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Radiation emission levels from a waste dumpsite in Calabar, cross river state, Nigeria

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ABSTRACT

Increase in human population of major cities increases the rate and volume of waste generated. These wastes are either recycled or put in refuse dumps which at times are close to human settlements. This study is to evaluate the exposure rates in a dumpsite located in Calabar in comparison to world standards, estimate a radiologic "safety zone" and the Excess Lifetime Cancer Risk (ELCR) in the area. Exposure dose rates were determined at 10 locations of increasing distances of 5 meters using a portable radiation survey meter (CRM 100) and measurements were taken in air for two minutes at 1metre from the ground for a period of 5 weeks. The average exposure rate was 0.018±0.003 uSv/hr. The mean absorbed dose rate ranged from 0.033mSv/yr – 0.040mSv/yr with an average of 0.031±0.005mSv/yr. The calculated outdoor Annual Exposure Dose Rate (AEDR) ranged between 0.023mSv/yr – 0.028mSv/yr. The corresponding estimated ELCR averaged at 0.08 x 10^{-3} with a range of 0.064x 10^{-3} – 0.098 x 10^{-3}. It was found that the mean average exposure values obtained from the site were higher than the normal background standard reading. The computed effective dose rates were within international permissible limits. From the absorbed dose rates, a perimeter of 15 metres from the dumpsite would serve as the radiologic “safety zone” and the ELCR for the scavengers, dumpsite workers and residents around the dumpsite is low and within limits. The exposure rates are within permissible limits and the risk of developing cancers in the area is low.

Key words: Radiation, Emissions, Waste, Dumpsite, Background, Calabar

1. INTRODUCTION

Refuse dumps can be regarded as primary sources of environmental health hazards to the general public in major cities of the world. Besides the offensive odour that emanates from them, there are radiation emissions that can be detrimental to health (Ojoawo *et al.,* 2011). Thus, waste management is considered by governments as an essential service which has to be put in place following population growth projections (Eja *et al.*, 2010). Towns and cities that have experienced rapid growth have had to contend with the increased levels of waste generation. Urbanization and development bring about higher concentration of commercial, infrastructural, industrial and government activities in such urban areas.

Human activities have always generated waste. In Nigeria with a population of about 187 million people (National Population Commission, 2017), waste is still a problem with several challenges to be addressed. The constituents of these wastes, which are usually complex blends of biodegradable and non-biodegradable substances, are compositions of both the domestic and industrial wastes that are disposed of (Olubosede *et al.*, 2012).

Land filling is one of the most common methods of waste disposal globally (Taylor, 2003). Its management and operation is relatively convenient and low cost, making it favourable for low and middle income countries. In moderate climates, guidelines exist regarding the running of these landfills. In tropical climates, these guidelines cannot be applied because the running of the sites here differs.

As much as this is an alternative to waste management, it still poses environmental hazards in varying degrees based on its location from residential areas. Indiscriminate and arbitrary waste dumping is still a problem faced in most developing countries. This may pose a health risk to the population as this can have effects on the soil and underground water by way of pollution which can also lead to land degradation (Odunaike *et al.*, 2008).

Background ionizing radiation (BIR) is constantly emitted by refuse dumps and also Naturally Occurring Radioactive Materials (NORM) in the soil. These emissions occur when weathering processes occur (Elles *et al.*, 1997). A huge percentage of human radiation exposure comes from natural sources, with the earth itself being one of the sources (Lee *et al.*, 2004). Radon gas particularly is capable of producing alpha rays upon decay and may pose increased risk to cancers, eye cataracts if inhaled.

From the foregoing, the monitoring of terrestrial BIR is important especially from waste dumpsites if they are close to residential areas. Previous studies have revealed the existence of radionuclides in the soil and staple foods obtained in Nigeria (Imitiaz *et al.*, 2005; Eyebiokin *et al.*, 2005; Jibiri *et al.*, 2007; Chiaghanam *et al.*, 2019). It has also been discovered that portions of vegetation in the country have trace amounts of radionuclides (Akinloye and Olomo, 2005).

