RADIATION ORGAN DOSES AND EXCESS LIFETIME CANCER RISK DUE TO EXPOSURE TO GAMMA RADIATION FROM TWO CEMENT INDUSTRIES IN NIGERIA

Abstract

A study of background ionizing radiation (BIR) levels to estimate organ dose rates and excess lifetime cancer risk in Unicem cement producing company, Calabar , Cross River state and Bua cement producing company, Okpella in Edo state have been carried out using Digilert 100 and Radalert-200 nuclear radiation monitor and a geographical positioning system (GPS) for GIS mapping of the area. The *in-situ* measurement of the exposure rate was between May, 2018 and June, 2019 at regular intervals. The average exposure rate of 0.023 mRh^{-1} was measured at Unicem, Calabar and 0.027 mRh^{-1} at Bua cement area, Okpella. The mean equivalent doses of 1.92 mSvy^{-1} and 2.29 mSvy^{-1} was recorded in Unicem and Bua Okpella respectively. The estimated mean outdoor absorbed dose rate value of 196.74 nGyh^{-1} in Unicem and its environment while in Bua cement industry, Okpella, the value of 234.9 nGyh^{-1} was obtained. The mean annual effective dose calculated was 0.24 and 0.29 mSvy^{-1} for Unicem and Bua Okpella respectively. The mean excess life time cancer risk recorded in the areas 0.72 x10^{-3} in Unicem area and 1.01 x10^{-3} in Bua cement environment. The calculated dose to organs showed that the testes have the highest organ dose of 0.74 mSvy^{-1} and 0.83 mSvy^{-1} for Unicem and Bua Okpella areas respectively while the liver has the lowest organ dose of 0.08 mSvy^{-1} and 0.11 mSvy^{-1} for Unicem and Bua Okpella respectively. This study revealed that the exposure rate and all the radiological risk parameters exceeded their recommended safe values. The area of study are radiologically polluted and may be detrimental to human health for long term exposure.

Keywords: Unicem cement, Okpella, Digilert 100, Radiation, Excess lifetime cancer risk

1. Introduction

The presence of contaminants in human environment has attracted serious attention in research community over the years. This is as a result of health risk associated with its exposure especially at levels above the prescribed safety limits [1]. Environmental and occupational pollution has always been a major cause of morbidity and mortality. The smoke and dust produced by some industries cause various types of pathogenesis [2]. Cement dust of Portland cement contains various types of metal oxides including calcium oxide, magnesium oxide, sand (which contains natural radionuclides) and other impurities [2]. Respiratory problems with high prevalence and varying degrees of airway obstruction due to Portland cement exposure have been reported by some researchers [3, 4, 5].

The exposure of human beings to ionizing radiation both from natural and man-made sources is a continuous and inescapable features of life on earth [6] environmental radioactivity measurement

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are necessary to determine the background radiation level due to natural radioactivity sources of terrestrial and cosmic origins. Background radiation consists of three primary types: primordial, cosmogenic and anthropogenic. Primordial radionuclides are present in the earth's crust and found throughout the environment. Cosmogenic radionuclide are produced when cosmic radiation interacts with elements present in the atmosphere and are deposited through wet and dry deposition [7]. Anthropogenic sources of radiation result from human activities but are considered background because their presence is ubiquitous.

According to UNSCEAR [8], about 87% of the radiation dose received by man is from natural sources and the remaining is due to anthropogenic sources. The activities of industries including gas flaring in flow stations, crude oil spills in the oil and gas installations, spills of imported toxic chemicals and radionuclide materials for geological mapping, x-ray welding and well logging and cement production activities can increase the background ionizing radiation levels [9]. Exposure to background radiation may add to radiation exposure levels that may cause detrimental health effects to workers and residents [10]. Research has shown that exposure to ionizing radiation can cause cancer and mental retardation in children of exposed mothers during pregnancy. High radiation doses may also cause other health effects as listed by the NRC [11, 12].

Avwiri *et al.*, [13], studied the terrestrial radiation levels around oil and gas facilities in Ugheli region of Nigeria and reported that exposure rates are within the safe levels. Michael [14] studied the environmental pollution and health risks of residents living near Ewekoro cement factory Ewekoro and showed that residents living less than 1 km to the cement company have high health risk than those living 4 km away. In Pakistan, Rafique evaluated the excess lifetime cancer risk from the measured BIR levels and reported a mean value of 1.62×10^{-3} and absorbed dose greater than world average value of 780 μRh^{-1} [12].

Evaluation of health risk indices from radiation exposure rate is important because it will be very useful in evaluating the likelihood of developing various health effects associated with radiation exposure in the area. Hence the aim of this study is to estimate the equivalent dose, the absorbed dose rate, the annual effective dose equivalent (AEDE) and excess lifetime cancer risk (ELCR) from the measured gamma exposure rate. The result of this work will serve as baseline data for future radiation monitoring of the study area.

