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RESEARCH PAPER

IONIZING RADIATION MEASUREMENTS AND ASSAY OF CORRESPONDING DOSE RATE AROUND BOTTLING AND PHARMACEUTICAL FACILITIES IN ILORIN, NIGERIA

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ABSTRACT

Measurements of ionizing radiation and corresponding dose rate around bottling and pharmaceutical facilities in Ilorin, Nigeria, have been carried out using three duly calibrated Radalert Nuclear Radiation Meters and Global Positioning System. The survey meters were held at 1 m above the ground surface while obtaining readings at 31 locations within the study area. Measured radiation levels range from 1.14±0.09 to 2.48±0.13 mSv/yr with a mean of 1.60±0.26 mSv/yr. The result shows that the exposure rates for all the stations are higher than the radiation dose limit of 1 mSv/yr for individual members of the public, while three stations are above the global average of 2.4 mSv/yr. It is recommended that areas with readings above global average be monitored closely to protect the public from adverse health effects.

Keywords: *Gamma radiation, Ionizing, Dose Rate, Ilorin, Nigeria*

INTRODUCTION

Industrial activities account for a significant percentage of contribution to total environmental pollution and general degradation of the natural environment that we experience today (Oke 2004; Inyang *et al*., 2009; EEA, 2011). Our environment contains naturally occurring radioactive materials, which spontaneously disintegrate to form stable nuclei and in the process release radiation to the environment (IAEA, 2004). In addition, technologically enhanced naturally occurring radioactive materials are produced as a result of industrial activities, which also contribute to the average radiation profile of the environment (NNRA, 2006). Hence the background ionizing radiation of the environment is a combination of natural and man-made sources (Chukwuocha and Enyinna, 2010). It is established that high level of radiation, above tolerable limits, carries serious health implications. Therefore, it is important that the quality of our environment be maintained in a good state, to ensure a high level of social performance that can be achieved by close monitoring of pollution factors (Avwiri *et al.,* 2009).

Radiation monitoring is a continuous or periodic measurement of dose or contamination for reasons related to the assessment or control of exposure to radiation or radioactive substances (IAEA, 2007). This is aimed at preventing deterministic health effects and reducing stochastic effects of radiation to an acceptable level (ICRP, 2012; 2013; UNSCEAR, 2001; USNRC, 2005). According to international recommendations, occupational exposure to radiation should not exceed 20 mSv/yr, while the public should not be exposed to more than an average of 1 mSv/yr (IAEA, 2004; Strom, 2003; USNRC, 2005; UNSCEAR, 2008), as depicted in Table 1.

Previous radiation study carried out at Asa-Dam industrial area of Ilorin, Nigeria showed that the average radiation level was approximately 1.13 mSv/yr (Nwankwo and Akoshile, 2005). In a similar work done by Chukwuocha and Enyinna (2010) within petroleum drilling areas of Rivers State, the authors showed that the average exposure rates ranged between 1.14 – 1.18, 1.09 – 1.18, 1.09 – 1.16 and 1.18 – 1.22 mSv/yr for the turbine joints, rig equipment environment, wellheads and mud tanks respectively.

Likewise, Chad-Umoren and Briggs-Kamara (2010), surveyed the distribution of environmental ionizing radiation in Rivers State. The results show a mean dose equivalent of 0.745±0.085 mSv/yr (for upland campus environment), 0.690±0.170 mSv/yr (for rural riverine communities) and 1.270±0.087 mSv/yr (for industrial zone), which indicate an inhomogeneous radiation profile within the state. They concluded that the differences may be due to variations in levels of industrial activities in the area. Similar increase in environmental radioactivity in other cities in Nigeria has also been reported (Ajayi, 2001; Kuforiji *et al.*, 2003; Arogunjo *et al.*, 2004; Isinkaye and Ajayi 2006; Ajayi *et al.*, 2006; Ademola, 2008; Farai *et al.*, 2008; Farai and Ademola, 2005; Alatise *et al.*, 2008; Inyang *et al*., 2009).

This study involves the determination of ionizing radiation levels around bottling and pharmaceutical facilities in Ilorin metropolis with a view to assessing whether the radiation profile is within tolerable limit.

