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Research Article

RADIOMETRIC SURVEY OF IMO RIVER IN RIVERS STATE, NIGERIA

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ABSTRACT

An *in situ* measurement of natural background radiation along the course of Imo River in Rivers State. The outdoor radiation exposure rate was measured in 20 randomly selected points along the river using well calibrated portable Geiger Muller and Scintillation detectors. Five measurements were made in each sampling point and an average value was used to determine the absorbed dose rate from natural background radiation. The absorbed dose rate was found to range from 104.4 and 217 $nGyh^{-1}$ with mean value of 150.95$nGyh^{-1}$ and the average annual effective dose of radiation was found to be 0.24$mSvy^{-1}$.The excess lifetime cancer risk determined ranges from 0.60 and 1.16×10^{-3} with mean value of 0.81. Though the annual effective dose equivalent are within the safe limit, the absorbed dose of radiation and the excess lifetime cancer risk exceeded the world accepted safe value of 89.0 $nGyh^{-1}$ and 0.29×10^{-3} respectively. The study showed an area of slightly higher background radiation and caution need to be taken in the use of the river course. This study does not indicate any immediate radiological hazards for the general public, however long term exposure may lead to some radiation sickness.

INTRODUCTION

Natural ambient radiations are present everywhere due to spontaneous emission by radioactive elements, thus every living thing is exposed to ionizing radiation (Sengupta *et al.*, 2014). This radiation is part of the earth and comes from cosmos and affects all the goods, food and even the air that we breathe and makes them partly radioactive. So, human beings are exposed to natural background radiation everyday from the ground, building materials, air, food, the universe and even elements in their own body. The terrestrial component of the natural background radiation is dependent on the composition of the soils, and rocks containing natural radionuclide (Senthilkumar *et al.*, 2010). The radioactivity of soils is essential for understanding changes in background radiation (Sroor *et al.*, 2001). The natural radioactivity of soil and sediment depends on the soil and sediment formation and transport processes that were involved since soil and sediment formation, chemical and biochemical interactions influence the distribution pattern of uranium, thorium and their decay products (Myrick *et al.*, 1983).

Natural environmental radioactivity and the associated external exposure due to gamma radiation depend mainly on the local geological and geographical conditions and appear at different levels in each region of the world (UNSCEAR 2000). The natural terrestrial gamma dose rate is an important contributor to the average dose received by the world's population (Tso and Leung, 2000). Estimation of the radiation dose distribution is vital in assessing the health risk to a population and serves as a reference for documenting changes in environmental radioactivity due to anthropogenic activities (Obed *et al.*, 2005). Humans are exposed to natural terrestrial radiation that originates predominantly from the upper 30cm of the soil (Chikasawa *et al.*, 2001). Humans are also exposed by contamination of the food chain which occurs as a result of direct deposition of radionuclide on plant leaves, root uptake from contaminated soil, sediment or water (Arogunjo *et al.*, 2004) and from direct ingestion of contaminated water (Avwiri and Agbalagba, 2007).

Apart from the natural sources like weathering and recycling of terrestrial minerals and rocks, anthropogenic activities also affect soil radioactivity. These artificial sources are medical and industrial activities. The dominant industry in the coastal region of Nigeria is oil industry – exploration and production. The petroleum industry is the largest importer and consumer of radioactive materials (Oni *et al.*, 2011). Despite employing all precautionary measures to ensure safety, there will always be a possibility, principally based on poor handling, accident, loss and theft that radioactive materials may pollute the terrestrial

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and aquatic areas which are mainly network of creeks and rivers. Radionuclide reaching the ocean become part of the marine ecosystem (water, sediments, biota) and may transfer through seawater – sediment – biota interface to human beings. The spread and accumulation of radioactive substances – water and sediment raise many questions concerning the safety of biotic life, the marine food chain and the ultimate consumers of seafood (IAEA, 1989). The major sources of natural radionuclide in water results from weathering and recycling of terrestrial minerals and rocks that give rise to ^{40}K, ^{232}Th, ^{235}U and ^{238}U. Water can pick up radioactive materials as it flows through rocks, soils or cracked cement surrounding of water source thereby contaminating the water source. Natural radionuclide which includes ^{40}K and those of thorium and uranium decay series in particular ^{226}Ra, ^{228}Ra, ^{234}U, ^{238}U and ^{210}Pb can be found in water as a result of naturally occurring radioactive materials or due to anthropogenic activities (Zapecza *et al*., 1988).

