reliable.

The F- values returned show that the availability of the individual radionuclides in the soil is not a function of location for both the *in situ* and Laboratory analysis. This was expected since we only considered natural radionuclides.

The result obtained from the comparison of the laboratory and *in situ* methods shows that a reasonable level of confidence could be placed on *in situ* method, if a good calibration factor is employed. Therefore, the drawbacks normally experienced during laboratory method will be removed thereby making it a useful tool in an emergency monitoring.

CONCLUSION

A properly calibrated *in situ* spectroscopic system is not only a powerful tool for radiation background characterisation, but an appropriate tool for an emergency response assessments (Benke and Kearfott, 1997). The reliability of the calibration factor for an *in situ* environmental monitoring is of paramount important to the entire global effort to promptly detect gross contamination of the environment. Effective and proper management of the environment could only be achieved if equipment needed in this regard are reliable.

Acknowledgement

Special thanks to the entire staff of Federal Radiation Protection Service, University of Ibadan, Western Nigeria.

REFERENCES

Alberto, M., Milena, R., and Annibale, G; 1997. A Radiological Investigation on the Monazite Sands of the Atlantic Brazilian Shore. Nuclear Geophysics, 19(5): 453 - 459

Beck, H.L., Decompo, J., Gologak, J; 1972. In-situ Ge(Li) and NaI(Tl) gamma ray spectrometry, HASL-258.

Benke, R.R. and Kearfott, K.J; 1997. Comparison of In situ and Laboratory gamma spectroscopy of natural radionuclides in desert soil. Health Physics, 73(2): 350-361.

Daling, L., Chunxiang, Z., Zujie, G., Xian, L., Guorang, H; 1990. Gamma - spectrometric measurements of natural radionuclide contents in soil and gamma dose rates in Yangjiang, PR . China Nucl. Istrum. Methods Phys. Res., AZ99: 687 - 689.

Ibrahiem, N.M., Abd El Ghani, A.H., Shawky, S.M., and Farouk, M.A; 1993. Measurement of Radioactivity

levels in soil in the Nile Delta and Middle Egypt. Health Physics, 64(6): 620 - 627.

Jaworoski, Z; 1982. Natural and man-made radionuclides in global atmosphere. IAEA Bulletin, 24(2): 35 - 40.

Murith, C.H., Ribordy. L., Surbeck, H., Voelkle, H., Czarnecki, J., Schuler, J; 1988. Environmental In-situ gamma spectroscopy in Switzerland. Environ. International, l(14): 353-361.

Miller, K.M. and Shebell, P; 1993. In situ gamma-ray spectroscopy; a tutorial for Environmental radiation scientists. New York: U.S Department of Energy; Environmental Measurements Laboratory, Report No. EML-557.

Miller, K.M., Shebell, P., Klemic, G.A; 1994. In situ gamma spectrometry for the measurement of Uranium in surface soils. Health Physics, 67: 140-150.

Zombori, P., Nemeth, I., Laszlo, K., Andor, A; 1983. Callibration factor for in situ measurements. Izotoptechnika 26 : 81.