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AREA MONITORING OF AMBIENT DOSE RATES IN PARTS OF SOUTH-WESTERN NIGERIA USING A GPS-INTEGRATED RADIATION SURVEY METER

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A radiation monitoring system comprising a Geiger–Muller counter connected to a smart phone via Bluetooth was used for a dose rate survey in some parts of south-western Nigeria. The smart phone has the Geographical Positioning System, which provides the navigation information and saves it along with the dose rate data. A large number of data points was obtained that shows the dose rate distribution within the region. The results show that the ambient dose rates in the region range from 60 to 520 nSv $^{-1}$ and showed a bias that is attributable to the influence of geology on the ambient radiation dose in the region. The geology influence was demonstrated by superimposing the dose rate plot and the geological map of the area. The potential applications of the device in determining baseline information and in area monitoring, e.g. for lost or abandoned sources, radioactive materials stockpiles, etc., were discussed in the article, particularly against the background of Nigeria's plan to develop its nuclear power program.

INTRODUCTION

The natural background radiation level in an area varies spatially according to the geology, but both spatial and temporal variations could also be caused by human activities, such as mining; nuclear weapon tests; accidental or normal releases from nuclear power reactors; transport, stockpile and abandonment of radioactive materials; etc. It is indispensable to establish baseline information on the natural background radiation of an area before commencement of any practice and/or occurrence of a radiological event[(1, 2)]. It is also important to delineate additional contributions from various anthropogenic sources of radiation[(3)], some of which are pertinent to nuclear security, which is the 'prevention and detection of, and response to, theft, sabotage, unauthorized access, illegal transfer or other malicious acts involving nuclear material, other radioactive substances or their associated facilities'[(4)]. Specifically, there is an IAEA draft document[(5)] that recommends that competent authorities should develop appropriate detection systems and instrument deployment plans to combat nuclear terrorism.

Gamma dose rate measurements have been used in various parts of the world to establish baseline information[(3)] and/or to delineate radiation anomalies in the environment[(4)]. In Taiwan, Chang *et al.*[(3)] used car-borne gamma dose rate device to detect enhanced radioactivity levels along a street, necessitating the removal of the top surface layer of the contaminated section of the street. Data of absorbed dose rates carried out in Tokyo[(1)] in 2003 served as baseline for the accurate assessment of the effects of radionuclides contamination from the Fukushima Daiichi nuclear power plant accident in 2011. Al-Azmi[(6)] also used a car-borne Geiger–Muller (GM)-based survey meter connected with a Geographical Positioning System (GPS)-integrated smart phone to measure the ambient gamma dose rates in Kuwait, which aimed at deriving the baseline information in Kuwait.

Many outdoor gamma dose rate measurements have also been reported at various times and in various locations in Nigeria[(7, 8)]. These surveys can be validated and used to construct the baseline data for the country, but there is also a proposal to develop a network of radiation monitoring systems that will conduct a well-coordinated environmental radiation monitoring program all over the country. The proposal was predicated on the plan to develop nuclear power program in Nigeria and the needs for environmental monitoring. It is anticipated that such a system will comprise mobile as well as stationary detection systems, and have capacities for delineation of temporal and spatial distributions of radiation and radionuclides. Results of a screening survey of dose rates carried out as a prelude to the proposed nationwide network are presented in this article. Correlation between the spatial distribution of the dose rates and the variations in the geology of the areas covered within the south-western part of Nigeria is discussed.

MATERIALS AND METHODS

The study area

The area covered in the study comprises the major towns (mainly Lagos, Abeokuta, Ibadan, Ife, Ilesha and Ondo, and the roads linking them) in the south-western part of Nigeria. Figure 1 shows the political map of Nigeria showing the major towns. The area is bound between latitudes 60°00′ and 8°00′ N and longitudes 2°40′ and 5°30′ E. The geology varies from the sandstones and clayey gravels in the coastal towns (Lagos, Ikorodu, etc.) to quartz and migmatite gneiss and complexes in the inter-land towns including Abeokuta, Ijebu-ode and Ibadan.

Dose rate monitoring device—BlueGeiger

The gamma radiation survey meter used in the work is a GM-based device with brand name 'BlueGeiger PG-15' from Kindenoo, France. The dose rate measurement ranges 0.05–300 $\mu Sv\,h^{-1}$ with an accuracy of ±10%, and its factory calibration was approved by the IRSN (France). It is light weight (124 g without batteries) and works with 1.5 V AA batteries (alkaline or rechargeable). The device has an inbuilt Bluetooth communication system, which enables data transfer to an Android™ phone with a dedicated Kindenoo application[6, 9] (Figure 2). The dose rate values are recorded every 6 seconds by the BlueGeiger and transmitted to the personal phone where the average is obtained every 2 minutes and then recorded together with the corresponding GPS location information to allow the visualization of the readings on a map. It is possible to export the data to other software packages like Excel® and geographical software package (like Google-Earth®)[6].

Dose rate measurements and area survey

Test measurements

A number of comparative measurements were performed between the BlueGeiger and another GM-based radiation dosemeter, which is an optional accessory to the radon detector called 'AlphaGuard'. The details of the comparison measurements, which include taking the background levels of the two devices when enclosed in lead shield, etc, were provided in an earlier publication by Al-Azmi[6]. The goal of the inter-comparison between the two devices is to evaluate the appropriateness and/or adequacy of the BlueGeiger as a gamma dose rate measuring device.