The main objective of this study is to determine the annual effective dose from gamma dose rate measured along Imo River and assess the excess lifetime cancer risk of the populace that might be exposed to such radiation due to the usage of the river. The result of this study will serve as baseline data for future radiological studies of the area.

MATERIALS AND METHODS

Study Area

Imo River is located in south eastern Nigerian and flows 150 miles (241.55km) into the Atlantic Ocean. Imo River is situated in the Northern part of Rivers State. The area is the boundary between

Abia State and Rivers State is the Niger Delta region. It lies between longitude 007^o 08^1 11.9^{11} and 007^o 11^1 33.5^{11} East of Greenwich meridian and latitudes 04^o 54^1 11.9^1 and 0.4^o 51^1 37.8^{11} North of equator. The area is occupied by virgin rainforest which has not been modified considerable by human activities. Along the banks of Imo River, economic trees like palm trees and raffia palm are found in commercial quantity. The exploration and exploitation of hydrocarbons in the study area has taking a toll on the agricultural potential of the area, fisheries and wildlife as oil spills, gas flares and associated thermal air and water pollution are the major environmental consequences of the activities of oil companies in the area.

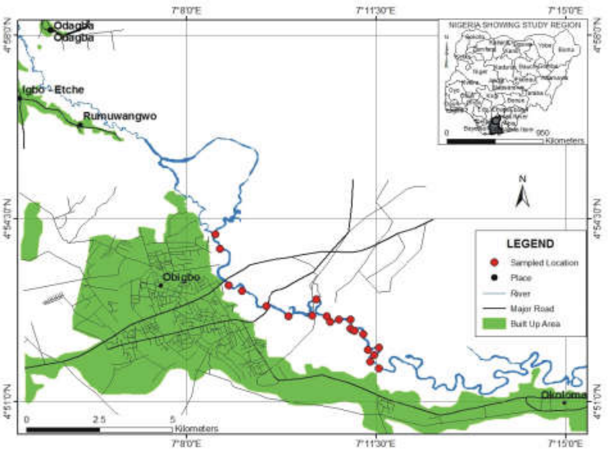

Fig. 1 Map showing sampling points and industrial study areas

Field Measurement

An *in situ* approach of background ionization radiation measurement was preferred and adopted to enable sample maintain their original environmental statistics (Avwiri *et al*., 2013). A well calibrated Digilert – 50 and Radalert – 100 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 Gieger 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. A geographical positioning system (GPS) was used to measure the precise position of sampling points. 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, Ononugbo *et al*., 2011). 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 (Muhammad *et al*., 2014):

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

RESULTS AND DISCUSSION

Table 1 shows the background radiation rate and other radiation parameters in different locations along Imo River. The minimum outdoor dose rates value of 104.4 $nGyh^{-1}$ was recorded at two sampling points along the river course (NNPC pipeline crossing) lying at latitudes 4º52' 38.0″N and 4º52'33.8″N respectively and longitudes 7º10'35.9″ E and 7º11'01.8″ E respectively whilst maximum value of 217.5 $nGyh^{-1}$ was measured at Imo River division 7, situated at latitude 4º52'21.3″ N and longitude 7º11'06.7″ E. other areas that recorded higher values of 208.8 $nGyh^{-1}$ are old Imo River bridge of latitude 4º52'49.5″ N and longitude 7º09'29.0″ E and Imo River division 5 which recorded absorbed dose of 200.1 $nGyh^{-1}$ lying at latitude 4º52'23.8″ N and longitude 7º11'02.2″ E. These higher values recorded are due to oil bunkering activities going on along the river bank which must have resulted in oil leakages.

