Journal of Environment and Earth Science www.iiste.org
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol.7, No.12, 2017

Estimation of Annual Effective Dose and Excess Lifetime Cancer Risk from Background Ionizing Radiation Levels Within and Around Quarry Site in Okpoto-Ezillo, Ebonyi State, Nigeria

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Abstract
A study to estimate the annual effective dose equivalent (AEDE) and excess lifetime cancer risk (ELCR) due to background ionizing radiation (BIR) within and around Okpoto quarry site has been carried out, using a portable GQ GMC-320 Plus Geiger Counter nuclear radiation detector. An in-situ measurement of absorbed dose rate (ADR) in air at 1.0 meter above ground level was carried out at twenty different locations each for within and around the quarry site. ADR values of 0.15 µSv/hr to 0.22 µSv/hr with mean value of 0.19±0.02 µSv/hr were recorded within the quarry site and values of 0.11 µSv/hr to 0.18 µSv/hr with mean of 0.14±0.02 µSv/hr were recorded for around the quarry site. These values are observed to be slightly lower than 0.274 µSv/hr global average value. Mean values of 0.32±0.04 $mSvy^{-1}$ and 0.24±0.03 $mSvy^{-1}$ for the AEDE were observed respectively for within and around the quarry site. Similarly, mean values of 1.115×10^{-3} and 0.847×10^{-3} for ELCR were reported for within and around the quarry site respectively. The AEDE values are within the permissible limits as recommended by the international bodies. The ELCR values exceed the average standard value of 0.29×10^{-3}. The implication of the AEDE and ELCR values is that the quarry site is radiation safe for any immediate radiological health burdens that might arise due to absorbed dose from BIR, but the probability of one developing cancer over a life time exposure in the quarry environment is very high. It is however recommended that periodic BIR monitoring and evaluation and radioactivity concentration of radionuclides in soil and rocks of the area be carried out by local authority, management of the quarry company and interested researchers to ascertain the absorbed dose level by workers and people living within the area from time to time. In the same vein, the time spent by workers in the excavation and quarry/crushing section of the quarry site, buyers of the quarry products, and other persons who visit the site regularly for commercial activities and sightseeing should be minimized.
Keywords: Background ionizing radiation (BIR), absorbed dose, Annual effective dose equivalent (AEDE), Okpoto quarry site.

1. Introduction

The environment we live in is constantly exposed to radiation. This means that all living things are continually and unavoidably exposed daily to varying doses of ionizing radiation. This radiation called background ionizing radiation emanates from both natural and man – made sources. The natural sources of radiation are mainly due to cosmic rays and naturally occurring long – lived radioactive nuclides that originated from the earth's crust and are present everywhere in the environment, including the human body itself (UNSCEAR, 2008). It is an established fact that naturally occurring radionuclides contribute significantly to the exposures of humans to background ionizing radiation (Bamidele, 2013; Farai and Jibiri, 2003; and Ibrahim, et al, 2014). Among these radionuclides are the radioactive isotope of potassium ^{40}K and the radionuclides that originated from the decay of ^{238}U and ^{232}Th series, both widely spread in soil and rocks of the earth's crust (Ibrahim, et al, 2014). Radiation from these radionuclides mainly depends on geological and geophysical conditions of the environment and it is higher in igneous (e.g. granite) and lower in sedimentary rocks with the exception of shale and phosphate rocks which in some cases may have relatively high content of radionuclides (Enyinna and Onwuka, 2014). In addition to the natural sources, human activities also contribute to the radiation level of the environment. The use of radionuclides and radioactive substances in nuclear reactors and power plants, medicine, industries and research institutions is usually accompanied with the release of radiation into the environment. It has been estimated that the global average dose of bacgroung ionizing radiation received by humans is about 0.274µSv/hr, of which 80% comes from nature, while the remaining 20% results from exposure to man-made radiation sources (UNSCEAR, 2008).

The assessment of the radiation level and its impact on the environment has received great attention worldwide. This is because of the negative health effects ionizing radiation has on biological tissues. When highly energetic ionizing radiation interacts with biological tissues, it causes ionization with subsequent release of charged particle and free radicals thereby causing alteration in cell structure and damage to deoxyribonucleic acid (DNA). A damage to the DNA results in gene mutation, chromosomal aberration and breakages or cell death (Emelue et al, 2014). Some of the health effects of long term exposure to radiation and the inhalation/ingestion of radionuclides are chronic lung disease, acute leucopoenia, anemia necrosis of the mouth, cataract, chronic lung cancer and leukemia (Qureshi et al, 2014; and Ononugbo et at, 2016). Cancer still remains one major harmful effects produced by ionizing radiation.