A study conducted by Avwiri *et al.* (2013) of the Aluu landfill showed that the radiation levels were higher than the standard background reading of 0.013mR/h. The equivalent dose was also found to be above the permissible value of 1.0mSv/y for the general public. Though no instantaneous radiological health threat to the public could be found in the area yet there may be future health concerns. This study becomes imperative as Calabar is a cosmopolitan city in Nigeria with a lot of human activities generating wastes. Land fill system of waste management is in use and the presence of human activities and residential apartments around the site raise a lot of concern.

2. STUDY SITE

This study was carried out in Calabar, Cross River State, Nigeria. It is the capital city of the State. Its Global Positioning System (GPS) coordinates are 4.9757° N, 8.3417° E with a population of 371,022 (National Bureau of Statistics). Calabar covers an area of approximately 604km^2 with an elevation of 32m. The city is divided into two local government areas: Calabar Municipal and Calabar South.

The sampling location is in Calabar Municipal. The dumpsite is located north east of the city with GPS coordinates 5.034899° N, 8.365246° E. The site accommodates all the waste generated in the capital city and is controlled by the State Ministry of Environment. The preliminary studies done included visitation of the dumpsite and identification of the management of the facility.

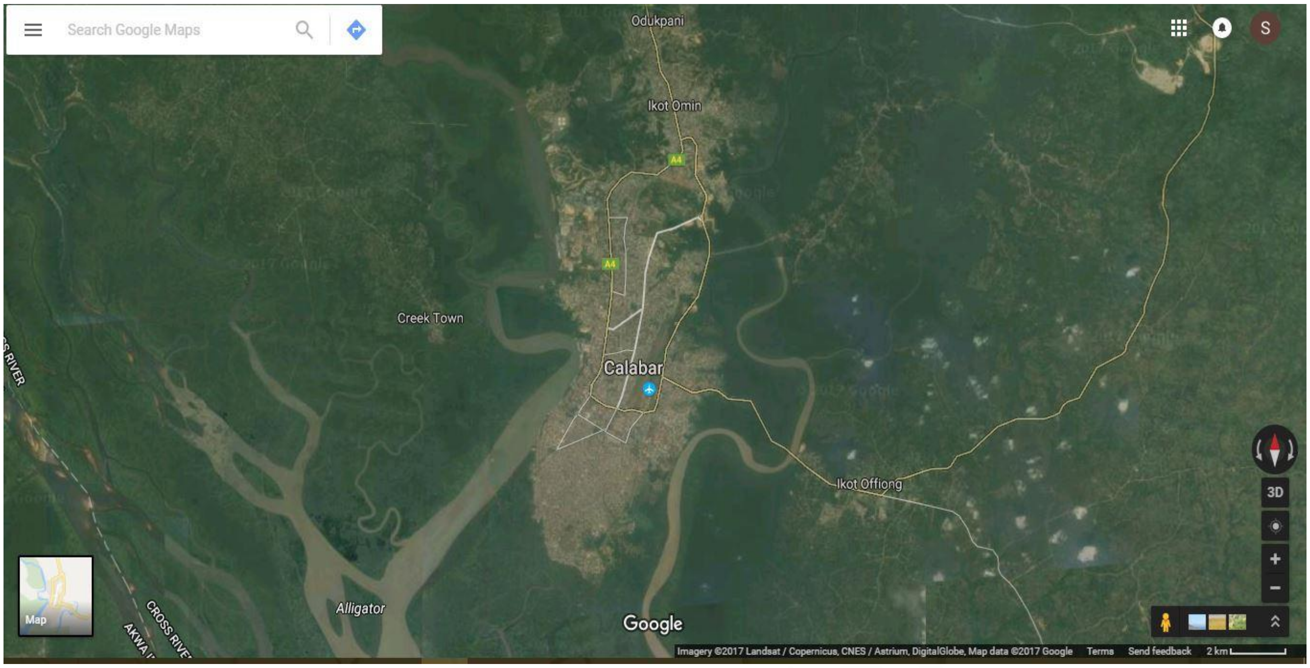

Figure 1 Aerial Map showing Calabar metropolis (Source: Google Maps. Accessed: 25/7/2017)

Figure 2 Aerial map showing the study site indicated by the red box (Source: Google Maps. Assessed: 25/7/2017)

Figure 3 Zoomed in view of the study site (Source: Google Maps. Assessed: 25/7/2017)

(a)

(b)

Figure 4 On-site photographs of the study site (Field Source)

3. DATA COLLECTION

A portable radiation survey meter CRM 100 with serial number 01697 was used to quantify the exposure levels in the field. Calibration was done in a standard laboratory of the National Institute of Radiation Protection and Research (NIRPR), Ibadan. It uses a Geiger-Muller tube for radiation detection, which generates an electrical pulse each time radiation passes through the tube. An *in situ* approach was ideal and implemented to ensure samples retained their unique environmental properties.

