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ORIGINAL ARTICLE

GIS mapping of impact of industrial activities on the terrestrial background ionizing radiation levels of Ughelli metropolis and its environs, Nigeria

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Abstract The assessment of industrial activities and effluents on the external background ionizing radiation (BIR) levels of Ughelli metropolis and its environs has been conducted, using a digilert 100 nuclear radiation monitor and geographical positioning system for GIS mapping. The monitoring of the terrestrial BIR levels was carried out for 2 years (from May 2013 to June 2015) in 21 locations within the city and 21 other major villages/towns in Ughelli North local government area of Delta state. Measured exposure rate in Ughelli metropolis revealed a mean value of 15.20 ± 2.80 μRh^{-1} (1.28 ± 0.23 mSvy^{-1}), while a mean value of 15.19 ± 2.70 μRh^{-1} (1.28 ± 0.23 mSvy^{-1}) was obtained in the villages/towns. The estimated mean outdoor absorbed dose rate for the Ughelli metropolis and Ughelli environs is 132.16 ± 24.36 ηGyh^{-1} and 132.15 ± 23.50 ηGyh^{-1}, respectively. The mean annual effective dose equivalent is 0.16 ± 0.03 mSvy^{-1}) while the mean excess life cancer risk is $(0.56 \pm 0.11) \times 10^{-3}$ mSvy^{-1}. GIS maps of the study area revealing the BIR distribution and higher radiation levels were recorded in areas/communities where there are industrial activities and oil and gas facilities. The overall results of the measured exposure rates and the estimated radiological indices show that 73.5% of the sampled location exceeded their permissible limits. The mean equivalent dose rate obtained is higher than the safe exposure limit of 1.0 mSvy^{-1}) recommended by UNSCEAR, and the mean radiation exposure levels in the study area is well above the normal background radiation level of 13.00 μRh^{-1} which shows that the studied area is radiologically contaminated. Though these values obtained may not cause immediate health hazard, there is the likelihood of long-term accumulating health side effects on the residents of some of these locations and communities sampled. Recommendations are made on the possible ways of reducing the impacts on the populace.

Keywords GIS mapping · Radiation impact · Industrial activities · Ughelli North

Introduction

The hazards to man and the environment from radioactive contamination depend on the nature of the radioactive contaminant, the level of contamination and the extent of the spread of the (ionizing radiation) contamination (Ogundare and Adekoye 2015). At present, studies on health effects due to ionizing radiation contamination have produced substantial evidences that exposure to high level of radiations can cause illness or even death. Scientists have discovered that ionizing radiations can cause cancer and mental retardation in children of mothers exposed to radiations during pregnancy period. High radiation doses may also cause other health effects as listed by NRC (2006) (Rafique et al. 2014). Avwiri et al. (2007) also reported that researchers have found a strong correlation between radiation exposure and health hazard on populace and workers in the environment eco-system. Thus, the issue of environmental degradation in the twenty-first century is of global concern because of its resultant health implications. Background ionization radiation could be considered as

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environment contamination especially when it exceeds safe occupational and public limits. The external background ionizing radiation comes from three major sources, namely terrestrial radiation, cosmic and man-made radiation. According to UNSCEAR (1993), about 87% of the radiation dose received by mankind is due to natural radiation sources.

With respect to the various radionuclide released to the environment, Foland et al. (1995) reported that human activities that have led to the depletion of the ozone layer increased the cosmic rays reaching the earth's surface, thereby affecting the background radiation levels. Jibiri et al. (1999) reported that an increase in the background ionizing radiation from numerous sources has various health side effects on the populace.

Farai and Jibiri (2000) reported the outdoor gamma radiation exposure dose rate for eastern zone of Nigeria as having values between 0.025 and 0.08 μGyh^{-1}. Akpabio et al. (2005) also studied the environmental radioactive levels in Ikot–Ekpene and reported that the radioactivity levels in the area is generally low ranging. But Avwiri et al. (2007) studied the terrestrial radiation around oil and gas facilities in Ughelli region of Nigeria (the study area) and reported an average value range of 12.00 ± 0.1 μRh^{-1} (5.33 ± 0.35 µSv/week) to 22.00 ± 2.1 μRh^{-1} (9.79 ± 0.16 µSv/week) in the oil field and 09.00 ± 1.0–11.00 ± 0.5 μRh^{-1} in the host communities. They concluded that though the radiation values are within international standard and are in consonant with other reported values in the country, the BIR levels exceeded the normal background level. Osimobi et al. (2015) monitored the background ionizing radiation level in some solid mineral mining sites in Enugu state and reported a 38.5% elevation above the normal background ionizing radiation level.