2. Materials and Method

This study was conducted between May, 2018 and June, 2019 which represented the seasons transition (dry-to-wet) period. This is to take care of variation of radionuclide concentration in atmosphere due to changes in atmospheric parameters. Two areas are involved in this study UNICEM Calabar and BUA cement Okpella, Edo state. UNICEM cement factory is situated in Mfamosing, Calaber, Cross River state, Nigeria. It lies between Latitude 5°31′0 N and Longitude 8°31′0 E and its original name is Mfamosing. Geologically, the area is composed of tertiary to

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recent, continental fluvialite sand clay, known as the coastal plan sand. Okpella is located at coordinate of 7^{o}27′21″N latitude, 6^{o}34′65″E longitude is the host community of BUA cement factory. Going by the last National census figure, it is the third largest autonomous clan in Edo state after. Okpella is known for its natural sedimentary rock based mineral resources, which include limestone, calcium and granite, feldspar, talc, clay, marble. The town play host to the Edo cement company. In view of the abundance of other solid minerals, it is home for several granite and marble-making industries, which gives the community a vibrant industrial outlook.

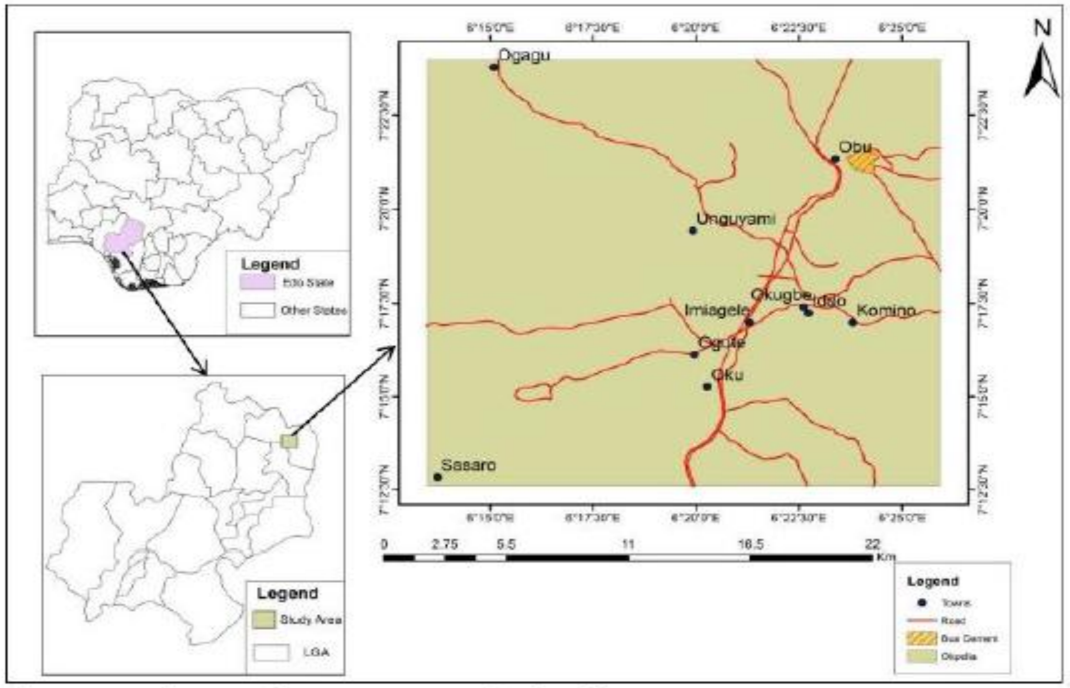

Figure 1: The Study Area Map of Okpella

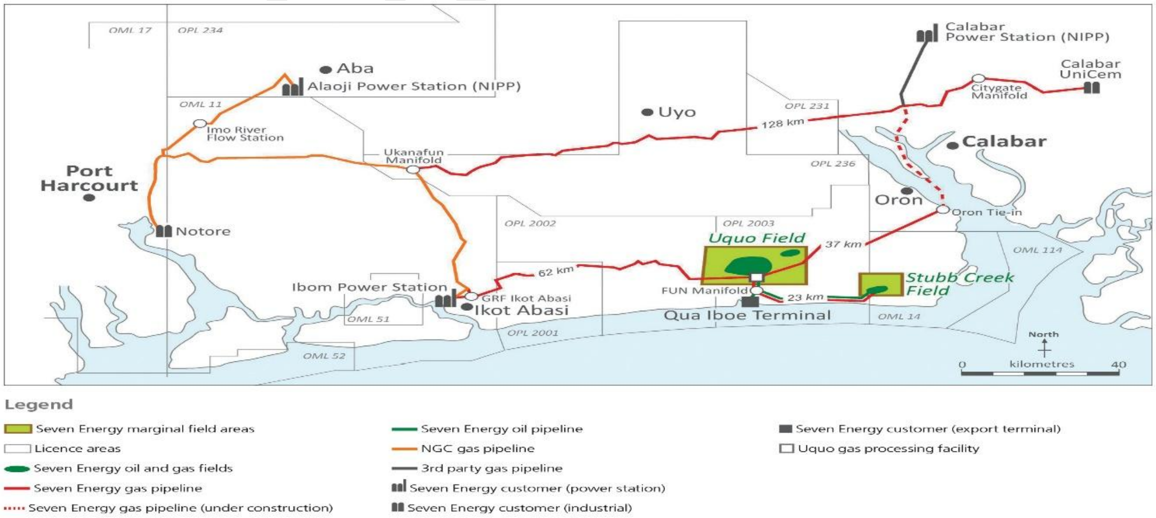

Fig.1b: The study Area UNICEM cement Calabar.