Readings were obtained in the field between the hours of 1pm and 4pm each day, because maximum response of the survey meter to radiation is achieved within this period (Louis *et al.*, 2005).

The detector was placed at one meter from the ground for effective detection. The highest stable point was recorded for each time the meter is switched on. The procedure was repeated at each selected distance and three readings in micro Sievert per hour ($\mu Svhr^{-1}$) taken. An average value was determined for each location. Measurements were taken weekly at 10 locations of increasing distances at an interval of 5 meters away from the reference point. The choice of having varying distances was to ascertain the exposure dose rate on scavengers, pedestrians, passengers in vehicles and residents around the dumpsite. The locations were marked and readings taken from the exact spots for uniformity.

A location was selected as control location, one kilometre from the study site, devoid of any buildings or waste from which normal background readings were taken. This was done to reduce interference of emissions from building materials, which have been found to emit some level of radiation (Inyang *et al.*, 2009).

The radiation exposure rate (σ) measurement was carried out using the survey meter in micro sievert per hour ($\mu Svhr^{-1}$). This is then converted to annual absorbed dose rate (ADR) in micro sievert per year ($\mu Svyr^{-1}$) using the formula:

$$\mathbf{ADR\ (mSv / yr) = \sigma\ (\mu Sv / h) \times OF \times 24hrs \times 365.25days \times 10^{-3}} \ldots\ldots(1)$$

Where:

ADR = Annual Absorbed Dose Rate in millisievert per year (mSv/yr)

σ = Exposure rate in millisievert per hour (mSv/h)

OF = Occupancy factor. This is described as the expected period members of the public would spend within the study area. It is set at 0.2 as it is expected that humans spend 20 percent of their time outdoors.

The absorbed dose was calculated from the measured exposure using the relationship:

$$D(nGy/h) = \frac{\sigma(\mu Sv/h)}{Q} \times 10^{-3} \quad \ldots\ldots\ldots\ldots(2)$$

Where:

D = Absorbed Dose measured in nano gray per hour (nGy/h)

σ = Exposure Rate measured in milliSievert per hour (mSv/h)

Q = Quality factor = 1.0 for gamma radiation

(UNSCEAR, 2000)

The annual effective dose rate (AEDR) per year received by workers and the population was obtained from the equation given below (UNSCEAR, 2000)

AEDR= D x 8760h x CF x OF................ (3)

Where:

AEDR = Annual Effective Dose Rate measured in milliSievert per year (mSv/yr)

D = Absorbed Dose Rate measured in nano Gray per hour

CF = Conversion factor of the absorbed dose in air to the effective dose (0.7Sv/Gy)

OF = Occupancy Factor = 0.2

Regarding one of the objectives of the study, the Excess Lifetime Cancer Risk (ELCR) was estimated using the equation

ELCR = AEDR x DL x RF.............. (4) (Taskin *et al.*, 2009)

Where:

ELCR= Excess Lifetime Cancer Risk

AEDR = Annual Effectiv`e Dose Rate

DL = Estimated duration of life (70 years)

RF = Risk Factor (Sv^{-1}). For stochastic effects in the body, ICRP 60 recommends values of 0.05 for the public (ICRP, 1990).

4. RESULTS

Radiation exposure rates were obtained from 10 locations at increasing distances of five metres from the study location. Calculated values of ADR, AEDR and ELCR are presented in Table 1. The mean background radiation measured at the study site was 0.013 uSv/hr. The mean exposure rates had a range of 0.015 uSv/hr to 0.023 uSv/hr with an average value of 0.018±0.003 uSv/hr. The study area had an overall mean absorbed dose rate ranged from 0.033mSv/yr – 0.040mSv/yr with an average of 0.031±0.005mSv/yr. The calculated outdoor AEDR ranged between 0.023mSv/yr – 0.028mSv/yr. The corresponding estimated ELCR averaged at 0.08 x 10^{-3} with a range of 0.064x 10^{-3} – 0.098 x 10^{-3}.