Ughelli and its environs are fast becoming an industrial area with different companies relocating to the area. These industrial activities ranged from manufacturing, water packaging and bottled factories, rubber processing factories, construction companies, asphalt processing plants and oil and gas exploration and exploitation companies. These companies deal with a lot of industrial chemicals that are toxic, corrosive and radioactive (low gamma, beta and alpha emitters) thus may enhance the naturally occurring radionuclides in the environment. These growing number of industrial activities (input/output materials), the reported elevated BIR levels in the oil facilities within the Ughelli region by Agbalagba et al. (2009), Agbalagba and Meindinyo (2010), Avwiri and Agbalagba (2012), and the inadequate data on radioactivity status of some part of the study area lay credence to this research work. More so, no known baseline BIR/outdoor gamma radiation levels have been reported about entire Ughelli metropolis and its environs. Hence, the data presented in this report represent the first set of information and may serve as baseline data of the background radiation levels of the area.

Materials and method

Study area

This study was conducted between May and June, 2013–2015 which represent the season's transit (dry to wet) period, while measurement was made in strategic areas of Ughelli metropolis and the neighboring towns and villages that make up Ughelli North local government area. The studies areas lie within longitude 6°00″E and 5°54″E and latitude 5°38″N and 5°20″N.

Sampling method

An in situ approach of background ionizing radiation measurement was adopted and preferred to enable samples maintain their original environmental characteristics. A digilert 100 nuclear radiation monitor (S.E international, INC. Summer town, USA), containing a Geiger Muller tube capable of detecting α, β, γ and X-rays within the temperature range of −10 to 50 °C, and a geographical positioning system (GPS) were used to measure the precise location of sampling. During measurement, the tube of the radiation monitoring meter was raised to a standard height of 1.0 m above the ground (Ayaji and Laogun 2006; Avwiri et al. 2013), with its window first facing vertically upward or the suspected source and then vertically downward while the GPS readings taken at that spot. Measurements were repeated six times at each site on different days within the 2 months to take care of any fluctuation in the environmental temperature, and this was repeated for 3 years in which the monitoring was carried out. Readings were taken between the hours of 1300 and 1600 h, since the radiation meter has the maximum response to environmental radiation within these hours as recommend by NCRP (1993). The count rate per minute recorded in the meter was converted to microroentgen per hour (μRh^{-1}) using the relation.

$$\text{Count rate per minute (CMP)} = 10^{-6}\,\text{roentgen} \times \text{Q.F} \quad (1)$$

where Q.F is the quality factor, which is unity for external environment.

The equivalent dose rate in micro-sieverts per week was obtained using the relation (Avwiri et al. 2007).

$$1\,\text{Rh}^{-1} = 0.445\,\text{Sv/week} \quad (2)$$

Table 1 Background ionizing radiation levels (BIR) Ughelli metropolis

S. no.	Sample site	Geographical location	Average exposure rate ($\mu Rh^{-1)}$)	Equivalent dose rate (μSv/week)	Equivalent dose rate ($mSvy^{-1}$)	Absorbed dose Rate (ηGyh^{-1})	Annual effective dose equivalent ($mSvy^{-1}$)	Excess life cancer risk × 10^{-3} ($mSvy^{-1}$)
1	IG global micro-finance bank	N05°29.839″ E006°00.696″	14.00 ± 3.00	6.23 ± 1.34	1.18 ± 0.25	121.80	0.15	0.53
2	Agbarha junction	N05°28.967″ E006°01.116″	11.00 ± 1.50	4.90 ± 0.67	0.93 ± 0.13	95.70	0.12	0.42
3	Ughelli stadium	N05°28.776″ E006°01.141″	16.10 ± 3.50	7.12 ± 1.56	1.35 ± 0.29	140.07	0.17	0.60
4	Ughelli Kingdom Ovie palace	N05°28.861″ E006°00.918″	14.00 ± 2.80	6.23 ± 1.25	1.18 ± 0.24	121.80	0.15	0.53
5	Ughelli centre mosque	N05°29.077″ E006°00.691″	14.00 ± 3.00	6.23 ± 1.34	1.18 ± 0.25	121.80	0.15	0.53
6	SPDC Logistic Centre	N05°29.315″ E006°00.375″	22.00 ± 4.40	9.79 ± 1.96	1.85 ± 0.37	191.40	0.23	0.81
7	Uloho Avenue Junction	N05°29.463″ E006°00.106″	13.00 ± 2.00	5.79 ± 0.89	1.09 ± 0.17	113.10	0.14	0.49
8	Post-office Junction	N05°29.611″ E005°.59.788″	14.00 ± 3.20	6.23 ± 1.42	1.18 ± 0.27	121.80	0.15	0.53
9	Ughelli Refused Waste dump site	N05°29.354″ E005°59.724″	15.00 ± 3.00	6.68 ± 1.34	1.26 ± 0.25	130.50	0.16	0.56
10	Delta state Urban Water board Ughelli	N05°29.470″ E005°59.516″	07.00 ± 1.00	3.12 ± 0.45	0.59 ± 0.08	60.90	0.07	0.25
11	Ughelli High courtII premises	N05°29.456″ E005°59.431″	11.00 ± 1.20	4.90 ± 0.53	0.93 ± 0.10	95.70	0.12	0.42
12	Ughelli North L.G.A secretarial	N05°29.291″ E005°59.341″	14.00 ± 2.40	6.23 ± 1.07	1.18 ± 0.20	121.80	0.15	0.53
13	Ughelli General Hospital yard	N05°29.530″ E005°59.016″	15.00 ± 2.70	6.68 ± 1.20	1.26 ± 0.23	130.50	0.16	0.56
14	All Saint Anglican Cathedral Ighwrekpokpo	N05°29.609″ E005°59.589″	09.00 ± 1.70	4.01 ± 0.76	0.76 ± 0.14	78.30	0.10	0.35
15	Ughelli centre Market	N05°29.837″ E005°59.364″	20.00 ± 3.90	8.90 ± 1.78	1.68 ± 0.33	174.00	0.21	0.74
16	Omotor street Junction	N05°29.983″ E005°59.384″	16.00 ± 3.00	7.12 ± 1.34	1.35 ± 0.25	139.20	0.17	0.60
17	St. Theresa Grammar Sch.	N05°30.201″ E005°59.030″	12.00 ± 2.20	5.32 ± 0.98	0.99 ± 0.19	104.40	0.13	0.46
18	Setraco Nig Ltd camp Site Ughelli	N05°30.441″ E005°59.697″	28.00 ± 4.60	12.46 ± 2.05	2.35 ± 0.39	243.60	0.30	1.05
19	Afiesere Junction Ughelli	N05°30.050″ E006°00.320″	25.00 ± 4.00	11.13 ± 1.78	2.1 ± 0.34	217.50	0.27	0.95
20	Agofure motor park Ughelli	N05°29.018″ E006°01.105″	11.00 ± 2.30	4.90 ± 1.02	0.92 ± 0.19	95.70	0.12	0.42