Measurement were made in strategic areas within and around the two cement production companies. An in-situ approach was adopted to enable samples to maintain their original environmental characteristics. A digilert-100 and Radalert-200 nuclear radiation monitors (SE International Inc Summer Town USA) containing a Geiger Muller tube capable of detecting α, β, γ and x rays. Preset for γ-rays measurement were used within the temperature range of -10 to 50 °C and a Global positioning System (GPS) was used to measure the precise location of sampling. The radiation meter's sensitivity is 3500 CPM/ mRh^{-1} relative to Cs-137 and its maximum alpha and beta efficiencies are 18 % and 33 % respectively.it has a halogen quenched Geiger- muller detector tube with an effective diameter of 45 mm and a mica window density of 1.5-2.0 $mgcm^{-2}$ (Inspector Alert operation manual).

The Unicem cement producing industrial areas was strategically divided into twenty two sampling points to cover the operational area and Bua cement production industry was divided into twenty sampling points which covered the residential areas of the workers. In each of the sampling points, the tube of the radiation monitoring meters was raised to a standard height of 1.0 m above the ground [15, 16] with its window facing the suspected source while the GPS reading was taken at that spot. Measurement were repeated four times at each sampling point during different months within the two seasons to account for any fluctuation in the environmental parameters. Reading were obtained between 1300 and 1600 hours because the radiation meter has a maximum response to environmental radiation within these hours according to NCRP (17). The meter was set to read in milli-roentgen per hour.

2.2 Radiological parameters

From the radiation exposure rate measured in each of the cement production sites in the two states, radiological health risk parameters were estimated to ascertain the radiological status of workers and residents around the cement factories due to exposure to background radiation.

2.2.1: Absorbed Dose Rate

This is the amount of energy deposited by radiation in a mass which could be human body or other objects. The measured exposure rate obtained in mRh^{-1} were converted into absorbed dose rates in $nGyh^{-1}$ using the conversion factor [12]:

$$1\ \mu Rh^{-1} = 8.7\ nGyh^{-1} = \frac{8.7\ x\ 10^{-3}}{(\frac{1}{8760}\ y)}\ \mu Gyy^{-1} = 76.212\ \mu Gyy^{-1} \qquad 1$$

2.2.2: Equivalent Dose Rate

This is calculated for individual organs. It is based on the absorbed dose to an organ, adjusted to account for the effectiveness of the type of radiation. To estimate the whole body equivalent dose rate over a period of one year, the National Council on Radiation Protection and measurement's recommendation was used [NCRP, 1993].

$$1\ mRh^{-1} = \frac{0.96\ x\ 24\ x\ 365}{100}\ mSvy^{-1} \qquad 2$$

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2.2.3: Annual Effective Dose Equivalent (*AEDE)*

The estimated absorbed dose rates were used to calculate the annual effective dose equivalent received by residents living in the area of the study and workers of the cement production. For the calculation of the AEDE, we used the dose conversion factor of 0.7 Sv/Gy recommended by UNSCEAR for the conversion coefficient from the absorbed dose in air to the effective dose received by adults and occupancy factor of 0.2 for outdoor exposure [8].

The annual effective dose equivalent was determined using the equation:

$$\text{AEDE}\ (\text{mSvy}^{-1}) = \text{Absorbed dose}\ (\text{nGyh}^{-1}) \times 8760\ \text{h} \times 0.7\ \text{Sv/Gy} \times 0.2 \qquad 3$$

2.2.4: Excess Lifetime Cancer Risk (ELCR)

The excess lifetime cancer risk (ELCR) was estimated based on the estimated values of the annual effective dose equivalent using equation 4.

$$\text{ELCR} = \text{AEDE} \times \text{Average duration of life (DL)} \times \text{risk factor (RF)} \qquad 4$$

Where AEDE is the annual effective dose equivalent, DL is duration of life (70 years) and RF is the fatal cancer risk factor (Sv^{-1}). For low dose background radiation which is considered to produce stochastic effects, ICRP 60 uses a fatal cancer risk factor value of 0.05 for public exposure [12].

2.2.5 The Effective dose rate (D_{organs}) to different body organs and Tissues

The effective dose rate to a particular organ can be estimated using the following relation:

$$D_{organ}\ (\text{mSvy}^{-1}) = O \times \text{AEDE} \times F \qquad 5$$

Where AEDE is annual effective dose equivalent, O is the occupancy factor (0.8) and F is the conversion factor for organ dose from ingestion.

