Evaluation of Excess Lifetime Cancer Risk from Gamma Dose Rates in Coastal Areas of Bonny Island, Rivers State, Nigeria

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Abstract
The study assesses the excess lifetime cancer risk from gamma dose rates measured in coastal areas of Bonny Island, Rivers state, Nigeria. An in-situ measurement of radiation exposure rate was done using well calibrated radiation meter (Digilert-100). The exposure rate ranges between 12.0 and 18.6 μRh^{-1} with an arithmetic mean of 14.47 μRh^{-1} . The absorbed dose rates ranges between 86.6 and 161.8 $nGyh^{-1}$ with an arithmetic mean value of 137.5 $nGyh^{-1}$. This value is higher than the population weighted world average value of 60.0 $nGyh^{-1}$. Inhabitant of Bonny Island are subjected to an external effective dose ranging between 133.22 to 248.04 μSvy^{-1} with an arithmetic mean value of 192.93 μSvy^{-1}. The excess lifetime cancer risk estimated from the effective dose ranges from 0.47 x 10^{-3} to 0.87 x $10^{-3}$with an arithmetic mean of 0.67× 10^{-3}. The background radiation of Bonny Island has been enhanced due to oil and gas exploitation activities in the area.
Keywords: Radioactive materials, excess lifetime cancer risk, gamma dose rate, Bonny, Digilert-100.

1. Introduction

Exposure from natural background radiation to human beings is natural, continuous and inescapable feature of life on earth (Rangaswany et al.,2015). The components of the natural radioactive background are the cosmic radiation and the natural radioactivity of ground, atmosphere and water. Natural environmental radioactivity arises mainly from primordial radionuclides, such as ^{40}K and the nuclides from the ^{232}Th and ^{238}U series, which are at trace levels in all ground formations. Natural environmental radioactivity and the associated external exposure due to gamma radiation are primarily due to the geological and geographical conditions (UNSCEAR, 2000). The specific concentrations of terrestrial environmental radiation are related to the composition of each lithologically separated area, and to the type of parental material from which the soils originate (Felix et al., 2015). The high geochemical mobility of radionuclides in the environment allows them to move easily throughout the environmental matrixes.

Soil and rocks are major source of radiation exposure to the population and also a means of migration for the transfer of radionuclides into the environment. Natural radioactivity in soil is mainly due to ^{238}U, ^{40}K and ^{226}Ra which cause external and internal radiological hazards due to emission of gamma rays and inhalation of radon and its daughters (UNSCEAR, 1998). ^{222}Rn results from radioactivity of ^{238}U and itself decays with a half life of 3.82 days. When it is inhaled, it penetrates the lungs; its most dangerous daughters are the α-emitters (^{218}Po and ^{241}Po) which emit α-particles with highs energy of action of 6.0 Mev and 7.69 Mev respectively. The continued deposition and interaction of high energy particle with lungs leads to its damage and the incidence of cancer (Maria et al., 1998).

It has been established that chronic exposure to even low dose rate of nuclear radiation has the potential to induce cytogenetic damage in humans (chad-Umoren et al., 2007). Researches on effects of radiation on humans has shown that exposure to radiation could lead to lung, pancreas, hepatic, bone, skin and kidney cancers, cataracts, sterility, atrophy of the kidney and leukemia (Taskin et al., 2009; Goodman 2010; and Nordquist, 2014). One of the radionuclide around man's environment that contributes to high amount of potential lethal dose is radon, which causes the majority of deaths resulting from lung cancer (Maria et al., 1996). Radiation dose depend on the intensity and energy of the radiation, type of radiation, exposure time, the area exposed and the depth of energy deposition (UNSCEAR, 1993)[l]. Quantities, such as the absorbed dose, the effective dose and the equivalent dose have been introduced to specify the dose received and the biological effectiveness of that dose (Akpa, 1985). However, it is important to note that the biological effect of radiation depend not only on the total dose the tissue is exposed to, but also on the rate at which the dose was received.

This paper therefore aims at measuring the radiation exposure rates around the Bonny island areas of Rivers state and also assess the excess lifetime cancer risk of the populace due to exposure to external gamma dose rates which will help in determining the radiological burden of the area. The result of this study will serve as radiation baseline data of the area for future references and radiation surveillance of the area.