Table 1 continued

S. no.	Sample site	Geographical location	Average exposure rate (μRh^{-1})	Equivalent dose rate (μSv/week)	Equivalent dose rate ($mSvy^{-1}$)	Absorbed dose Rate (ηGyh^{-1})	Annual effective dose equivalent ($mSvy^{-1}$)	Excess life cancer risk $\times 10^{-3}$ ($mSvy^{-1}$)
21	Otovwodo Centre Motor park	N05°28.773″ E006°01.144″	18.00 ± 3.30	8.01 ± 1.46	1.51 ± 0.28	156.60	0.19	0.67
	Mean		15.20 ± 2.80	6.76 ± 1.25	1.28 ± 0.24	132.16 ± 24.36	0.16 ± 0.03	0.56 ± 0.10

Results and discussion

Equivalent dose rate

To estimate the whole body equivalent dose rate over a period of 1 year, we use the National Council on Radiation Protection and Measurement (NCRP 1993; Avwiri et al. 2013) recommendation:

$$1\ mRh^{-1} = \frac{0.96 \times 24 \times 365}{100}\ mSvy^{-1} \quad (3)$$

The results of the measured background ionizing radiation (BIR) levels and calculated equivalent dose, absorbed dose rate, the annual equivalent dose rate and the excess life cancer risk obtained in this study are presented in Tables 1 and 2. Table 1 shows the average exposure rate determined for the twenty-one sampled locations within Ughelli metropolis. The values obtained range from 7.00 ± 1.0 μRh^{-1} (3.12 ± 0.45 μS/week) in Ughelli Urban Water Board to 28.00 ± 4.6 μRh^{-1} (12.46 ± 2.05 μSv/week) near Setraco Asphalt Plant/Camp Site with a mean value of 15.19 ± 2.80 μh^{-1} (6.76 ± 2.05 μSv/week). The corresponding equivalent dose rate over 1 year ranged from 0.59 ± 0.08 $mSvy^{-1}$ to 2.35 ± 0.39 $mSvy^{-1}$ with a mean value of 1.28 ± 0.24 $mSvy^{-1}$.

The lowest radiation exposure value was recorded at the abandoned Delta State Urban Water Board in Ughelli, while the highest value was recorded at the Setraco campsite with asphalt processing plant. The high radiation levels observed at the Setraco camp site may be attributed to the presence of the road construction materials like granites, stone base, asphalt, cement, etc. and chemicals, which contained some radioactive elements used by the company. These are called Technically Enhance Naturally Occurring Radioactive Materials (TENORM). The average exposure rate and equivalent dose rate value obtained in the Ughelli metropolis exceeded the recommended ambient BIR level of 13.00 μRh^{-1} and 1.00 $mSvy^{-1}$, respectively, by ICRP (1990) for the general public. The results indicate that 71% of the sampled location or points exceeded the ambient/permissible levels for the general public.