The land of Ebonyi State is blessed with lots of solid rock mineral deposits and as such mining and quarry activities span across the length and breadth of the state. Mining and quarry activities which involve, first, excavation, then followed by crushing, blasting and haulage of deep buried rocks and rock like mineral deposits, redistribute radionuclides into the environment and have the capability of increasing the radiation dose level of the environment. When these rocks are excavated and crushed, the radionuclides associated with them find their way to the earth surface alongside with the dust particles thereby increasing the radiation level content of the environment. Due to human activities which enhance the radionuclide content and radiation level of the environment, it is customarily to monitor and access the radiation level in order to keep the exposure to as low as reasonably achievable (ALARA principle). Ugwu et al (2008) carried out the assessment of radioactivity content of quarry dust in Abakaliki, Ebonyi State and reported a higher count rate and specific activity for ^{232}Th than that of ^{238}U and ^{226}Ra in the quarry dust samples collected. Also, Enyinna and Onwuka (2014) reported a mean radiation exposure rate from 12.7μR/hr to 14.6μR/hr within crush rock quarry site in Ishiagu, Ebonyi state. Presently, quarry activities are taking place in Okpoto, Ezillo in Ishielu Local Government Area of Ebonyi State and to the best of our knowledge, no radiation assessment and measurement within and around the quarry site has been reported in literature. This present study is thus the first of such investigation in the area and it is aimed at assessing and measuring the background radiation absorbed dose rate in air of the area. The measured dose rate is then used to calculate the annual effective dose equivalent (AEDE) received by workers, visitors and people living near the area. The excess lifetime cancer risk (ELCR) associated with the exposure is also evaluated. The result obtained from this study is compared with the standard recommended value to know to the radiological health implication. The result will also serve as a radiation base-line data for the area since there has not been any radiological study of the area. Fig. 1 shows picture of quarry activities going on in Okpoto-Ezillo quarry site in Ishielu Local Government Area of Ebonyi State.

Figure 1: Picture showing quarry activities taking place in Okpoto-Ezillo quarry site in Ishielu Local Government Area of Ebonyi State.

2. Materials and Methods

A portable GQ GMC-320 Plus Geiger Counter nuclear radiation detector, manufactured by GQ Electronics LLC, USA was used to measure the radiation absorbed dose rates in μSv/h within and around okpoto quarry site. The detector can detect β-particles, γ- rays and x-rays. Whenever radiation passes through the Geiger tube, it triggers an electrical pulse for the CPU to register as a count. A total of forty (40) points which comprises of 20 points each within (inside) the quarry site and around (outside) the quarry site were marked out for measurement. The points were chosen to evenly cover the area under study. An in-situ approach of measurement was adopted in this study to enable samples maintain their original environmental characteristics. Measurement was done at 1.0 m above the ground level with the window of the detector facing the point under investigation. Three measurements of absorb dose were taken at each point at an interval of 3 minutes and these were then averaged to a single value as absorbed dose rate (ADR) in air in units of μSv/h. The average absorbed dose rates (ADR) were used to calculate the annual effective dose equivalent (AEDE) in μSv/yr received by workers, visitors and people living around the area. The AEDE was computed using the relation;

$$AEDE(\mu Sv/yr) = ADR \times T \times OF \times 10^{-3} \quad (1)$$

Where T is total time in hours per year (8760) and OF is the occupancy factor. For this work, an outdoor occupancy factor of 0.2 (UNSCEAR, 2008) was used. Based on the values from the AEDE, the excess lifetime cancer risk (ELCR) was calculated using the equation:

$$ELCR = AEDE \times DL \times RF \quad (2)$$

Where DL is the average duration of life (70 years) and RF is risk factor (Sv^{-1}), which is the fatal cancer risk per sievert. For stochastic effects from low dose background radiation, ICRP 103 suggested the value of 0.05 for the public exposure (ICRP, 2007).

3. Results and Discussion

The results of the measured BIR absorbed dose rates and the calculated annual effective dose equivalent and excess lifetime cancer risk are presented in Tables 1 and 2 for within and around the quarry site respectively.

Table 1: Calculated Annual Effective Dose Equivalent (AEDE) and Excess Lifetime Cancer Risk (ELCR) Within Okpoto Quarry Site