2. Materials and Methods

2.1 Study Area

Bonny Island is approximately 40km South of Port Harcourt in Rivers State of Nigeria and on the eastward side of the Cameroon Mountain. The Island lies on the E7°10' N4°27'with an estimated population of 270,000 (NPC, 2006) and plays host to multinational oil and gas companies such as Shell Petroleum Development Company

(SPDC) Export terminal, Mobil Producing Unlimited, Chevron Nigeria Limited and Nigerian Liquefied Natural Gas Company (NLNG) . Other cottage industries exist but on a small scale. These include bakeries, block molding, tile manufacturing as well as gas and welding industries (Saquan et al., 2001). The region produces a type of crude oil as Bonny light oil. Much of the oil extracted on shore in Rivers State is piped to Bonny for export.

The Island has a relatively flat topography on an elevation of 3.05 atmospheric mean sea level with a total land area of 214.52m^2 (NLNG, 2005) with about 70% of its size suffering from tidal flooding and land subsidence. The geology of the area comprises basically of alluvial sedimentary basin and basement complex. The sub strata of the island consist mainly of fine sands, down to about 10m with occasional clay layers. Figure 1 shows the map of Bonny indicating sampling points.

Economically, the main occupations of people on Bonny Island are farming, fishing and trading. Farming takes place on the dry land ridges within the galloping swamp forest. Fishing is a very important economic activity at Bonny Island. It has been estimated that fish may account for as much as 80% of protein consumption in such coastal areas of Nigeria. The catches are partly retained for consumption and partly sold at market.