Table 2 shows the experimental results for the average background environmental radiation levels, within the major towns and villages that constitute Ughelli North L.G.A. The background ionizing radiation levels obtained ranges from 10.00 ± 1.6 μRh^{-1} (4.45 ± 0.71 μSv/week) in Ighwrekpokpo Community to 23.00 ± 4.1 μRh^{-1} (10.24 ± 82 μSv/week) in Ekiugbo community with a mean value of 15.19 ± 2.70 μRh^{-1} (6.76 ± 1.20 μSv/week). The corresponding equivalent dose rate over 1 year ranged from 0.84 ± 0.13 to 1.93 ± 0.34 $mSvy^{-1}$ with a mean value of 1.28 ± 0.23 $mSvy^{-1}$.

The highest radiation value was recorded in Ekiugbo community; this could be attributed to the community proximity to the Alcon and Setraco Nig. Ltd campsites where the companies' asphalt plants are located, stone base are stored and asphalts for road tiring which have some history of radioactive materials are processed. It may also be attributed to the oil exploration activities that are going on in the area (Agbalagba et al. 2009; Agbalagba and Meindinyo 2010; Avwiri and Agbalagba 2012). The elevation in the radiation levels obtained in Gana, Evwreni and Emeragha communities may be as a result of the presence and proximity of these communities to the flow and flare stations and other oil facilities in those environments which are also in conformity with the values reported by Avwiri et al. (2007). The results of the studies indicate a mean radiation value of 15.19 ± 2.70 μRh^{-1} (6.76 ± 1.20 μSv/week) for the two environments, which show a close to uniform distribution of radionuclides within the L.G.A. The results indicate that sixteen out of the twenty-one (76%) of the sampled communities exceeded the ambient levels for the general public. The average exposure rate and equivalent dose rate value obtained in the Ughelli metropolis exceeded the recommended ambient BIR level of 13.19 ± 2.80 μh^{-1} and 1.00 $mSvy^{-1}$, respectively, by ICRP (1990) for the general public.

Figure 1 shows the radiation distribution pattern within Ughelli North and the comparison of the equivalent dose rate within Ughelli metropolis, the adjoining communities in the local government area with the standard permissible level of 1.0 $mSvy^{-1}$, while Figs. 2 and 3 are the GIS maps of Ughelli metropolis and Ughelli environs, respectively, showing the BIR distribution with levels within and above global ambient standard. These values obtained are in agreement with previous study in Niger Delta environment

Table 2 Background ionizing radiation (BIR) levels of major communities in Ughelli North L.G.A

S. no.	Location (community)	Geographical location	Average exposure rate (μRh^{-1})	Equivalent dose (μSv/week)	Equivalent dose rate ($mSvy^{-1}$)	Absorbed dose Rate (ηGyh^{-1})	Annual effective dose equivalent ($mSvy^{-1}$)	Excess life cancer risk $\times 10^{-3}$ ($mSvy^{-1}$)
1	Orogun	N05°35.046″ E006°05.207″	13.00 ± 2.40	5.79 ± 1.07	1.09 ± 0.20	113.10	0.14	0.49
2	Agbarha-Otor	N05°32.207″ E006°04.571″	12.00 ± 3.00	5.34 ± 1.34	0.99 ± 0.25	104.40	0.13	0.46
3	Omavovwe	N05°32.810″ E006°03.196″	16.00 ± 3.40	7.12 ± 1.51	1.35 ± 0.29	139.20	0.17	0.60
4	Gana	N05°31.505″ E006°03.041″	18.00 ± 3.60	8.01 ± 1.60	1.51 ± 0.30	156.60	0.19	0.67
5	Saniko-Owevwe	N05°31.103″ E006°02.828″	16.00 ± 2.80	7.12 ± 1.25	1.35 ± 0.24	139.20	0.17	0.60
6	Uduere	N05°30.344″ E006°01.116″	11.00 ± 1.40	4.90 ± 0.62	0.93 ± 0.12	95.70	0.12	0.42
7	Otogor	N05°27.212″ E006^{0}01.746″	13.00 ± 2.70	5.79 ± 1.20	1.09 ± 0.23	113.10	0.14	0.49
8	Edjekota	N05°26.488″ E006°.01.177″	11.00 ± 1.90	4.90 ± 0.85	0.93 ± 0.16	95.70	0.12	0.42
9	Evwreni	No5°24.135″ E006°03.967″	21.00 ± 3.60	9.35 ± 1.60	1.77 ± 0.30	182.70	0.22	0.77
10	Uwheru	N05°23.221″ E006°04.327″	14.00 ± 2.20	6.23 ± 0.98	1.18 ± 0.19	121.80	0.15	0.53
11	Oteri-Ughelli	N05°29.554″ E005°58.326″	15.00 ± 3.10	6.68 ± 1.38	1.26 ± 0.26	130.50	0.16	0.56
12	Ekiugbo	N05°30.587″ E005°58.653″	23.00 ± 4.10	10.24 ± 1.82	1.93 ± 0.34	200.10	0.25	0.88
13	Eruemukohwoarien	N05°29.530″ E006°59.016″	17.00 ± 3.00	7.57 ± 1.34	1.43 ± 0.25	147.90	0.18	0.63
14	Agbarho	N05°35.825″ E006°59.589″	16.00 ± 2.50	7.12 ± 1.11	1.35 ± 0.21	139.20	0.17	0.60
15	Emekpa	N05°35.837″ E005°54.148″	10.00 ± 2.00	4.45 ± 0.89	0.84 ± 0.17	87.00	0.11	0.39
16	Ighwrekpokpo	N05°30.200″ E006°00.950″	10.00 ± 1.60	4.45 ± 0.71	0.84 ± 0.13	87.00	0.11	0.39
17	Afiesere	N05°31.601″ E006°00.796″	15.00 ± 2.70	6.68 ± 1.20	1.26 ± 0.23	130.50	0.16	0.56
18	Emeragha	N05°32.582″ E006°01.530″	21.00 ± 3.30	9.35 ± 1.47	1.77 ± 0.28	182.70	0.22	0.77
19	Ofuoma	N05°33.115″ E006°01.320″	17.00 ± 3.10	7.57 ± 1.38	1.43 ± 0.26	147.90	0.18	0.63
20	Awirhe	N05°37.664″ E006°03.712″	14.00 ± 2.30	6.23 ± 1.02	1.18 ± 0.20	121.80	0.15	0.53
21	Odovie	N05°34.667″ E006°02.001″	16.00 ± 2.40	7.12 ± 1.07	1.35 ± 0.20	139.20	0.17	0.60
	Mean		15.19 ± 2.70	6.76 ± 1.20	1.28 ± 0.23	132.15 ± 23.50	0.16 ± 0.03	0.56 ± 0.11

