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TERRESTRIAL GAMMA RADIATION EXPOSURE MEASUREMENT AND RISK ESTIMATES IN THE ENVIRONMENTS OF MAJOR INDUSTRIES IN OTA, NIGERIA

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Abstract

Measurements of the terrestrial gamma radiation exposure have been carried out in the environments of major industries in Ota using a portable survey meter. When fast estimates are required, the in-situ method is more appropriate as this allows for quick results; preventing further exposure of the public and permitting quick intervention. The motivation for this study resulted from the uncertainty in the general public opinion on the effect of the presence, and activities of some of these industries in their environment. Measurements were taken twice daily within the vicinity of each industry to determine the dose levels. The mean values obtained range from 0.11 – 1.80 µSv/h. These values are within the results obtained from normal background areas except for site number 10. Annual effective dose values range from 0.25 – 5.21 mSv with a mean value of 1.21 mSv. Routine activities in some of these environments may have contributed significantly to the ambient natural background radiation resulting in values obtained in some of these locations. The total risks disparately estimated for cancer and genetic effects resulting from the results obtained range from 0.17×10^{-4} – 3.80×10^{-4} with a mean value of 0.94×10^{-4}. These levels are within the range of the average annual risk for accidental death for all industries.

Key words: *air exposure, industrial contamination, risk estimates.*

Introduction

Awareness on exposure to radionuclides and its technological enrichment, in industrial as well as environmental spheres is on the increase. Unfortunately generic errors repeatedly arise, namely associating ambient radioactivity only with the nuclear industry, and actually the assumption that radioactivity is strictly unnatural. The natural radiation environment has also activated and catalyzed some of the key stages in the evolution of life. Moreover, the fusion reactors – the sun and stars – have provided the nuclear energy which is the primary source of our daily light, heat, climate, and in fact our alternative and secondary energy sources such as coal, oil, gas, wood, peat, wind, and others. Radioactivity in rocks likewise serves as geothermal energy supplies (Baxter, 1993). Hence, nearly all industrial

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and domestic heating sources are primarily of nuclear origin. Similar radioactivity enhancements are associated with industries such as production of titanium oxides, rare earth compounds, mineral waters, paint and ceramics, and in the use of tailings from the alum shale industry and of zirconium-rich sands; in the colouring, clothing, lime burning, oil and construction industries (Baxter, 1993).

The fundamental drive for measurement of radioactive contamination in the environment is that it results in human exposure (Akinloye et al., 2010). In order to achieve accurate assessment of the average dose to human population from natural radiation sources, gathering much data on natural background radiation is crucial, and all involvement towards this is deemed valuable. Land and water can be contaminated through deposition of materials initially hosted in the atmosphere, or from waste products released into surface or subsurface waters or the ground, from which they are ultimately mobilized by the ground water or erosion (Dimovska et al., 2010). The radiological impact to the human population is from exposure to terrestrial gamma radiations, inhalation of air containing radon, consumption of industrial and agricultural products and, water. Human beings are exposed to the terrestrial gamma radiation dose which depends on the type of the soil, geological features and geographical conditions (Dimovska et al., 2010).

Naturally occurring radioactivity is found in greater quantity in some areas of the country than others (Akinloye et al., 2012). Radiation exposure rate will ultimately vary from one area to another. The knowledge of the natural terrestrial gamma radiation dose levels to the population in this study area will play an important role in radiation protection. Several studies have investigated the radiation exposure rate in both indoor and outdoor environments in some other parts of the country (Ajayi, 2000; Mokobia and Balogun, 2004; Akinloye et al., 2004; Ademola and Oguneletu, 2005; Chad-Umoren et al., 2006; Akinloye et al., 2010; Okeji and Agwu, 2011; Akinloye et al., 2012).

Monitoring radiation levels involves both *in situ* and laboratory methods (Akinloye et al., 2012). The particular method to be employed depends on several factors. When fast estimates is required, the in-situ method is more appropriate as this allows for quick results; preventing further exposure of the public and permitting quick intervention.

The motivation for this study is born out of the uncertainty in the general public opinion on the effect of the presence, and activities of some of these industries in their environment. Hence, the current study has employed in-situ method. The results obtained will add to the literature on this basis and guide any future monitoring and recommendations. The objectives of this study include assessment of the radiation exposure levels around the major industries in the city of Ota, and to investigate the risk due to the dose levels observed in these areas. The data obtained will be useful to regulatory authorities in the implementation of radiation protection standards for the general population in the country.