The F values for lungs, ovaries, bone marrow, testes, kidneys, liver and whole body were 0.64, 0.58, 0.69, 0.82, 0.62, 0.46, and 0.68 respectively as obtained from ICRP [30]. The same occupancy factor was used for the data from two different areas because of their similarity of cultural settings. The work force spend 80% of their lifetime indoor [29].

3 Results and Discussion

3.1 Results

The result of the measured exposure rate and the calculated hazard risks for the two cement production companies and its surroundings are presented in Table 1-2. Analysis using different radiation models to arrive at a more reliable health risks to an irradiated person was performed. To assess the radiation hazards associated with the gamma radiation levels in unicem industry and its environmental and Bua cement and its surrounding environment. The following radiation

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hazard indices were used: equivalent dose, absorbed dose rate, annual effective dose equivalent, excess lifetime cancer risk and effective dose to different organs.

3.1.1 Background ionizing radiation (BIR) exposure levels

The results of the BIR levels measured in Unicem Cement Company and its surroundings are presented in Table 1 while that for Bua Cement Company and its environment are presented in Table 2. The radiation exposure rate measured at Unicem and its environs ranged from 0.011 to 0.037 mRh^{-1} with an average value of 0.023 mRh^{-1} and for Bua cement in Okpella and its environment, the exposure rate measured ranged from 0.012 to 0.038 mRh^{-1} with mean value of 0.027 mRh^{-1}. The mean values obtained from all the cement production companies and their host communities are all above the world average BIR level of 0.013 mRh^{-1}; this indicates that the BIR levels in Unicem environment in Calabar and Bua cement environs in Edo state are elevated. All the sampling points in both areas recorded high exposure values which could be attributed to anthropogenic activities in the two areas. It could be due to mining activities that brings naturally occurring radioactive materials to the surface of the earth and the cement production activities.

Exposure rate measured at Okpella, Bua Cement Company and their host communities were higher than the one recorded in Calabar, Unicem and their host communities. Okpella is known for its natural sedimentary rock based mineral resources, which include limestone, calcium and granite, feldspar, talc, clay, marble and more. In view of the abundance of other solid minerals, it is home for several granite and marble-making industries, which gives the community a vibrant industrial outlook. The activities of all these miners may have contributed to higher levels of background ionizing radiation in the area. High background radiation levels measured in Unicem and Bua cement production companies and their host communities could also be due to the urban mix nature of these areas, where companies and factories sandwich residential areas. These companies may be using materials that contain radioactive sources such as paint producing company. The lowest exposure rate of 0.011 and 0.012 mRh^{-1} for Unicem and Bua Cement areas respectively obtained at the entrance to the community could be due to its location away from industrial sites.

The radiation contour map of the average measured BIR levels of the two areas are shown in Figure 4 and 5 . It helps to identify areas of high exposure levels and areas of low radiation levels. The average BIR levels obtained in this work are similar to reported values in other areas of Nigeria and in some parts of the world. Agbalagba [9] in Effurun and Warri city, Avwiri et al. [18] in the Ugheli region of Nigeria, Akpabio et al., [19] in Ikot Ekpene South-South Nigeria, Farai and Jibiri [20] , Ononugbo et al., [21], Rafigue et al., [12], in Jhelum valley in Pakistan, in Turkey by Erees et al., [22] and in Japan by Chikasawa et al.,[23].

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Table 1: Exposure rate measured with their radiation parameters at Unicem Cement Company and its Environ

S/N	Location	GPS	Mean Exposure rate (mRh^{-1})	Equivalent dose (mSvy^{-1})	Absorbed dose (nGy/hr)	AEDE (mSv/y)	ELCR x10^{-3}
1	UNIC$_1$	N05°021′4.1″ E008°29′12.9″	0.015	1.261	130.5	0.160	0.56
2	UNIC$_2$	N05°04’05.3” E008°30′45.0″	0.018	1.514	156.6	0.192	0.67
3	UNIC$_3$	N05°04′05.6″ E008°30′43.1″	0.025	2.102	217.5	0.267	0.934
4	UNIC$_4$	N05°04′05.2″ E008°30′41.5″	0.017	1.430	147.9	0.181	0.635
5	UNIC$_5$	N05°04′06.5″ E008°30′44.6″	0.020	1.682	174.0	0.213	0.747
6	UNIC$_6$	NO5°04′12.1″ E008°30′30.5″	0.035	2.943	304.5	0.373	1.307
7	UNIC$_7$	N05°04′19.5″ E008°30′28.7″	0.017	1.429	147.9	0.181	0.635
8	UNIC$_8$	N05°04′09.8″ E008°30′32.6″	0.021	1.766	182.7	0.224	0.784
9	UNIC$_9$	N05°04′15.0″ E008°30′25.5″	0.018	1.514	156.6	0.192	0.672
10	UNIC$_{10}$	NO5°04′08.3″ E008°30′24.5″	0.019	1.597	165.3	0.203	0.710
11	UNIC$_{11}$	NO5°04′15.1″ E008°30′27.4″	0.034	2.859	295.8	0.363	1.270
12	UNIC$_{12}$	N05°04′02.5″ E008°30′27.4″	0.027	2.271	234.9	0.288	1.008
13	UNIC$_{13}$	N05°04′09.2″ E008°30′39.3″	0.013	1.093	113.1	0.139	0.485
14	UNIC$_{14}$	N05°04′29.7″ E008°30′32.2″	0.022	1.850	191.4	0.235	0.822
15	UNIC$_{15}$	NO5°O4′57.2″ E008°30′30.2″	0.036	3.027	313.2	0.384	1.344