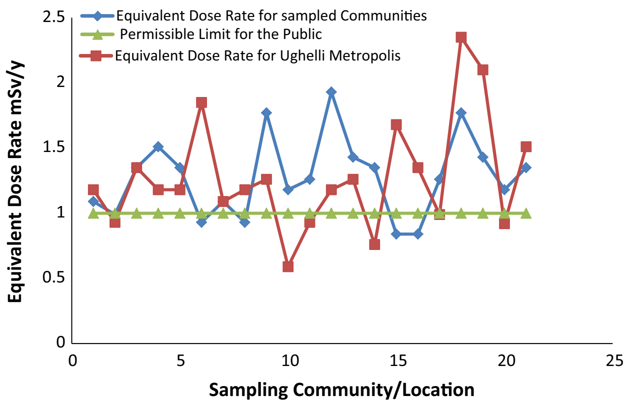

Fig. 1 Comparison of the equivalent dose rate in sampled communities and Ughelli metropolis with permissible limit

(Arongunjo et al. 2004; Akpabio et al. 2005; Avwiri et al. 2007, 2013), which reflect a picture of radioactive contaminated environment.

Absorbed dose rate

The data obtained for the external exposure rate in μRh^{-1} were also converted into absorbed dose rate μGyy^{-1} using the conversion factor (Rafique et al. 2014)

$$1\,\mu Rh^{-1} = 8.7\,\eta Gyh^{-1} = \frac{8.7\times 10^{-3}}{\left(\frac{1}{8760y}\right)}\,\mu Gyy^{-1} = 76.212\,\mu Gyy^{-1} \quad (4)$$

The result of the outdoor gamma radiation absorbed dose rates for Ughelli metropolis and the major communities in Ughelli North local government area is presented in column 6 of Tables 1 and 2. The estimated minimum and maximum outdoor absorbed gamma dose rates of 60.90 and 243.10 ηGyh^{-1} were recorded at Delta State Urban Water Board Ughelli and Setraco Nig. Ltd Camp site, respectively, in Ughelli metropolis with a mean value of $132.16 \pm 24.36\ \eta Gyh^{-1}$. While in the adjoining communities, the minimum and maximum gamma absorbed dose rates values of 87.00 and 200.10 ηGyh^{-1} were obtained in Emekpa/Ighwrekpokpo and Ekiugbo communities, respectively, with a mean value of $132.15 \pm 23.50\ \eta Gyh^{-1}$. The obtained mean gamma absorbed dose rates in this current study are higher than the values previously reported by Rafique (2013) and Rafique et al. (2013), of 710 ηGyy^{-1} (81.61 ηGyh^{-1}) and 893.50 ηGyy^{-1} (102.70 ηGyh^{-1}) for Muzaffarabad and Poonch Turkey, respectively, and for the Greek population value of 280 ηGyy^{-1} (32 ηGyh^{-1}) (Clouvas et al. 2004). They are also higher than values reported in some part of the world as documented in the UNSCEAR (2000) report. These countries include New Zealand (20 ηGyh^{-1}), USA (38 ηGyh^{-1}), UK (60 ηGyh^{-1}), Poland (67 ηGyh^{-1}), Norway (80 ηGyh^{-1}), China (100 ηGyh^{-1}), Portugal (102 ηGyh^{-1}), Italy (105 ηGyh^{-1}) (UNSCEAR 2000). However, the current gamma dose rates are similar to the range of values report in Turkey, 686–1189 μGyy^{-1} (78.30–135.70 ηGyh^{-1}) (Erees et al. 2006), Japan, 121–1638 ηGyy^{-1} (13.8–187.0 ηGyh^{-1}) (Chikasssawa et al. 2001) and 75.0–509.38 ηGyh^{-1} (Amekudzie et al. 2011). The mean value obtained in both the metropolis and its environ that made up Ughelli local government area is higher than the world population weighted average gamma dose rates value of 59 ηGyh^{-1} (UNSCEAR 2000).