The Study Area

The study area falls within the central part of Ilorin, Nigeria (Fig.1). This area lies entirely within the basement complex terrain of Nigeria. The basement rocks are mainly bounded gneiss and auger gneiss with granodiorites and granites intrusions. The Nigeria basement complex consists of at least four main groups of rocks: The migmatite gneiss complex, the metasediment (composed of schist, calc-gneiss, quartizite and meta-conglomerate), the porphyritic older granite and the miscellaneous rock types, which are mostly post orogenic rocks like aplite, pegmatites, and dolerites dykes. These rocks are younger and are found to cut through pre-existing rocks (Rahaman, 1973).

METHOD OF STUDY

Basic Theoretical Considerations

The fundamental equation of radioactivity is based on the concept of radioactivity decay. This decay is a phenomenon by which large number of nuclei spontaneously emits elementary particles or nuclear radiation. The rate of decay has been found to be proportional to the number of nuclei N present in the material (Weinert, 2009; Kragh, 2012):

$$-\frac{dN}{dt} \propto N \qquad (1)$$

where the negative sign indicates increasing N as time t increases.

Consequently, the radioactive decay law is derived:

$$\frac{dN}{dt} = -\lambda N \qquad (2)$$

where λ is a positive constant called decay con-

Table 1: Basic exposure limits

Exposure	IAEA Basic Safety Standards (Safety Series-15)	ICRP-103
Effective Dose Annual (Occupational) Effective Dose Cumulative (Occupational)	20 mSv/y averaged 5 years, not exceed 50 mSv in any single year	20 mSv/y averaged 5 years, not exceed 50 mSv in any single year
Equivalent Dose Annual (Occupational)	For lens of eye: 20 mSv/y; 500 mSv/y for skin, hands and feet	For lens of eye, Skin and hands and feet: 20 mSv/y averaged 5 years, not exceed 50 mSv in any single year
Effective Dose Annual (Public)	1mSv/y	1 mSv/y; higher if needed, provided 5-yr annual average is less or equal to 1 mSv
Equivalent Dose Annual (Public)	15mSv/y for lens of eye; 50mSv/y for skin, hands, feet	15 mSv lens of eye; 50 mSv skin, hands, feet

Fig. 1: Geographical map of Nigeria showing Ilorin City

stant. It depends on the radioactive material and has a unit of s^{-1}

The solution of Equation 2 has a form which gives what happens at all times:

$$N_t = N_0 \exp(-\lambda t) \qquad (3)$$

where N_0 is the amount of material at time t = 0.

Equation 3 shows that the number of radioactive nuclei will decrease exponentially with time and the rate of decrease being controlled by the decay constant λ. Invariably, when the decay constant has a low value, the exponential curve decreases relatively slowly and when high, the curve decreases very quickly.

Another important concept is the Half Life. This is the time taken for the radioactive material to decrease by half. This is shown mathematically as:

$$N_T = \frac{N_0}{2} = N_0 \exp(-\lambda T) \qquad (4)$$

and

$$T = \frac{1}{\lambda} \ln 2 \qquad (5)$$

Equation 5 gives the relationship between radioactive decay constant and half-life. The half-lives of some materials and the radiation released by them are shown in Table 2.

Field Measurements

In-situ measurements of the background radiation level were carried out using three portable Nuclear Radiation Monitors (Radalert-100) and Global Positioning System (GPS). Calibration of the monitors was done using Cesium-137 as the standard radionuclide. The procedure for calibration is as reported in the monitors' operating manual (International Medcom, 2006). Field measurements were taken simultaneously using the three monitors at every 20 minutes interval for 10 successive readings per station.

Following standard procedure, the window of the radiation meters was held at a height of 1.0 m above the ground level (Kurnaz *et al.,* 2011). Thirty one (31) measurement points were strategically selected for adequate coverage of the industrial facilities in the study area.

Readings from the Radalert-100 monitors were obtained in units of mR/hr but recorded in mSv/yr. The conversion was done as follows: one (1) mR/hr is approximately equal to 9.6 x 10^{-3} mSv/hr; consequently, multiplying by the number of hours in a day (24) and the number of days in a year (365.242), the resulting conversion gives the results in mSv/yr.

RESULTS AND DISCUSSION

The results obtained from the measurements represent the external background radiation level of the studied area. The mean of the readings from each measurement location is shown in Tables 3 and 4.