Material and methods

The Study Area

Ota is a city that has an estimated population of 300,000 and estimated land cover of 878 km^2, lying between 6^o 41 N and 3^o 41 E. Ota is founded on a wide undulating lowlands, a part of the coastal sedimentary rocks of Western Nigeria. It has the third largest concentration of industries in Nigeria, hence many of the residents earn their living as workers in these industries. The products and raw materials for these industries include latex, cereals, cassava, iron, polymer, steel, copper, silica, limestone, timber, automobile, metals, pharmaceutical, beverages, liquor, Aluminum, glass, pulp, chemicals, gas, paint, PET, plastics, detergent, resin, etc. Other major occupations include farming, trading and teaching. Resulting from unregulated population distribution and inefficient land use act in Ota, many of these industries are surrounded by residential buildings. Ota serves as an important road function between Abeokuta and Lagos, the lead commercial center of Nigeria.

Methodology

The detector used for this work is a portable, digital Rados (RDS-30) survey meter, manufactured by Arrow Tech Inc., located at 417 Main Ave. West Rolla. This survey meter was designed for a wide range of applications with the possibility of detecting abnormal radiation levels. It measures the dose rate within a range of 0.01 – 100 µSv per hour, and 0.1 – 10 rem per hour. During measurement, the meter was held at approximately 1 m from the ground. Once the survey meter stabilizes, the readings were taken from the indicator. At every location, measurements were repeated to generate an average value. Measurements were taken twice daily at 9 am and 3 pm within the vicinity of each industry to determine the dose levels to the workers occupying the area and the general public who through their visit to these industries may be exposed.

Determination of Annual Effective Dose

It was observed during this survey that most of the workers work for an average hour of 8 per day. Thus an occupancy factor of 0.33 was derived for the workers in this environment for accurate estimation of the effective dose. At this occupancy level, the annual effective dose H_E ($\mu Sv\ y^{-1}$) was estimated with equation 1.

$$H_E = E \times T \qquad [1]$$

where E ($\mu Sv\ h^{-1}$) is the measured exposure rate values, T (hy^{-1}) is the occupancy time given in equation 2 as (Akinloye et al., 2012):

$$T = \text{occupancy factor} \times 24h \times 365.25\ d \qquad [2]$$

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Results and discussion

The mean values obtained from the daily measurements are recorded in Table 1 (column 2). The effective dose values and the estimated risk level due to the measured exposure level are also presented in the Table (Column 3 and 4, respectively). The exposure rate values range from 0.09 – 1.80 µSv/h with an average value of 0.45 µSv/h. The mean deviations obtained from these daily measurements range from 0.000 – 0.320. These show minimal variation and account for good stability of the instrument employed throughout the measurement period. Only one location (number 10) recorded value above the results obtainable from normal background radiations environment, a range of 0.27 – 1.55 µSv/h (UNSCEAR 1988, 2000).

Table 1
The exposure rate E, the annual effective dose H_E and the risk level.

SITE	MEAN E (µSv/h)	H_E (mSv/y)	RISK LEVEL (x 10^{-4})
1	0.11 ± 0.000	0.30	0.22
2	0.18 ± 0.063	0.51	0.37
3	0.14 ± 0.110	0.40	0.29
4	0.33 ± 0.075	0.96	0.69
5	0.75 ± 0.050	2.17	1.58
6	0.28 ± 0.203	0.82	0.59
7	0.78 ± 0.075	2.24	1.63
8	0.58 ± 0.175	1.66	1.21
9	0.75 ± 0.300	2.17	1.58
10	1.80 ± 0.050	5.21	3.80
11	0.10 ± 0.010	0.28	0.20
12	0.78 ± 0.075	2.24	1.63
13	0.09 ± 0.030	0.25	0.17
14	0.11 ± 0.003	0.33	0.23
15	0.15 ± 0.003	0.43	0.31
16	0.81 ± 0.295	2.33	1.69
17	0.15 ± 0.015	0.43	0.31
18	0.53 ± 0.075	1.52	1.10
19	0.14 ± 0.018	0.41	0.30
20	0.63 ± 0.125	1.81	1.31
21	0.78 ± 0.025	2.24	1.63
22	0.43 ± 0.320	1.24	0.90
23	0.09 ± 0.005	0.25	0.17
24	0.13 ± 0.018	0.35	0.25
25	0.12 ± 0.013	0.34	0.24
26	0.73 ± 0.273	2.10	1.53
27	0.14 ± 0.018	0.40	0.29
28	0.75 ± 0.000	2.17	1.58
29	0.13 ± 0.020	0.36	0.26
30	1.05 ± 0.050	3.04	2.21