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16	UNIC$_{16}$	N05°04′42.0″ E008°30′64.7″	0.014	1.177	121.8	0.149	0.523
17	UNIC$_{17}$	NO5°04′42.8″ E008°30′0.96″	0.024	2.018	208.8	0.256	0.896
18	UNIC$_{18}$	N05°04′40.0″ E008°30′02.5″	0.037	3.111	321.9	0.395	1.382
19	UNIC$_{19}$	N05°04′40.3″ E008°30′58.6″	0.026	2.186	226.2	0.277	0.971
20	UNIC$_{20}$	N05°04′65.0″ E008°30′32.8″	0.029	2.439	252.3	0.309	1.083
21	UNIC$_{21}$	N05°04′10.1″ E008°30′15.6″	0.025	2.10	217.5	0.267	0.934
22	UNIC$_{22}$	N05°04′05.9″ E008°30′41.6″	0.011	0.925	95.7	0.117	0.411
	Mean		0.023	1.922	196.738	0.24	0.72

Table 2 : Exposure rate measured with their radiation parameters at Bua Cement (Okpella) Company and its Environ

S/N	Location	GPS Reading	Mean Exposure Rate (mRh^{-1})	Equivalent dose (mSvy^{-1})	Absorbed dose (nGy/hr)	AEDE (mSv/y)	ELCR x10^{-3}
1	Okpella$_{1}$	N07°21′06.4″ E006°23′38.5″	0.031	2.61	269.7	0.331	1.158
2	Okpella$_{2}$	N07°21′24.7″ E006°23′24.6″	0.029	2.44	252.3	0.309	1.083
3	Okpella$_{3}$	N07°21′42.8″ E006°23′72.2″	0.027	2.27	234.9	0.288	1.008
4	Okpella$_{4}$	N07°21′14.4″ E006°23′19.3″	0.017	1.43	147.9	0.181	0.635
5	Okpella$_{5}$	NO7°21′39.5″ E006°23′68.6″	0.021	1.77	182.7	0.224	0.784
6	Okpella$_{6}$	N07°21′35.8″ E006°23′65.9″	0.035	2.94	304.5	0.373	1.307
7	Okpella$_{7}$	N072147.2 E006°23′81.4″	0.031	2.61	269.7	0.331	1.158

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8	Okpella$_8$	N07°21′51.4″ E006°23′90.2″	0.038	3.20	330.6	0.405	1.419
9	Okpella$_9$	N07°21′51.4″ E006°23′82.0″	0.027	2.27	234.9	0.288	1.008
10	Okpella$_{10}$	N07°21′30.1″ E006°23′56.2″	0.025	2.10	217.5	0.267	0.934
11	Okpella$_{11}$	N07°21′27.7″ E006°23′34.2″	0.033	2.78	287.1	0.352	1.232
12	Okpella$_{12}$	N07°21′21.8″ E006°23′32.5″	0.036	3.03	313.2	0.384	1.344
13	Okpella$_{13}$	N07°21′20.0″ E006°23′29.2″	0.032	2.69	278.4	0.341	1.195
14	Okpella$_{14}$	N07°21′47.5″ E006°23′26.1″	0.025	2.10	217.5	0.267	0.934
15	Okpella$_{15}$	N07°21′28.7″ E006°23′22.0″	0.015	1.26	130.5	0.160	0.56
16	Okpella$_{16}$	N07°21′01.0″ E006°23′53.2″	0.036	3.03	313.2	0.384	1.344
17	Okpella$_{17}$	N07°21′02.1″ E006°23′38.8″	0.028	2.35	243.6	0.299	1.046
18	Okpella$_{18}$	N07°21′64.2″ E006°23′40.4″	0.033	2.78	287.1	0.352	1.232
19	Okpella$_{19}$	N07°21′30.0″ E006°23′60.4″	0.020	1.68	174.0	0.213	0.747
20	Okpella$_{20}$	N07°21′57.4″ E006°23′39.5″	0.012	1.01	104.4	0.128	0.448
	Mean		0.027	2.27	234.9	0.288	1.008