The annual effective dose equivalent (AEDE)

The computed absorbed dose rates were used to calculate the annual effective dose equivalent (AEDE) received by residents living in the study area. For the calculation of the AEDE, we used dose conversion factor of 0.7 Sv/Gy recommended by the UNSEAR 1993 for the conversion coefficient from absorbed dose in air to effective dose received by adults and occupancy factor of 0.2 for outdoor.

The annual effective dose equivalent is determined using the equation

$$\begin{aligned}\mathrm{AEDE(Outdoor)}\left(mSvy^{-1}\right) &= \text{Absorbed dose}\left(\eta Gyh^{-1}\right) \times 8760\,h \times 0.7\,Sv/Gy \times 0.2 \\ &= \text{Absorbed dose}\left(\eta Gyh^{-1}\right) \times 1.2264 \times 10^{-3}\end{aligned} \quad (5)$$

Estimated values of annual effective dose equivalent for the outdoor exposure ranges from 0.07 to 0.30 $mSvy^{-1}$ with a mean value of $0.16 \pm 0.03\ mSvy^{-1}$ in the Ughelli metropolis, and in the Ughelli environs, the value ranges from 0.11 to 0.25 $mSvy^{-1}$ with a mean value of $0.16 \pm 0.03\ mSvy^{-1}$. These annual effective dose equivalent values obtained are similar to the values reported in Al-Rakkah in Saudi Arabia (Al Mugren 2015). The worldwide average of the annual effective dose is 0.41 mSv of which 0.07 $mSvy^{-1}$ is from outdoor and 0.34 $mSvy^{-1}$ from indoor exposure (UNSCEAR 2000; Amekudzie et al. 2011; Al Mugren 2015), and the values obtained in this study are well above the world average normal annual effective dose level for outdoor which is an indication of radiological contamination of the terrestrial environment of Ughelli North L.G.A.