The measured radiation levels for the studied locations range from 1.14±0.09 to 1.86±0.15 mSv/yr, with an average of 1.48±0.19 mSv/yr for Tuyil zone and 1.25±0.13 to 2.48±0.13 mSv/yr, with an average of 1.71±0.18 mSv/yr for bottling zone, while 1.14±0.09 to 2.48±0.13 mSv/yr, with an average of 1.60±0.26 mSv/yr is recorded for the entire surveyed area. The results reveal that the areas around the bottling facilities have the highest radiation levels (≥ 2 mSv/yr), with three measurement points having readings above global average (≥ 2.4 mSv/yr) for the general public. It has been reported that each member of the world population is exposed, on average, to 2.4 mSv/yr of ionizing radiation from natural sources (WHO, 2012). The results also show that the exposure rates for all the locations are more than the radiation dose limit of 1 mSv/yr for individual members of the public (USNRC, 2005). Comparisons of the mean exposure rates of each surveyed zone and that of the entire area with the dose limit are shown in Figs 2 and 3 respectively. Laboratory analysis of some soil samples in the area using gamma-ray spectroscopy revealed the presence of naturally occurring radionuclides.

Average activities of 412.27, 11.24 and 12.01 Bq/kg were obtained for ^{40}K, ^{238}U and ^{232}Th respectively, which give an estimated dose equivalent value of 0.27 mSv/yr. This is found to be within the typical range of 0.2 – 0.6 mSv/yr for average terrestrial gamma rays exposure due to radionuclides in the soil (WHO, 2012). Therefore, it could be suggested that more con-

Table 2: Natural radiation decay series (Radiation, 2013)

Radioisotope	Half Life (approx.)	Radiation
Uranium-238	4.47 billion years	alpha, x-rays
Thorium-234	24.1 days	beta, gamma, x-rays
Protactinium-234m	1.17 minutes	beta, gamma
Uranium-234	245,000 years	alpha, x-rays
Radon-222	3.83 days	Alpha
Polonium-218	3.05 minutes	Alpha
Lead-214	26.8 minutes	beta (700 keV), gamma, x-rays
Bismuth-214	19.7 minutes	beta (0.5, 3 MeV), gamma
Polonium-214	164 microseconds	Alpha
Lead-210	22.3 years	beta, gamma, x-rays
Polonium-210	138 days	Alpha
Thorium-232	14.1 billion years	alpha, x-rays
Radium-228	5.75 years	Beta
Thorium-228	1.91 years	alpha, gamma, x-rays
Radium-224	3.66 days	alpha, gamma
Radon-220	55.6 seconds	Alpha
Polonium-216	0.15 seconds	Alpha
Lead-212	10.64 hours	beta (335 keV), gamma, x-rays
Bismuth-212	60.6 minutes	alpha, beta, gamma, x-rays
Polonium-212	0.305 microseconds	Alpha
Potassium-40	1.28 billion years	beta (1.3 MeV) , gamma

Table 3: Radiation levels around Tuyil pharmaceutical facilities

Stations	GPS	Mean Radiation Level (mSv/yr)
1	N08° 28.869′ E004° 33.324′	1.14±0.11
2	N08° 28.809′ E004°33.316′	1.14±0.09
3	N08° 28.779′ E004° 33.311′	1.37±0.15
4	N08° 28.707′ E004° 33.296'	1.70±0.23
5	N08° 28.669′ E004° 33.283′	1.34±0.27
6	N08° 26.645′ E004° 33.282′	1.49±0.27
7	N08° 28.610′ E004° 33.270′	1.16±0.20
8	N08° 28.574′ E004° 33.268′	1.64±0.46
9	N08° 28.501′ E004° 33.243′	1.78±0.13
10	N08° 28.468′ E004° 33.236′	1.82±0.16
11	N08° 28.458′ E004° 33.174′	1.86±0.15
12	N08° 28.453′ E004° 32.202′	1.62±0.08
13	N08° 28.411′ E004° 33.231′	1.47±0.19
14	N08° 752′ E004° 33.295′	1.25±0.16
	Average	**1.48±0.19**