Table1 Values of ADR, AEDR and estimated ELCR

READING	DISTANCE (metres)	MEAN EXPOSURE RATE (uSv/hr) ± SD	*ADR (mSv/year)	**AEDR Outdoor (mSv/year)	***ELCR x10^{-3}
1	CONTROL	0.013±0.002	0.023	0.016	0.056
2	5	0.019±0.006	0.033	0.023	0.081
3	10	0.023±0.003	0.040	0.028	0.098
4	15	0.021±0.007	0.038	0.026	0.092
5	20	0.016±0.004	0.027	0.019	0.067
6	25	0.018±0.008	0.032	0.023	0.079
7	30	0.019±0.004	0.034	0.024	0.082
8	35	0.015±0.003	0.026	0.018	0.064
9	40	0.017±0.006	0.029	0.020	0.071
10	45	0.015±0.004	0.027	0.019	0.066
11	50	0.020±0.004	0.035	0.025	0.086

*ADR = Annual Absorbed Dose
**AEDR = Annual Effective Dose Rate
***ELCR = Estimated Lifetime Cancer Risk

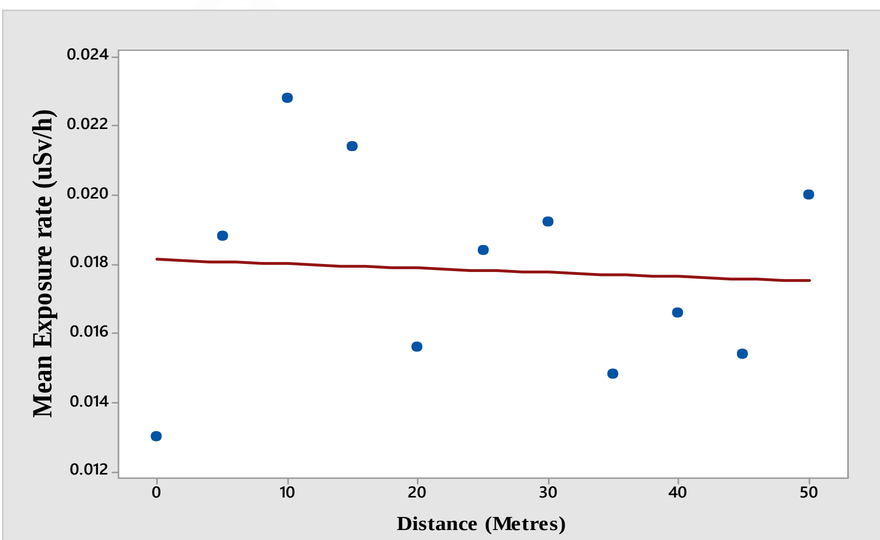

Figure 5 Scatter plot showing the observed exposure rates in the field

The observed exposure rates as shown in figure 5 depict an inverse relationship between the exposure rates and increasing distance with a mild slope. Figure 6 is similar to figure 5 with the negative mild slope of the calculated values of the mean absorbed dose rates against distance.