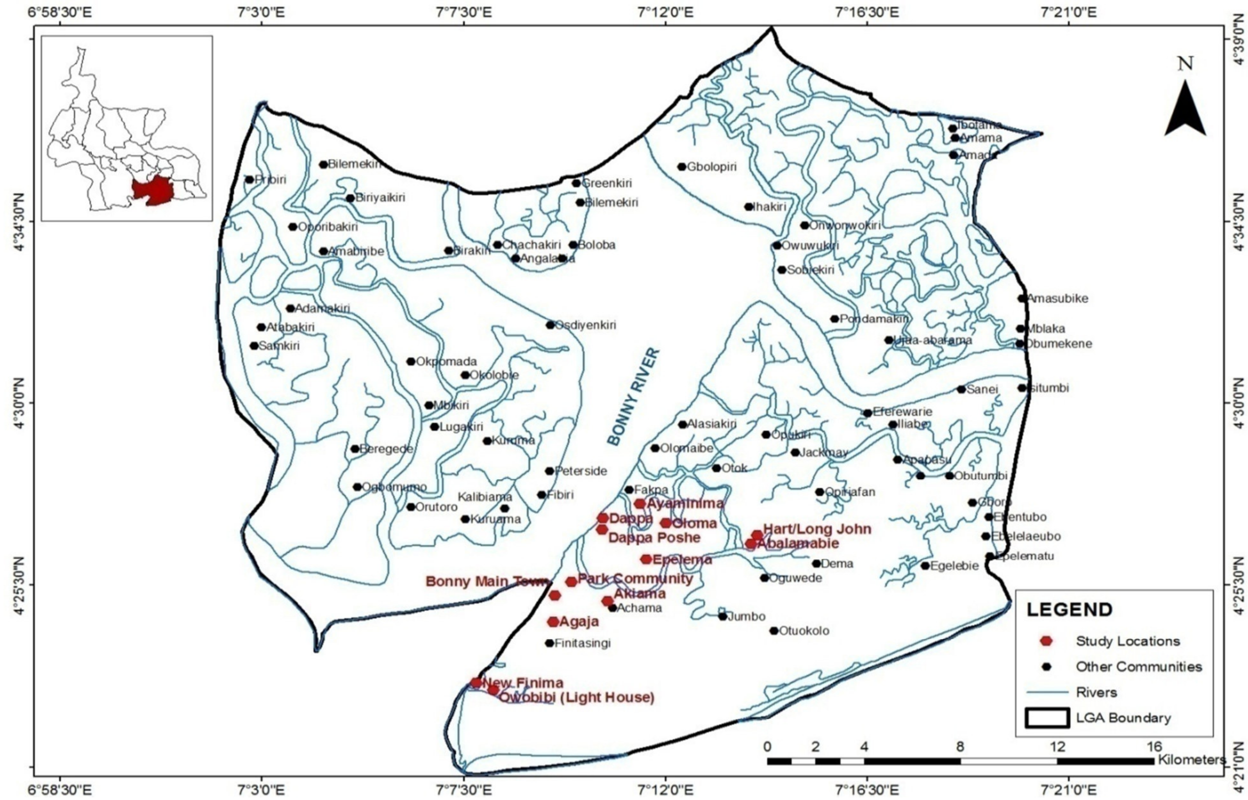

Figure 1: Map of Bonny Island showing sampling points

2.2 Field Measurement

An *in-situ* measurement of the background radiation level was done using two well calibrated radiation meters (Digilert $_{Tm}$- 100 and Radalert $_{Tm}$ 200 nuclear radiation monitoring meter ,S.E. International Inc, Summer Town, USA) containing a Geiger-Muller tube capable of detecting alpha, beta, gamma and X-rays within the temperature range of – 10^{o}C and 50^{o}C was used to measure radiation levels. The Geiger Muller tube generates a pulse current each time radiation passes through the tube and causes ionization (Avwiri, et al., 2012). Each pulse is electronically detected and registered as a count. The radiation meters were calibrated with a ^{137}Cs source of a specific energy and set to measure exposure rate in milli-Roetgen per hour. The readings were taken within the hours of 1300 and 1600 hours because exposure rate meter has a maximum response to environmental radiation within these hours (Louis et al., 2005). The tube of the radiation meter was raised to a height of 1.0m above the earth surface with its window facing first the earth surface and then vertically downwards (Avwiri et al., 2007). For each location two measurements spanning over 2 minutes were carried out and these measurements were then averaged to single value. Data obtained for outdoor exposure rate in mR/h was converted into absorbed dose rate nGy/h using the conversion factor (Ononugbo, et al., 2011) :

$$1\mu R/h = 8.7\ nGy/h = 8.7 \times 10^{-3}\mu Gy/(1/8760)yr = 76.212\mu Gyy^{-1} \quad \ldots\ldots\ldots\ldots\ldots..(1)$$

3. Results and Discussion

The radiation exposure rate of coastal areas of Bonny Island is presented with the associated radiation hazard parameters in Table 1. The highest exposure rate was observed in Hart/Long John community and the lowest in Minima 2 community with respective values of 18.60 and 10.0 μRh^{-1}. The highest absorbed dose rate of 161.8 $nGyh^{-1}$ was recorded in Hart/LongJohn community while the least dose rate of 86.9 $nGyh^{-1}$ was obtained in Minima2 community. The annual effective dose calculated from the absorbed dose rate and also the excess lifetime cancer risk is presented in Table 1. Comparison of the absorbed dose rate, annual effective dose rate and excess lifetime cancer risks with their respective standards are shown in Figures 2, 3 and 4.

3.1 Annual Effective Dose Equivalent (AEDE)

The annual effective dose equivalent received outdoor by a member of the public is calculated from the absorbed dose rate using dose conversion factor of 0.7Sv/Gy and the occupancy factor for outdoor of 0.25 (UNSCEAR, 2000) .

AEDE (Outdoor) (mSv/y) = Absorbed dose rate ($nGyh^{-1}$) × 8760h × 0.7Sv/Gy × 0.25 - (2)

The corresponding outdoor annual effective dose range from 133.22 to 248.04 μSvy^{-1} with an average value of 192.93 μSvy^{-1}. The world wide average annual effective dose is 70.0 μSvy^{-1}. The result of annual effective dose in this study is 62.3% higher than the world average.

3.2 Excess Lifetime Cancer Risk (ELCR)

Excess Lifetime Cancer Risk is the probability of developing cancer over a lifetime at a given radiation exposure level . It is presented as a value representing the number of extra cancers expected in a given number of people on exposure to a carcinogen at a given dose. It is calculated using the relation in (Taskin et al., 2009) .

Excess lifetime cancer risk (ELCR) = AEDE×DL×RF - - - - (3)

where AEDE is the Annual Effective Dose Equivalent, DL is average Duration of Life (estimated to be 70years) and RF is the Risk Factor (Svy^{-1}), i.e. fatal cancer risk per Sievert. For stochastic effects, ICRP uses RF as $0.05Sv^{-1}$ for the public exposure (Taskin et al., 2009) From Table 1, the excess lifetime cancer risk ranges from 0.47×10^{-3} to 0.87×10^{-3} with arithmetic mean of 0.67×10^{-3}. This value is higher than the world permissible value of 0.29×10^{-3}.