Around the riverbank close to the village, a high value of 191.4 $nGyh^{-1}$ was recorded due to radionuclide migration from the bunkering site. The implication of this result is that the illegal activities of bunkering along the river bank which releases unrefined petroleum as waste products to the environment, in addition to sand dredging activities have enhances the background radiation of the Imo river and its environ. Figure 2 is the three dimensional radiation map of the study area. The peak areas correspond to sampling point with high BIR level. The relative high radiation of the environment conforms to previously reported work of Arogunjo (2004) that oil activities constitute a radiological burden to the environment. The exposure rate obtained in the host community (Mama Town-Obigbo) 0.013mR/h is lower than that recorded in all other sampling points. Though the value recorded in the host community is within the safe limit set by UNSCEAR (2000), the river banks recorded higher values. This imply that the environment is gradually becoming unsafe for the general populace living in the area though the residential areas are quite some distance from the Imo River bank except Mama town. There is the danger of the radionuclide build up in the soil and the river which is a major source of drinking water in Mama town.

The annual Effective Dose Equivalent (AEDE)

Measured absorbed gamma dose rates were used to calculate the annual effective dose equivalent

(AEDE) received by individuals of the study area. In calculating AEDE, dose conversion factor of 0.7 Sv/Gy and the occupancy factor for outdoor and indoor of 0.25 (6/24) and 0.75 (18/24) respectively was used. The occupancy factor for outdoor and indoor was calculated based upon interviews with peoples of the area.

People of the study area spend almost 6 hours outdoor and 18 hours indoor daily due to the nature of their custom. The annual effective was determined using the following equation (UNSCEAR, 2000):

AEDE (outdoor) (mSv/y) = Absorbed dose rate (nGy/h) ×8760 h ×0.7Sv/Gy × 0.25 -----------(2)

AEDE (indoor)(mSv/y) = Absorbed dose rate (nGy/h) ×8760 h ×0.7Sv/Gy × 0.75 --------------(3)

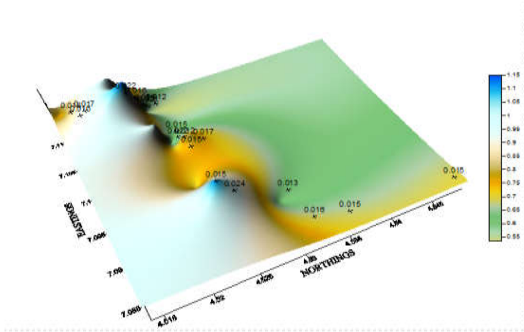

Fig. 2 3-D Radiation Map of the study area

Table 1 Exposure Rate Measured and Radiation Risk parameters calculated for Imo River