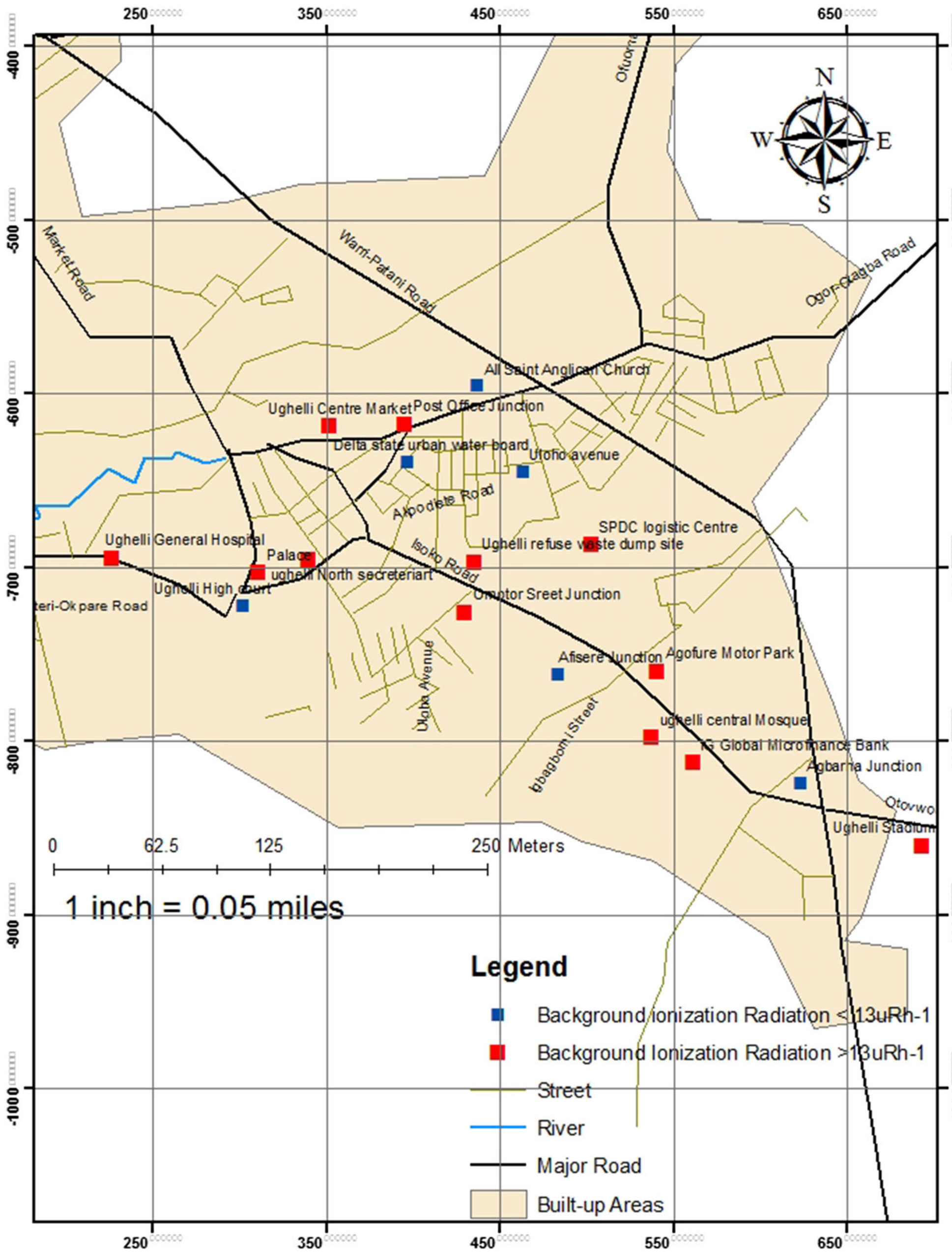

Fig. 2 GIS map of Ughelli metropolis showing the BIR distribution with levels within and above global ambient level

Excess Life Cancer Risk (ELCR)

The Excess Life Cancer Risk (ELCR) was estimated based on the calculated values of AEDE, using the equation

$$\mathrm{ELCR}\left(\mathrm{mSvy}^{-1}\right) = \mathrm{AEDE} \times \text{Average Duration of Life(DL)} \times \text{Risk Factor(RF)} \quad (6)$$

where AEDE, DL and RF are the annual effective dose equivalent, duration of life (70 years) and the risk factor (Sv^{-1}), fatal cancer risk per sievert. For low dose background radiations which are consider to produce stochastic effects, ICRP 60 uses value of 0.05 for the public exposure (Taskin et al. 2009; Rafique et al. 2014).

The excess life cancer risk (ELCR) exposure ranges from 0.25×10^{-3} to 1.05×10^{-3} mSvy^{-1} with a mean value of $(0.56 \pm 0.10) \times 10^{-3}$ mSvy^{-1} in the metropolis, while the ELCR exposure in the adjoining communities ranges from 0.39×10^{-3} to 0.88×10^{-3} mSvy^{-1} with a mean value of $(0.56 \pm 0.11) \times 10^{-3}\mathrm{mSvy}^{-1}$. The overall average ELCR value obtained in current study area is twice the world average value of $0.29 \times 10^{-3}\mathrm{mSvy}^{-1}$ (Taskin et al. 2009). This result obtained for ELCR indicates that the chance of contacting cancer by residents of the study