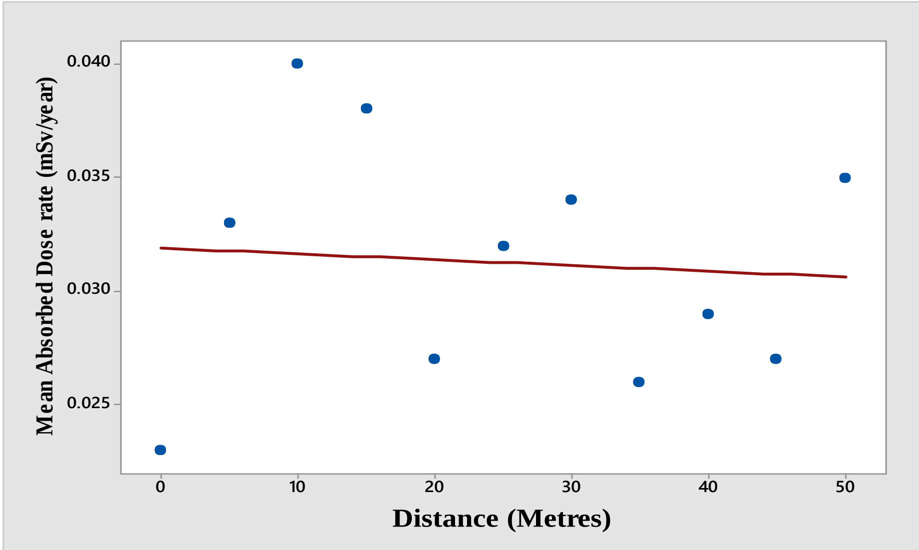

Figure 6 Scatter plot showing the calculated mean absorbed doses in the field.

5. DISCUSSION

The mean measured exposure was 0.018±0.003 uSv/hr. This was higher than the background ionizing radiation (BIR) of 0.013uSv/hr in the study area. It was also higher than the standard BIR value of 0.13uSvh^{-1}. It is known that the levels of radiation especially of the gamma type is directly associated with the activity of concentration of radionuclides in materials found at dumpsites (Taskin *et al.*, 2009).On physical inspection, wastes found in the study area include plastic, car tires, paper products, metal scraps, human waste, electronics and vegetable remains. The putrefying process that these items undergo could have been responsible for the high value recorded at the dump, where energy conversions occur.

The values as presented in figure 5 show that the exposures were highest within 15 metres of the dump. This means that the scavengers and site workers in the area are at greater risk of radiation hazards since by convention, radiation intensities decrease with increasing distance. This is in line with a study carried out by Olubosede *et al.*, (2012) who recorded that there was an inverse relationship of the exposure and absorbed dose rate as the distance from the dumpsite increased. Okoro *et al.* (2015) equally agrees with this finding.

The subsequent spiking in the graph at farther distances from the dumpsite may be due to the cumulative readings from emissions from residential building clusters in the area.

The mean of the computed absorbed dose rates recorded at the dumpsite was below the limit of 1mSv/year for the public and also below the dose limit of 20mSv/year for radiation workers as recommended by the ICRP (ICRP, 1990). Similar results were obtained by Olubosede *et al.,* (2012) and Emelue *et al.,* (2013). This could be attributed to the fact that more hazardous materials like medical waste, chemical wastes were not co-disposed at the dump. However, the groundwater and soil around the dumpsite may still be contaminated by the radionuclides.

Figure 6 shows the trend of the absorbed dose rates with increasing distance. Every dose of radiation exposure poses a risk of cancer. It was therefore imperative to compute a "radiologic safety zone" using the linear regression plot shown in figure 13. The "safety zone" was found to be at a distance of 15 metres. This zone is a region that can mitigate increased exposure rates to the public and offer them some protection, employing one of the cardinal points of radiation protection. Okoro *et al.,* (2015) computed the safety zone in their study to be 10 meters.

The mean calculated annual effective dose for outdoor radiation as presented in Table1 shows that the annual effective dose rate as well as the mean (1.78 x 10^{-5} mSv/year) were below international permissible limits for radiological workers and also below that for the general public. The AEDR values were lower than those obtained in another study carried out in landfills in another region in Southern Nigeria where a value of 2.4 mSv/yr was recorded (Avwiri and Olatubosun, 2014). This could be due to the difference in the type of waste deposited (plastic, car tires, paper products, metal scraps, human waste, electronics and vegetable remains) and the activity concentration of the radionuclides in the region.

In this study, excess lifetime cancer risks (ELCR) were estimated and the value obtained was 0.08 x 10^{-3}. This was observed to be lower than the world limit of 0.29 x 10^{-3} (Taskin *et al.*, 2009). The ELCR from the background radiation reading (0.06 x 10^{-3}) was also lower than the world limit. This implies that the probability of developing cancer over a lifetime by the scavengers and residents around the dump is low.

6. CONCLUSION

The radiation emission levels from the study area are within permissible limits for the general population. The risk of developing cancers from the radiation emissions from the site is low. Also, the radiologic safety zone is estimated at 15 metres from the dumpsite for workers and residents.

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