S/N	Geographical Location	Location description	Exposure Rate (mRh^{-1}) Digilert- 50	Rad- 100	Average Exposure Rate(mR/h)	Absorbed Dose (D) ($nGyh^{-1}$)	AEDE outdoor $mSvy^{-1}$	AEDE Indoor (mSv/yr)	ELCR $\times 10^{-3}$
1	N04^o 54^1 9^{11} E007^o 08^1 32.3^{11}	OTAMIRI-Imo River Link	0.016	0.0153	0.015±0.002	130. 5	0.20	0.60	0.70
2	N04^o 53^1 55.1^{11} E007^o 08^1 37.2^{11}	NNPC-ALSCON PIPELINE LINK	0.015	0.016	0.015±0.002	130.5	0.20	0.60	0.70
3	N04^o 53^1 13.5^{11} E007^o 08^1 47.1^{11}	OBIGBO BRIDGE(EXPRESS ROAD)	0.015	0.017	0.016±0.001	139.2	0.21	0.64	0.74
4	N04^o 53^1 06.6^{11} E007^o 09^1 02.0^{11}	MAMA TOWN (OBIGBO) (Host Site)	0.012	0.017	0.013±0.006	113.1	0.17	0.52	0.60
5	N04^o 52^1 49.5^{11} E007^o 09^1 29.0^{11}	OLD IMO RIVER BRIDGE	0.022	0.025	0.024±0.007	208.8	0.32	0.96	1.12
6	N04^o 52^1 37.9^{11} E007^o 09^1 53.6^{11}	IMO RIVER VILLAGE	0.018	0.014	0.015±0.002	130.5	0.20	0.60	0.70
7	N04^o 52^1 38.1^{11} E007^o 10^1 19.2^{11}	BACK OF KOM-KOM VILLAGE (BUNKERING SITE)	0.016	0.014	0.015±0.002	130.5	0.20	0.60	0.70
8	N04^o 52^1 57.3^{11} E007^o 10^1 24.0^{11}	IMO RIVER RAILWAY CROSSING	0.016	0.017	0.017±0.001	147.9	0.23	0.68	0.81
9	N04^o 52^1 38.0^{11} E007^o 10^1 35.9^{11}	NNPC PIPELINE CROSSING	0.012	0.012	0.012±0.006	104.4	0.16	0.48	0.56
10	N04^o 52^1 31.5^{11} E007^o 10^1 39.3^{11}	IMO RIVER	0.029	0.015	0.022±0.003	191.4	0.29	0.88	1.02
11	N04^o 52^1 34.4^{11} E007^o 10^1 49.1^{11}	IMO RIVER DIVISION 1	0.016	0.012	0.015±0.002	130.5	0.20	0.60	0.70
12	N04^o 52^1 33.8^{11} E007^o 11^1 01.8^{11}	IMO RIVER DIVISION 3	0.013	0.011	0.012±0.005	104.4	0.16	0.48	0.56
13	N04^o 52^1 23.8^1 E007^o 11^1 02.2^1	IMO RIVER DIVISION 5	0.034	0.015	0.023±0.006	200.1	0.31	0.92	1.09
14	N04^o 52^1 21.3^{11} E007^o 11^1 06.7^{11}	IMO RIVER DIVISION 7	0.029	0.025	0.025±0.007	217.5	0.33	1.00	1.16
15	N04^o 52^1 21.3^{11} E007^o 11^1 06.7^{11}	IMO RIVER BANKS 1	0.031	0.011	0.019±0.002	165.3	0.25	0.76	0.88
16	N04^o 52^1 17.4^{11} E007^o 11^1 21.2^{11}	IMO RIVER BANKS 2	0.018	0.015	0.016±0.001	139.2	0.21	0.64	0.74
17	N04^o 52^1 10.7^{11} E007^o 11^1 33.6^{11}	IMO RIVER BANKS 3	0.027	0.018	0.022±0.005	191.4	0.29	0.88	1.02
18	N04^o 51^1 53.4^{11} E007^o 11^1 28.3^{11}	IMO RIVER BANKS 4	0.018	0.017	0.017±0.001	147.9	0.23	0.68	0.81
19	N04^o 51^1 45.4^{11} E007^o 11^1 23.7^{11}	IMO RIVER BANKS 5	0.016	0.016	0.016±0.001	139.2	0.21	0.64	0.74
20	N04^o 51^1 37.7^{11} E007^o 11^1 33.5^{11}	MMIRI-NWAYI (IMO RIVER DIVISION 14)	0.020	0.022	0.018±0.001	156.6	0.24	0.72	0.84
						150.95	0.24	0.69	0.81

In the UNSCEAR (1993) report the Committee used 0.7SvGy^{-1} for the conversion coefficient from absorbed dose in air to effective dose received by adults. Estimated values of annual effective dose equivalent for outdoor exposure ranges from 0.16 to 0.33mSvy^{-1} with mean value of 0.24mSvy^{-1}. For indoor exposure AEDE ranges from 0.48 to 1.00mSvy^{-1} with mean value of 0.69 mSvy^{-1}. The resulting average of the annual effective dose is 0.934 mSvy^{-1} which is larger than the worldwide average value of 0.48 mSv (Muhammad *et al.* 2014).

Excess Lifetime Cancer Risk (ELCR)

The annual effective dose calculated was used to estimate the excess lifetime cancer risk (ELCR) is calculated using equation (4).

Excess Lifetime cancer risk (ELCR) = AEDE × Average duration of life (DL) × Risk factor (RF) ----- (4)

Where AEDE, DL and RF is the annual effective dose equivalent, duration of life (70 years) and risk factor (Sv^{-1}), fatal cancer risk per sievert. For low dose background radiations which are considered to produce stochastic effects, ICRP 60 uses values of 0.05 for the public (Taskin *et al*. 2009, Muhammad *et al*., 2014). ELCR for outdoor exposure ranges from 0.56 × 10^{-3} to 1.16 × 10^{-3} with an average value of 0.81 × 10^{-3}. For indoor exposure, ELCR varies from 1.68 × 10^{-3} to 3.5 × 10^{-3} with mean value of 2.43 × 10^{-3}.