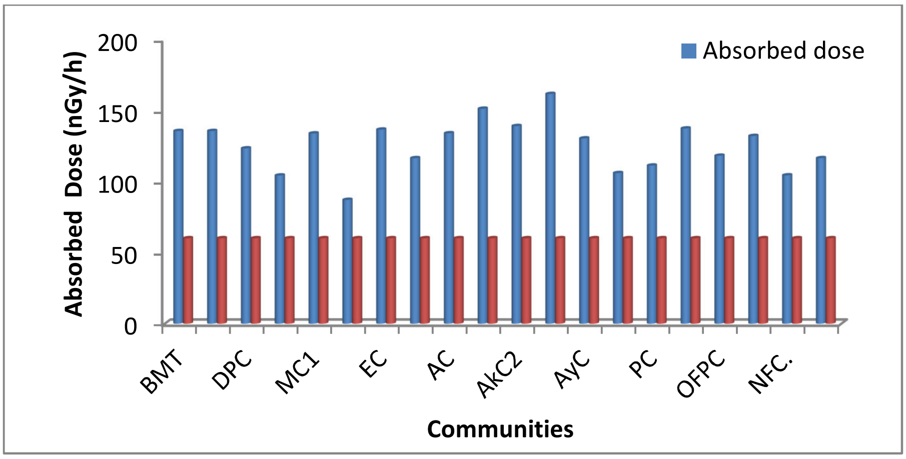

Fig. 2: Comparison of absorbed dose rate with UNSCEAR, 2000 standard

Table 1: Average exposure rate measured and their radiation parameters in Bonny

S/N	Communities sampled	Exposure Rate(μRh^{-1})	Absorbed Dose rate (nGyh^{-1})	AEDE (μSvy^{-1})	ELCR $\times 10^{-3}$
1	Bonny Main Town	15.5	135.7	208.02	0.73
2	Dappa Community	15.6	135.7	208.02	0.73
3	DappaPoshe Comm.	14.2	123.5	189.33	0.67
4	Iwuoma Community	12.0	104.4	160.05	0.56
5	Minima 1 Community	15.4	134.0	205.39	0.53
6	Minima 2 Community	10.0	86.9	133.22	0.47
7	Epelema Community	15.8	136.7	209.56	0.75
8	Oloma Community	13.4	116.6	178.75	0.63
9	Abalamabie Comm.	15.4	134.1	205.58	0.72
10	Akiama 1 Community	17.4	151.4	232.10	0.82
11	Akiama 2 Community	16.0	139.2	213.39	0.75
12	Hart/LongJohn Comm.	18.6	161.8	248.04	0.87
13	Ayanbo Community	15.0	130.5	200.06	0.70
14	Ayanbo 2/ Angaya Com	12.2	106.1	162.65	0.57
15	Park Community 1	12.8	111.4	170.78	0.60
16	Park Community 2	15.8	137.5	210.79	0.74
17	Owobibi(Fishing Port – Light House) Comm.	13.6	118.3	181.35	0.64
18	Ajolomonia Comm.	15.2	132.2	202.66	0.72
19	New Finima Comm.	12.0	104.5	160.20	0.56
20	Agaya/NLNG Area	13.4	116.6	178.75	0.60
	Mean	**14.47**	**137.5**	**192.93**	**0.67**
	World Average	**13.0**	**60.0**	**70.0**	**0.29**

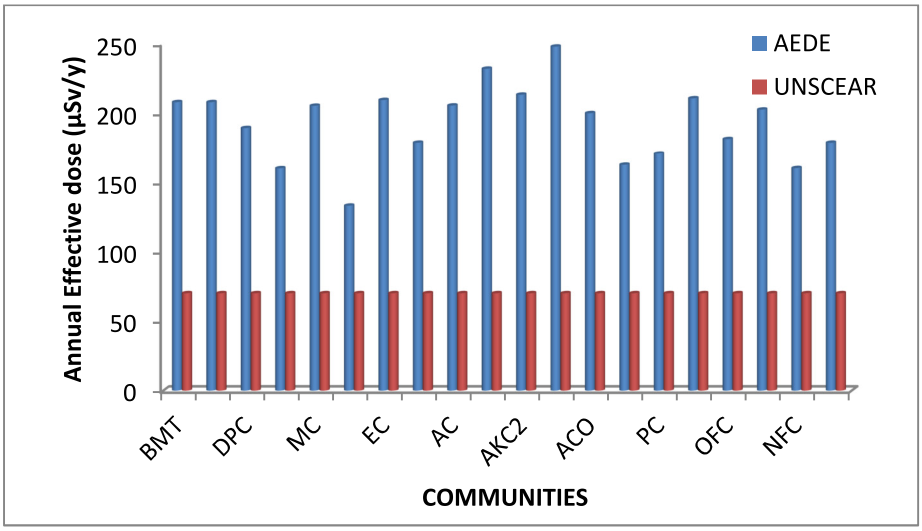

Fig.3: Comparison of annual effective dose equivalent with UNSCEAR, 2000 standard

The absorbed dose measured ranged from 86.9 to 161.8nGyhr^{-1} with mean value of 137.5 nGyh-1 is higher than the world weighted average of 60 nGyh^{-1}. The community that recorded the highest exposure rate, absorbed dose, annual effective dose and excess lifetime cancer risk (Hart/LongJohn) houses a lot of farm settlers especially fisher men/women. Industrial waste from gas Exploitation Company are channeled into the creek surrounding the area which might account to high radiation level recorded in the community.