Area survey

The BlueGeiger and the Android phone were transported from one location to another within the specified region, mainly along the major roads linking the major towns. Most of the measurements were concentrated around the town of Abeokuta, which have been associated with higher natural background radiation levels in some of the previous survey[7, 8].

Figure 1. Political map of Nigeria showing major towns.

Figure 2. The BlueGeiger PG−15 and an Android™ cell phone[9].

RESULTS

Results of test measurements

Result of the inter-comparison test between the responses of BlueGeiger PG-15 and the AlphaGuard-integrated GM radiation dosemeter is presented in Table 1. The BlueGeiger PG-15 data are generally higher than those of the AlphaGuard-integrated GM by ~30–40 $nSv{\cdot}h^{-1}$. The readings recorded with the BlueGeiger show a wider variations of data possibly due to the shorter sampling time interval (2 minutes) compared to the 10-minute sampling interval of the AlphaGuard-integrated GM dosemeter and probably due to a difference in their sensitivities. The BlueGeiger GM was further enclosed in a 5-cm lead shield in the Radiation Physics laboratory at the Department of Physics, Federal University of Agriculture, Abeokuta, Nigeria, and monitored continuously for over 1 hour. The result varied from 60 to 100 nSv·h^{-1}.

Result of area dose rate survey

A total of 1853 data points were obtained across the towns. The dose rates vary widely from 60 to 520 nSv h^{-1}, with the corresponding mean and standard deviation of 210 ± 79 nSv h^{-1}. Figure 3 shows the histogram distribution of the dose rates in air across the region. It is log-normal and skewed towards the lower values.

To demonstrate the influence of geology on the dose rates distribution, the dose rates were color coded and the data points were plotted and superimposing on the geological map of the area (Figure 4). The 'hot' zone is around the town of Abeokuta, which is underlain with basement/granitic rock formation. This area has earlier been reported as a high natural background radiation area[7, 8].

DISCUSSION

The result of this screening survey suggests that the dose rates distribution is 60–520 nSv h^{-1} with a mean of 210 ± 79 nSv h^{-1}, which is generally high compared to the typical values (Range: 7–140 nSv h^{-1} corresponding to 20–200 nGyh^{-1}; global population-weighted average: 39 nSv h^{-1} corresponding to 59 nGyh^{-1}) reported elsewhere around the world[10]. This may be attributable to the nature of the geology of the study area that is predominantly of the Precambrian basement complexes. The highest dose rates correspond to places around Abeokuta, which have also been identified by various authors as one of the highest natural background radiation areas in Nigeria [7, 8]. In this regard, the device has demonstrated good potential for discerning variations in the environmental radiation level, which could be due to differences in the geology or other anomalies, including those that may be human induced. It should also be noted that the present survey has not taken the influence of travel rates and vehicle shielding into

Table 1. Comparison of the results of gamma dose rates measured using the BlueGeiger PG−15 and AlphaGuard-integrated GM dosemeter (Source: Al-Azmi[6]).

S/No		Mean value (and range) of dose rates (nSv h^{-1}) BlueGeiger GM (2-minute sampling)	AlphaGuard GM (10-minute sampling)
1.	Inside 10-cm lead shield	61.8 (20–100)	30.6 (14–52)
2.	Indoor location	134.4 (70–190)	94.6 (76–108)

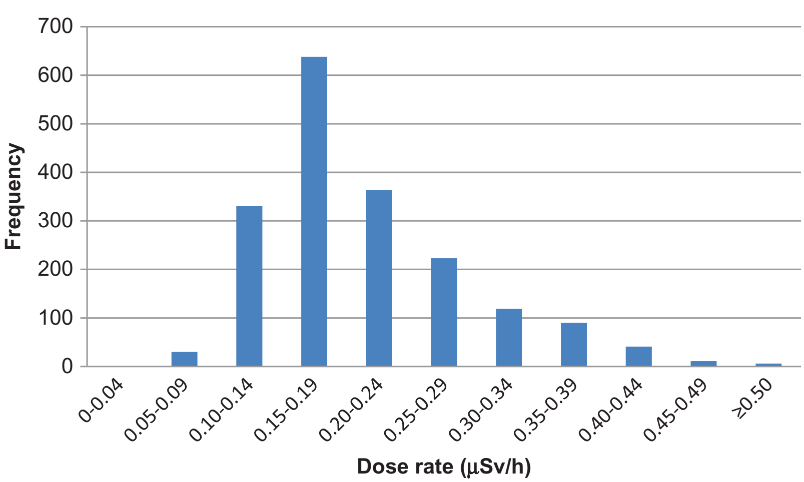

Figure 3. Histogram of dose rate distribution.

Figure 4. Absorbed dose rate. Superimposition of absorbed dose rates on geological map of south-western Nigeria.

consideration and should be explored further in future study.

The test measurements carried out with the BlueGeiger enclosed in lead shields, however, shows that the device has generally overestimated the terrestrial background radiation levels in the area by as high as 60–100 nSv h^{-1} due to its inability to discriminate against the contribution from cosmic radiation. This is a serious limitation in the applicability of the device for environmental radiation monitoring. In that case, a scintillation detector-based device would be more appropriate. But special feature of the BlueGeiger, particularly its capability to login dose rate and GPS data by coupling it with an Android mobile phone through Bluetooth connection, as well as the ease of uploading and transferring the data for further analysis, should be emphasized and adopted.

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