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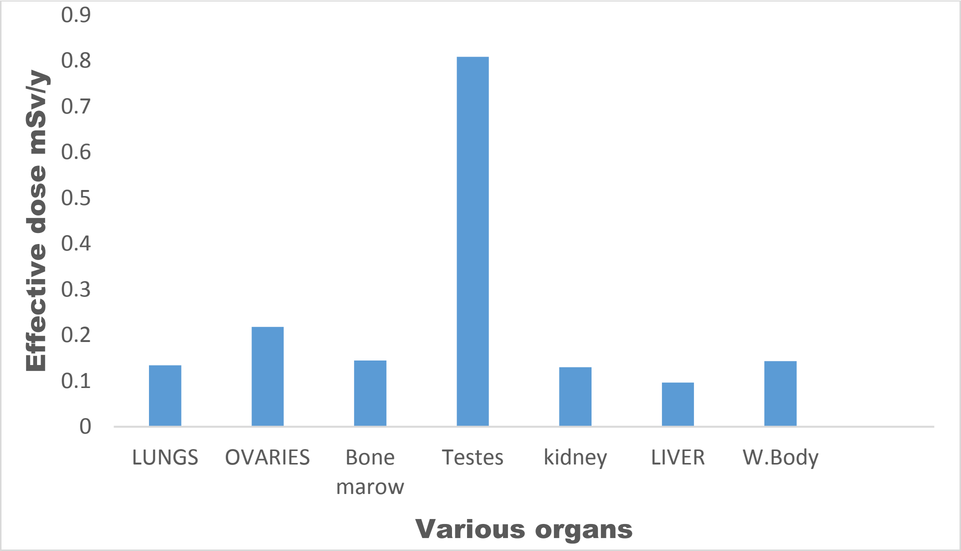

Fig 2: Comparison of effective doses of different organs from Calabar

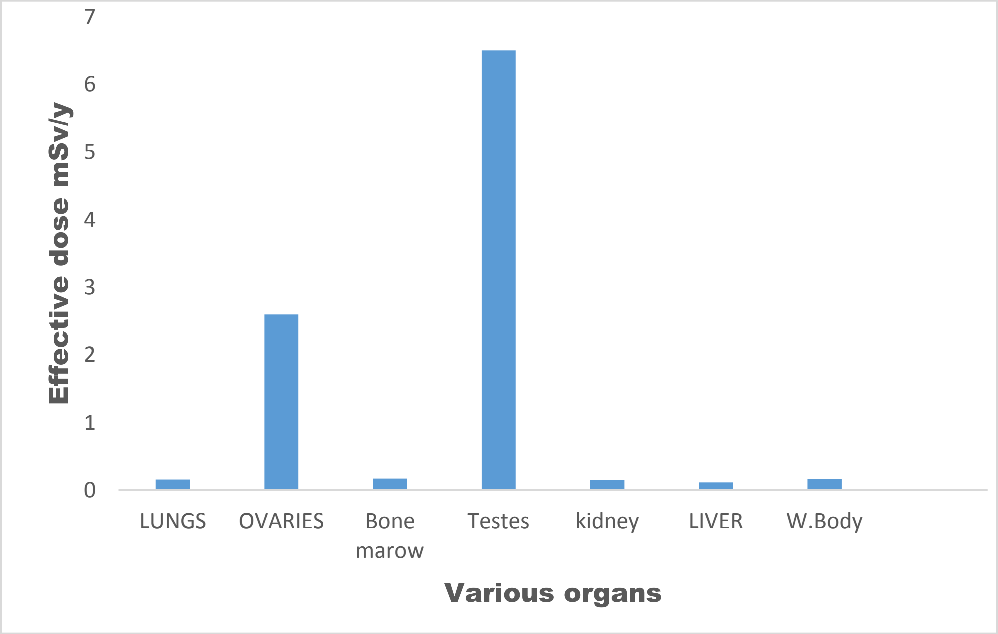

Fig 3: Comparison of effective doses of different organs from Okpella

3.1.2 Radiological parameters

The result of the calculated whole body equivalent dose rate are presented in column 5 of Tables 1-2. The results obtained in Unicem and its host community's ranges from 0.93 to 3.11 $mSvy^{-1}$ with mean value of 1.92 $mSvy^{-1}$ while that obtained in Okpella Bua cement and their host communities ranged from 1.01 to 3.20 $mSvy^{-1}$ with mean value of 2.27 $mSvy^{-1}$. The computed equivalent dose rate in all the areas sampled are well above the recommended permissible limit of 1.0 $mSvy^{-1}$ for the general public and also their mean values were above the recommended occupational permissible limit of 1.5 $mSvy^{-1}$ [24]. These values are in agreement with those obtained in previous studies of the Niger Delta environment [18, 9, 21] but higher than values reported in some countries of the world [12, 25, 22] which indicated that the environment is radiologically contaminated.

The obtained gamma radiation absorbed dose rates for Unicem , Calabar and their host community and Okpella Bua cement and its host community are presented in Table 1-2. The absorbed dose rate in Unicem, Calabar ranged from 95.7 to 321.9 $nGyh^{-1}$ with mean value of 196.74 $nGyh^{-1}$ while at Bua cement Okpella, absorbed dose rate ranged from 104.4 to 330.6 $nGyh^{-1}$ with mean value of 234.9 $nGyh^{-1}$. The mean values obtained in this study area are higher than the values previously obtained by Agbalagba, [9] of 141.30 ±31.31 $nGyh^{-1}$ for warri city, Rafique et al.,[12] of 81.61 $nGyh^{-1}$ for Muzaffarabad and 102.70 $nGyh^{-1}$ for Poonch in Turkey [26] and the Greek population value of 32 $nGyh^{-1}$ [25]. However the gamma dose rate obtained in this work are similar to the range of values reported in Turkey (78.30-135.70 $nGyh^{-1}$) [22] and Japan (13.8-187.0 $nGyh^{-1}$) [23] and 75.0 - 509.38 $nGyh^{-1}$ [27]. The mean absorbed dose rate obtained in the two areas studied are higher than the world population weighted average of 59.0 $nGyh^{-1}$ [9].