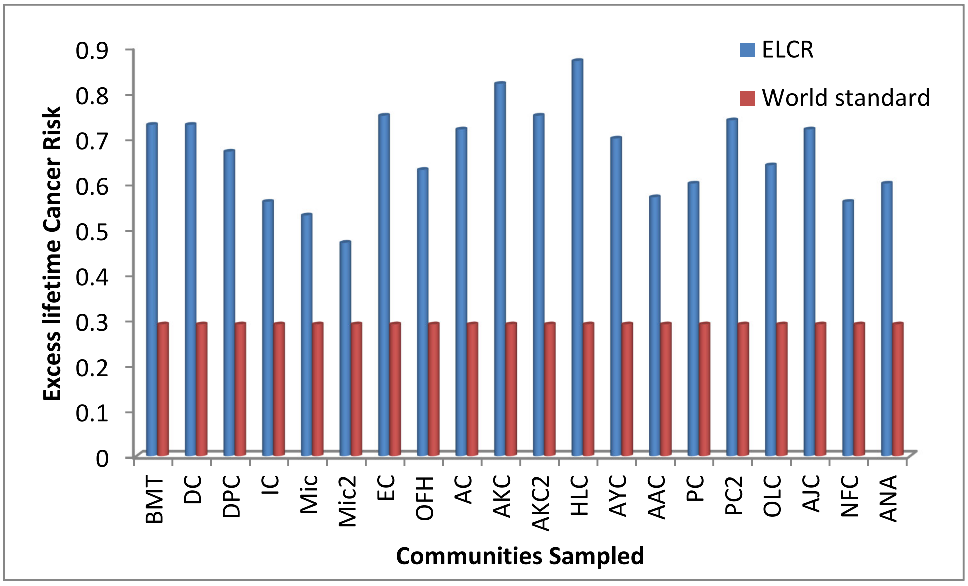

Fig. 4: Comparison of ELCR with world standard

The annual effective dose (AEDE) measured ranged from 133.22 to 248.04 µSv/yr with arithmetic mean value of 192.93 µSvy^{-1}. This is higher than the world weight value of 70 µSvy^{-1}[2]. The ECLR measured ranged from 0.47 to 0.87 x 10^{-3} with arithmetic mean value of 0.67 x 10^{-3} which when compared with the world standard value of 0.29 x 10^{-3}. The values of the radiation hazard parameters were highest for Hart/LongJohn followed by Akiama 1, Akiama 2, Epelema, and Park communities in that order when compared with the standard value implies that the communities' background radiations have been enhanced due the gas exploitation activities in the area. Radon gas ^{222}Rn results from radioactivity of Uranium-238 and itself decays with a half life of 3.82 days. Flaring is a high-temperature oxidation process used to burn combustible components, mostly hydrocarbons, of waste gases from industrial operations. Toxic compounds like poly-nuclear aromatic hydrocarbons, aromatics and volatile organic compounds formed in these diffusion flames are introduced to the environment causing harm to the populace (Muhammadu *at el*., 2014). Also comparing with the work done by Ismail and UMukoro (2012), the values of ELCR for Bonny Island were far higher than the value of the ECLR for Mini-Okoro/Oginiba Creek. This could be due to oil and gas exploitation activities in Bonny Island. The result compared well with the result of the study on the radioactivity of Northern Pakistan River done by (Avwiri et *al*, 2014).

The excess lifetime cancer risk estimated from the annual effective dose in all the communities exceeded the world weighted average of 0.29 x 10^{-3}. Therefore the probability of developing extra cancer due to exposure to natural radioactivity in this area is significant. This suggest further studies of other environmental media such soil, water and crops from the area of study.

4. Conclusion

An inhabitant of Bonny Island receives appreciably high gamma ray than other communities far away from NLNG Company. Hart/LongJohn community recorded the highest exposure rate, absorbed dose rate; annual effective dose and excess lifetime cancer risk while Minima 2 community recorded the least. All the radiation hazard parameters determined exceeded their respective world safe values.

The relatively high gamma dose rates measured in almost all the communities shows that the oil and gas exploitation activities in Bonny has enhanced the background radiation level of the area and therefore further studies on radioactivity level in soil, water and grains from Bonny island is recommended for effective monitoring of the envirom

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