Measurement of radiation exposure rate and its associated radiological parameters along Imo River and it's environ has shown an elevated values in 86% of the sampling points. The average exposure rate value measured is higher than the values previously reported by Oni *et. al*, (2011) who measured the radioactivity level in the coastal areas of Nigeria by gamma counting of the river sediments samples and assess the radiological impact associated with the use of the river sediments as building materials. This could be because of varying activities going on along Imo river that releases radionuclide to the environment. Also the exposure rate measured are well above previously reported values in other environment in Nigeria by Akpabio (2005) who reported a radiation level of range of 0.007-0.015mR/hr in Ikot Ekpene area of Akwa Ibom State of Nigeria which was within the limit of standard background radiation level. Also, these values obtained were comparable to values obtained by Kuroda (1991) whose level is fairly constant over the world standard being 0.008-0.013mR/hr which is primarily due to the presence of high concentration radioactive elements in the soil. The highest values observed at the Division 7, Old Imo River bridge area, Division 5, Imo River Bank 3 are points closer to the bunkering sites where activities contribute to the migration of petroleum products via water transport.

Variations in ambient gamma dose rate for all the area sampled along the river bank can be seen in the 3-D radiation map of the area (Figure 2). These areas lie in Akata formation, exposed by almost the same lithology. External exposure from outdoor sources arises mainly from radionuclides present in soils, rocks, and industrial discharges into the river. For this study, the mean outdoor gamma dose rates may be due to shales which contain relatively higher levels of radionuclide concentrations. The variation of gamma dose rates from place to place may be attributed to changes in weathering conditions. Changing weathering conditions causes fluctuations in radon progeny concentration in air due to soil moisture, rainfall and snow (UNSCEAR, 2000). High absorbed dose rates of 217.0 nGyh^{-1}in air for Imo River Division 7 may be due to thorium-bearing and uranium bearing minerals in the river which is associated with oil bunkering and dredging activities.

Mean outdoor gamma dose rate measured for this study 150.95 nGyh^{-1} is higher than the values previously reported by Muhammad *et al*., 2014, Rafique *et al*., 2013(106 nGyh^{-1} and 102 nGyh^{-1}) respectively. The measured outdoor gamma dose rates are also higher than the values reported in Turkey (78.3-135.7 nGyh^{-1}) by Erees *et al*., (2006).The mean outdoor gamma dose rate, annual effective dose and excess lifetime cancer risk estimated were all higher than their world acceptable safe values of 89.0 nGyh^{-1}, 0.48mSvy^{-1} and 0.29 × 10^{-3} respectively.

CONCLUSION

Measurement of outdoor gamma dose rates have been carried out in Imo river using two radiation meters (Radalert-50 and Digilert-100). The following results were obtained from the study.

1. Minimum and maximum dose rate value of 104.4 nGyh-1 and 217.5 nGyh-1 respectively were obtained.
2. Mean values of outdoor gamma doses were found to be greater than the world population weighted average dose rates (89.0 nGyh^{-1})
3. Estimated values of annual effective dose equivalent for outdoor exposure ranges from 0.16 to 0.33mSvy^{-1} with mean value of 0.24mSvy^{-1} while for indoor exposure AEDE ranges from 0.48 to
4. 1.00mSvy^{-1} with mean value of 0.69 mSvy^{-1}.
5. ELCR for outdoor exposure ranges from 0.56 × 10^{-3} to 1.16 × 10^{-3} with mean value of 0.81 × 10^{-3}. For indoor exposure, ELCR varies from 1.68 × 10^{-3} to 3.5 × 10^{-3} with mean value of 2.43 × 10^{-3}.

Though our results showed high level of gamma dose rates, it may not have any immediate health hazards but could lead to some radiological problems for long term exposure of people living or working along the river bank of Imo River. Therefore, we recommend that government should totally stop the activities of illegal crude oil bunkering in the area and also reduce the rate of dredging from the river. Radiological assessment of the river sediment is recommended to determine its suitability as building material.

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