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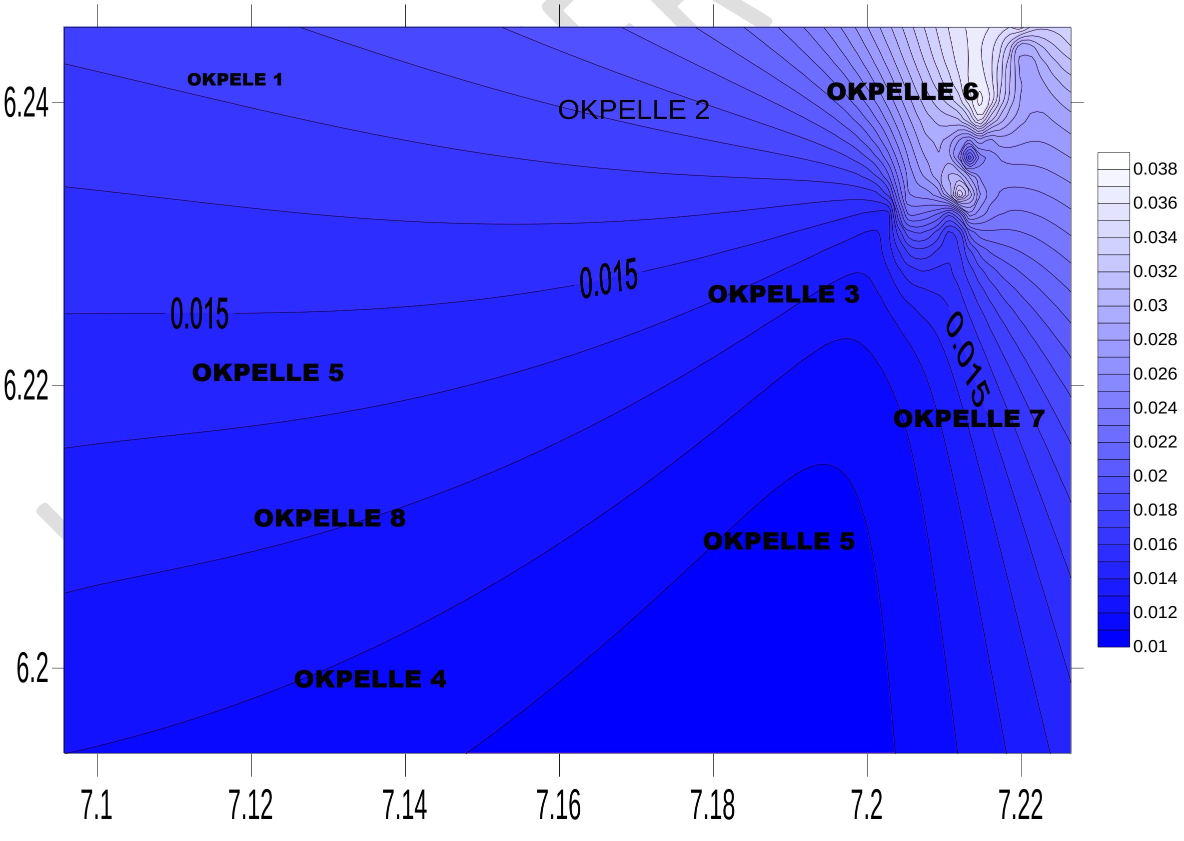

Fig.4: Radiation contour map of the Bua cement company (Okpella) and its environs