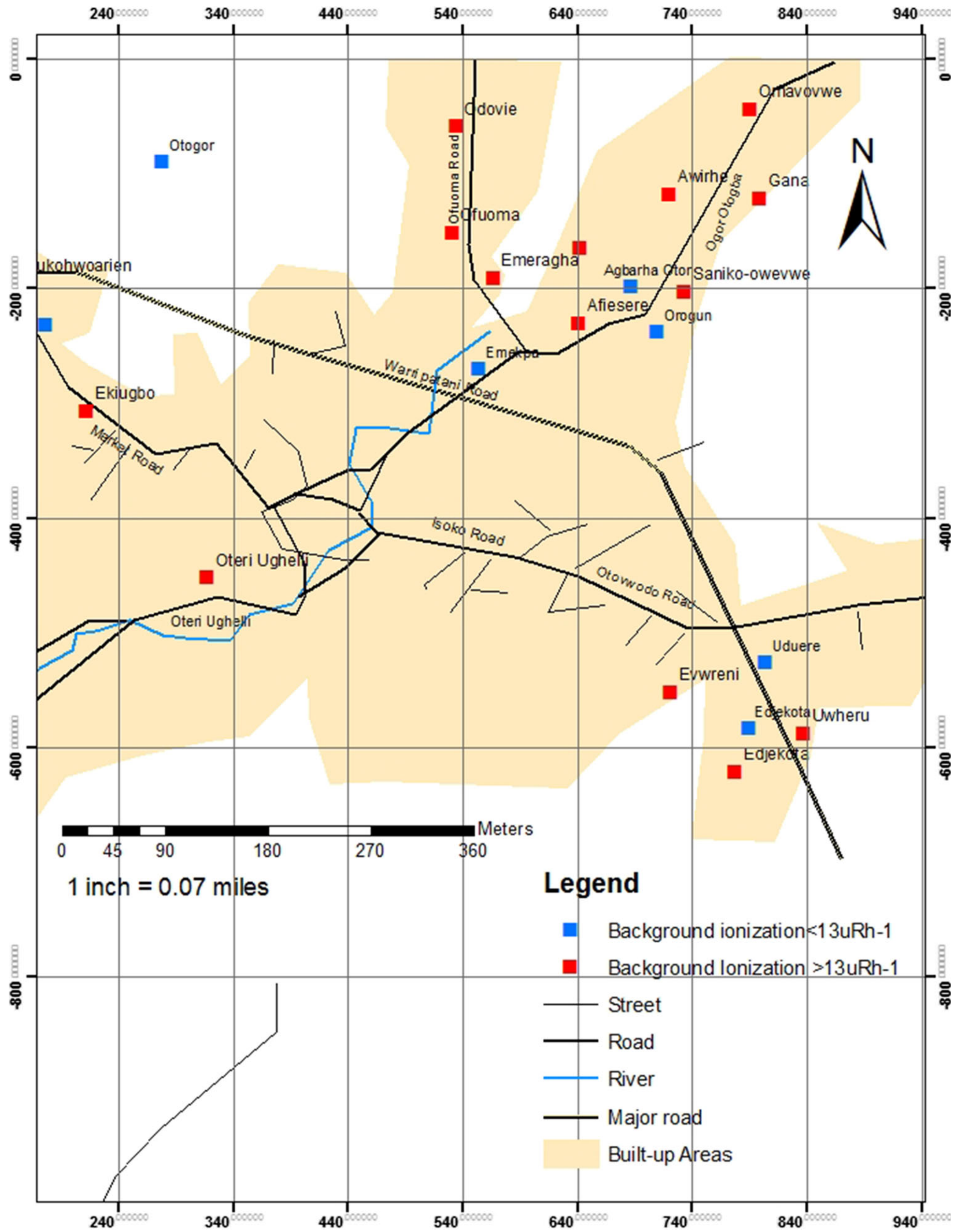

Fig. 3 GIS map of Ughelli environs showing the BIR distribution with levels within and above global ambient level

area who will spend all their life time in Ughelli is probable.

The overall results obtained shows a significant elevation of the radiation level in the study area compared to other parts of the world, but these values may not constitute immediate health hazard to the resident of these communities/areas investigated within the Ughelli North L.G.A. But the highest equivalent dose rate, annual effective dose equivalent rate and excess life cancer recorded at Setraco campsite are of great concerns since majority of the workers (Security, Plant operators, Plant maintenance Engineers, plant attendance, etc.) spends over 8 h per day in this environment while some top management officers including Expatriates resides within this premises while others leave close to the premises. The accumulate dose at the present level may cause lung cancer in the future in the ratio 1/20,000, if residents and worker are exposed to this level of radiation continually. More so, there is still the likelihood of future (long-term) health side effects to the populace living in Ughelli metropolis and its environ due to accumulation of radiation doses, precipitates (that contain radioactive elements) which on condensation as rain constitutes radioactive pollution of rainwater. Unfortunately, this serves as a major source of water for drinking and agriculture in the study area. As a result of this indirect ingestion of these radionuclides, the levels of exposure of the residents may be enhanced.

Conclusion

The study of the terrestrial background radiation levels using GIS mapping of Ughelli and its environs has been carried out. The mean equivalent dose rate obtained is higher than the safe exposure limit of 1.0 $mSvy^{-1}$ recommended by UNSCEAR, and the mean radiation exposure levels in the study area are well above the normal background radiation level of 13.00 μRh^{-1} which shows that the studied area is radiologically contaminated. The obtained gamma absorbed dose rates and the annual effective dose equivalent in the study are well above the world average levels. The estimated ELCR indicates that the chance of contacting cancer by residents of the study area who will spend all their life time in Ughelli is probable.

The overall results of the measured exposure rates and the estimated radiological hazard indices show that 73.5% of the sampled location exceeded their permissible limits. Though these values obtained may not cause immediate health hazard, continuous exposure to BIR level at this rate and level may lead to long-term accumulating health side effects on the residents of some of these locations and communities sampled.

Since radiation exposure in this environment may constitute health hazard on the long term, it is therefore safe to recommend the following as interim measures while detail research is ongoing.

- Government and the operators of facilities should device mean of reducing radionuclide input and output to prevent increase in BIR.
- Asphalt processing plant and oil and gas facilities identified as potential sources of enhancing BIR levels should be relocated away from residential area.
- There should be a regular monitoring of radiation levels in these environments by the operating companies, friend of the environment and government agencies responsible for the safety (radiation) of the environment.
- Further research work on the levels of contamination of the soil, water and sediment of these flash points (high BIR levels) should be carried out.
- Research on the radiation dispersion and transportation mechanism and modeling should be conducted.

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