Table 4: Radiation levels around bottling facilities

Stations	GPS	Mean Radiation Level (mSv/yr)
1	N08° 27.995′ E004° 33.633′	1.51±0.06
2	N08° 28.037′ E004° 33.624′	1.74±0.08
3	N08° 28.067′ E004° 33.62′	1.51±0.23
4	N08° 28.083′ E004° 33.62′	1.69±0.17
5	N08° 28.134′ E004° 33.624′	1.67±0.11
6	N08° 28.183′ E004° 33.629′	2.40±0.33
7	N08° 28.221′ E004° 33.633′	2.48±0.13
8	N08° 28.273′ E004° 33.639′	1.25±0.13
9	N08° 28.504′ E004° 33.652′	1.96±0.19
10	N08° 28.327′ E004° 33.662′	2.41±0.27
11	N08° 28.376′ E004° 33.654′	1.30±0.13
12	N08° 28.420′ E004° 33.669′	1.48±0.09
13	N08° 28.480′ E004° 33.670′	1.57±0.16
14	N08° 28.491′ E004° 33.650′	1.64±0.20
15	N08° 28.546′ E004° 33.688′	1.59±0.19
16	N08° 28.608′ E004° 33.692′	1.51±0.33
17	N08° 28.327′ E004° 33.662′	1.41±0.23
	Average	**1.71±0.18**

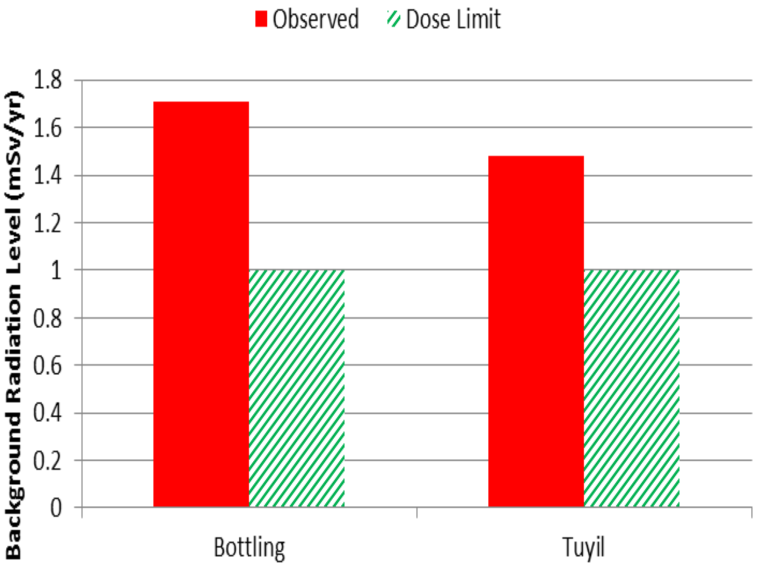

Fig. 2: Mean background radiation profile of each surveyed zone compared with radiation dose limit of 1 mSv/yr (USNRC, 2005) for the public.

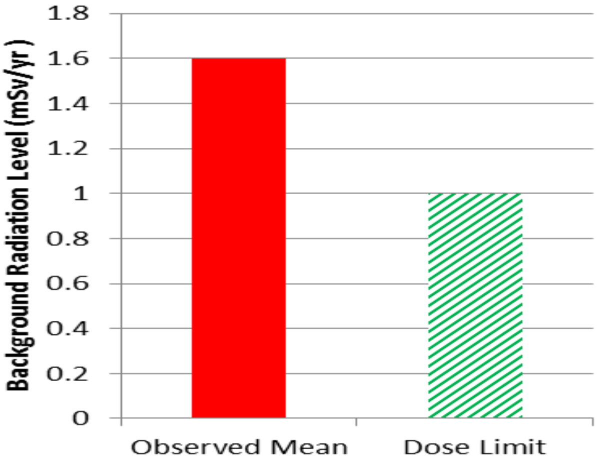

Fig. 3: Mean background radiation profile of the entire surveyed area compared with radiation dose limit of 1mSv/yr (USNRC, 2005) for the public

tributions to the radiation profile of the area are from other sources.

CONCLUSION

This study reveals the levels of external background radiation in parts of Ilorin where very little published data exists on such topics. Although the radiation levels measured in the study area are far below the safe radiation limit as recommended for non-nuclear work environment, the levels recorded are higher than the standard background radiation level for the general public. More so, three of the surveyed stations are above the global average for the general public. Although, the results obtained in this study may not pose any serious health implication to the occupational worker, it is highly recommend that the areas with considerable high readings (≥ 2.4 mSv/yr) be monitored closely to protect the general public from adverse health effects and remedial solution should be taken.

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