Annual effective dose values range from 0.25 – 5.21 mSv with a mean value of 1.21 mSv. Values of the annual effective dose obtained in this work are higher in locations 5, 7, 8, 9, 10, 12, 16, 18, 20, 21, 22, 26, 28 and 30 than the lower limit of 1 mSv recommended for continuous exposure (NCRP, 1993; ICRP, 2007). People who occupy these locations continuously (the case of workers) may be, subject to these results, overly exposed. All the values obtained however (except site 10 whose value exceeds by just 0.2), are below the recommended lower limit of 5 mSv for infrequent exposures (NCRP, 1993; ICRP, 2007). This therefore implies that the general public who may be exposed by reason of their visitations to these industries for any form of transaction, are within the safe limit of exposure.
Routine activities in some of these environments may have contributed significantly to the ambient natural background radiation resulting in high values as obtained in some of these locations. There is a need to characterize the radioactivity level observed in these environments, in order to ascertain the precise value and the major contributor to the exposure. Hence, subsequent study will employ in-situ and laboratory based spectrometers.

Risk Estimates for Radiation Protection

The probability coefficients for stochastic effects, otherwise the risk for cancer and genetic effects from these exposure levels, were estimated in terms of the total detriments to the whole population i.e. 7.3×10^{-2} per Sv (ICRP, 1991), since there are no radiation factory or radioactive wastes from the sampling sites. The total risk disparately estimated for cancer and genetic effects resulting from the results obtained range from 0.17×10^{-4} – 3.80×10^{-4}. The mean value is 0.94×10^{-4}. According to Turner (1995), the annual rate of fatal accidents vary from about 0.2×10^{-4} – 5×10^{-4}, the lowest being for trade, manufacturing and service industries, and the highest for mining and agriculture. Therefore, the estimated risk levels from the current work are approximately within the range of the average annual risk for accidental death in a "safe" industry. Also, the risk estimates from the studies of industrial miners from many parts of the world have been averaged at value per WLM^{-1} of 0.16, 0.34, 0.42, 0.89, 0.76, 0.95, 1.72, 2.21, 0.36, 0.19 and 5.06 respectively from China, Czech Republic, Colorado-USA, Ontario-Canada, Newfoundland-Canada, Sweden, New Mexico-USA, Beaverlodge-Canada, France, Port Radium-Canada and Australia (HPA, 2009). Adjusting these values using the dose conversion factor of 5 mSv WLM^{-1} (Vaillant and Bataille, 2012), results in risk (detriment) per Sv value of 3.2×10^{-2}, 6.8×10^{-2}, 8.4×10^{-2}, 17.8×10^{-2}, 15.2×10^{-2}, 19.0×10^{-2}, 34.4×10^{-2}, 44.2×10^{-2}, 0.72×10^{-2}, 3.8×10^{-2} and 101.2×10^{-2} respectively. The risk estimates from these studies are obviously higher than the results obtained from the current study. However, an analysis on risk to fatal occupational accidents from various industries in the United State reported a decline to 4.3×10^{-5} (Loomis et al., 2003), a value clearly lower than the results obtained from this study.

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Conclusions

The fundamental incentive concerning radioactive contamination of the environment is that it gives rise to human exposure. Measurements of the exposure rate in air due to gamma radiations in the environments of some industries in Ota have been undertaken in this work. A portable survey meter was used for the measurement. Measurements were taken twice daily within the vicinity of each industry to determine the dose levels. The mean values obtained range from 0.11 – 1.80 µSv/h. These values are within the results obtained from normal background areas except for site number 10. From the annual effective dose values obtained in this work, the general public who may be exposed by reason of their visitations to these industries for any form of transaction, are within the safe limit of exposure. Values obtained are however high for continuous exposures. The risk levels estimated from the results obtained are within the range of the average annual risk for accidental death for all industries. Also, the risk estimates from this study are lower than those estimated from the studies of industrial miners from many parts of the world. This study advocates further monitoring of this environment so as to characterize and determine precise elevation to the background radioactivity level.

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