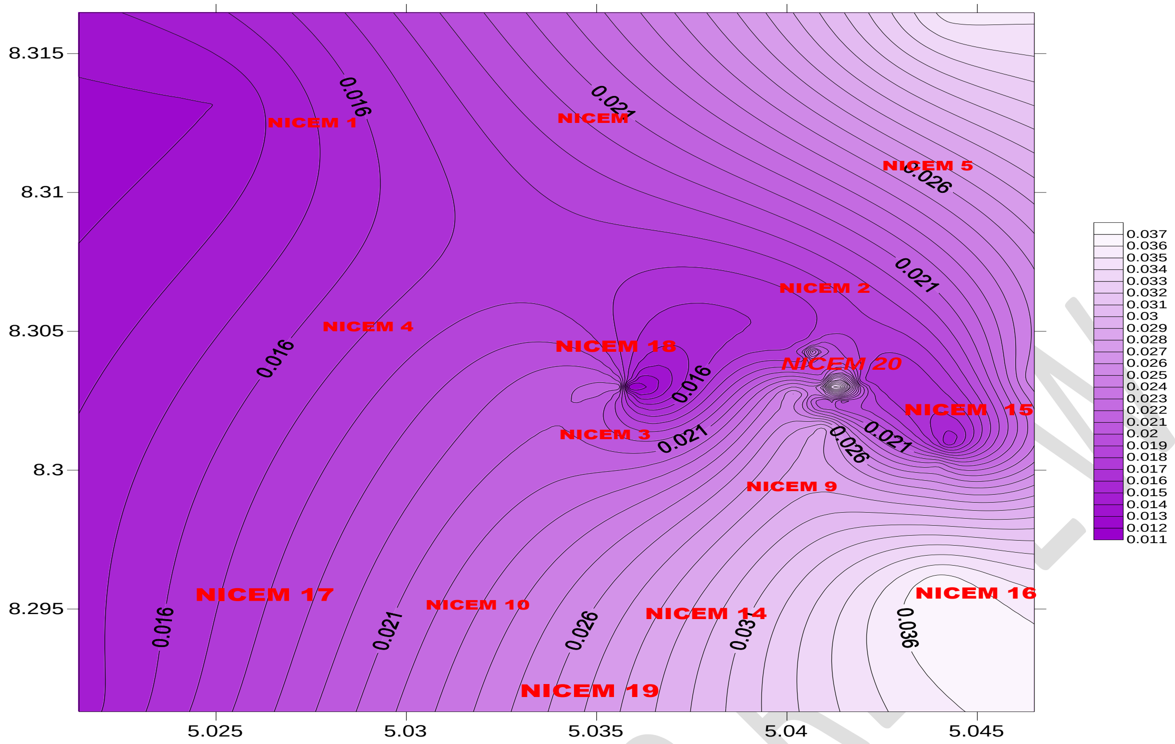

Fig 5: **Radiation contour map of the Unicem cement company (Calabar) and its environs**

The annual effective dose equivalent estimated ranged from 0.12 to 0.31 mSvy^{-1} with mean value of 0.24 mSvy^{-1} and 0.13 to 0.41 mSvy^{-1} with mean value of 0.29 mSvy^{-1} for Unicem and Bua Okpella respectively. These annual effective dose equivalent are similar to the values reported in AL-Rakkah, Saudi Arabia [28] and higher than the reported values of 0.19, 0.15, and 0.20 mSvy^{-1} by Agbalagba, [9]. The worldwide average annual effective dose is 0.41 mSv, of which 0.07 mSvy^{-1} is from outdoor exposure and 0.34 mSvy^{-1} is from indoor exposure [28, 27]. The values obtained in this study are well above the world average annual effective dose level for outdoor environments which is an indication of radiological contamination of Okpella in Edo state and UNICEM, Calabar in Cross River State.

The estimated excess lifetime cancer risk ranged from 0.41 x 10^{-3} to 1.38 x 10^{-3} with mean value of 0.72 x 10^{-3} in Unicem, Calabar and 0.45 x 10^{-3} to 1.42 x 10^{-3} with mean value of 1.01 x 10^{-3} in Bua cement Okpella. The average excess lifetime cancer risk obtained in this study areas are higher than the world average of 0.29 x 10^{-3} [29]. The ELCR value obtained indicates that the probability of contracting cancer by residents and workers of the study area who spends all their lives there are likely from BIR exposure.

The calculated effective dose rates delivered to the different organs are presented in Figure 2 and 3. The model of the annual effective dose to organs estimates the amount of radiation intake by a person that enters and accumulates in various body organs and tissues. Seven organs were examined and the results show that the testes received the highest dose with average values of 0.74 mSvy^{-1} and 0.83 mSvy^{-1} for Unicem and Okpella respectively while the dose was found to be lowest in the liver, with average values of 0.08 mSv and 0.11 mSv for Unicem and Bua

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cement Okpella. These results indicate that the estimated doses to the different organs examined are all below the international tolerable limits on dose to the body organs of 1.0 mSv annually. The relatively higher dose to the testes and low dose intake to the liver is justified by the food nutrient absorption rate [31, 32]. This result shows that exposure to BIR levels in the two areas of study contributes slightly significant radiation dose to these organs in adults.

4 Conclusion

A study of the terrestrial background ionizing radiation levels around cement producing companies in Niger Delta region of Nigeria to estimate the associated organ radiation doses and excess lifetime cancer risk has been carried out. The following conclusions were drawn from the results:

1. The result showed that the exposure rate (background ionizing radiation) levels of the areas exceeded normal BIR levels and have been enhanced by the cement production and other mineral mining activities in the study areas.
2. The calculated equivalent dose rate, absorbed dose rate, annual effective dose equivalent and excess lifetime cancer risk in the two study areas exceeded their recommended safe limits. These values were also higher than values obtained in other parts of the world.
3. The estimated excess cancer risk revealed that there is a probability of residents of those areas contracting cancer if they spend all of their lives in those areas. The effective dose to different organs investigated are significant in testes but insignificant in liver.
4. Prolonged stay of the workers and residents of these cement producing companies may lead to detrimental health risk. Constant monitoring of these areas and other environmental media of the area is necessary.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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