Location Code	Geographical Position	Absorbed Dose Rate (ADR) Within (µSv/hr)	Annual Effective Dose Equivalent (AEDE) Within (µSv/hr)	Excess Lifetime Cancer Risk ($\times 10^{-3}$)
W_1	N6°24′56.7″ E7°51′29.6″	0.17	0.29	1.015
W_2	N6°24′58.1″ E7°51′29.4″	0.19	0.33	1.155
W_3	N6°24′59.5″ E7°51′29.9″	0.19	0.33	1.155
W_4	N6°24′57.4″ E7°51′28.1″	0.15	0.26	0.910
W_5	N6°24′58.0″ E7°51′25.3″	0.17	0.27	0.945
W_6	N6°25′03.7″ E7°51′25.4″	0.18	0.32	1.120
W_7	N6°25′04.0″ E7°51′25.6″	0.19	0.33	1.155
W_8	N6°25′05.7″ E7°51′27.3″	0.20	0.35	1.225
W_9	N6°24′59.5″ E7°51′20.7″	0.18	0.32	1.120
W_{10}	N6°24′54.6″ E7°51′27.7″	0.18	0.32	1.120
W_{11}	N6°24′55.6″ E7°51′15.2″	0.17	0.27	0.945
W_{12}	N6°24′53.0″ E7°51′18.7″	0.21	0.37	1.295
W_{13}	N6°24′53.7″ E7°51′12.0″	0.20	0.35	1.225
W_{14}	N6°24′54.0″ E7°51′21.9″	0.17	0.27	0.945
W_{15}	N6°24′54.2″ E7°51′18.3″	0.18	0.32	1.120
W_{16}	N6°24′53.6″ E7°51′23.0″	0.19	0.33	1.155
W_{17}	N6°24′55.0″ E7°51′31.8″	0.22	0.39	1.365
W_{18}	N6°24′52.6″ E7°51′32.4″	0.19	0.33	1.155
W_{19}	N6°24′54.4″ E7°51′33.2″	0.17	0.27	0.945
W_{20}	N6°24′52.3″ E7°51′34.0″	0.20	0.35	1.225
Mean±SD		**0.19±0.02**	**0.32±0.04**	**1.115±0.13**

Table 2: Calculated Annual Effective Dose Equivalent (AEDE) and Excess Lifetime Cancer Risk (ELCR) Around Okpoto Quarry Site

Location Code	Geographical Position	Absorbed Dose Rate (ADR) Within (µSv/hr)	Annual Effective Dose Equivalent (AEDE) Within (mSv/yr)	Excess Lifetime Cancer Risk ($\times 10^{-3}$)
A_1	N6°24′56.7″ E7°51′29.6″	0.15	0.26	0.910
A_2	N6°24′58.1″ E7°51′29.4″	0.14	0.25	0.875
A_3	N6°24′59.5″ E7°51′29.9″	0.13	0.23	0.805
A_4	N6°24′57.4″ E7°51′28.1″	0.11	0.19	0.665
A_5	N6°24′58.0″ E7°51′25.3″	0.12	0.21	0.735
A_6	N6°25′03.7″ E7°51′25.4″	0.12	0.21	0.735
A_7	N6°25′04.0″ E7°51′25.6″	0.16	0.28	0.980
A_8	N6°25′05.7″ E7°51′27.3″	0.14	0.25	0.875
A_9	N6°24′59.5″ E7°51′20.7″	0.12	0.21	0.735
A_{10}	N6°24′54.6″ E7°51′27.7″	0.14	0.25	0.875
A_{11}	N6°24′55.6″ E7°51′15.2″	0.15	0.26	0.910
A_{12}	N6°24′53.0″ E7°51′18.7″	0.18	0.32	1.120
A_{13}	N6°24′53.7″ E7°51′12.0″	0.11	0.19	0.665
A_{14}	N6°24′54.0″ E7°51′21.9″	0.16	0.28	0.980
A_{15}	N6°24′54.2″ E7°51′18.3″	0.14	0.25	0.875
A_{16}	N6°24′53.6″ E7°51′23.0″	0.14	0.25	0.875
A_{17}	N6°24′55.0″ E7°51′31.8″	0.16	0.28	0.980
A_{18}	N6°24′52.6″ E7°51′32.4″	0.11	0.19	0.665
A_{19}	N6°24′54.4″ E7°51′33.2″	0.13	0.23	0.805
A_{20}	N6°24′52.3″ E7°51′34.0″	0.14	0.25	0.875
Mean±SD		**0.14±0.02**	**0.24±0.03**	**0.847±0.12**

Figure 2: Graph of estimated AEDE within quarry site

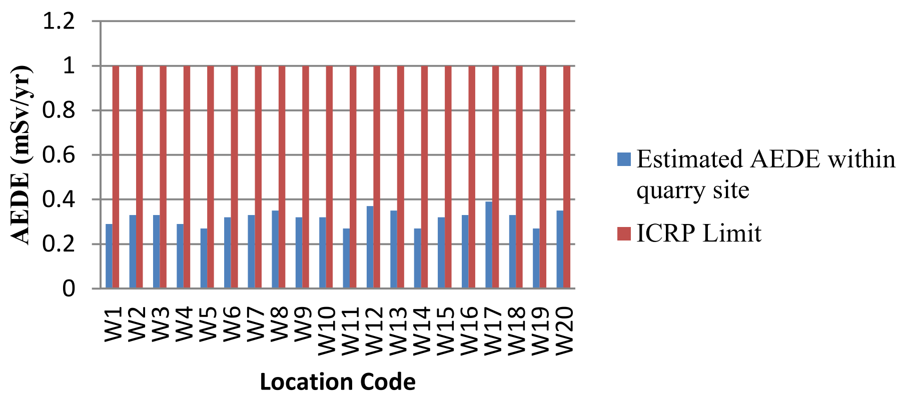
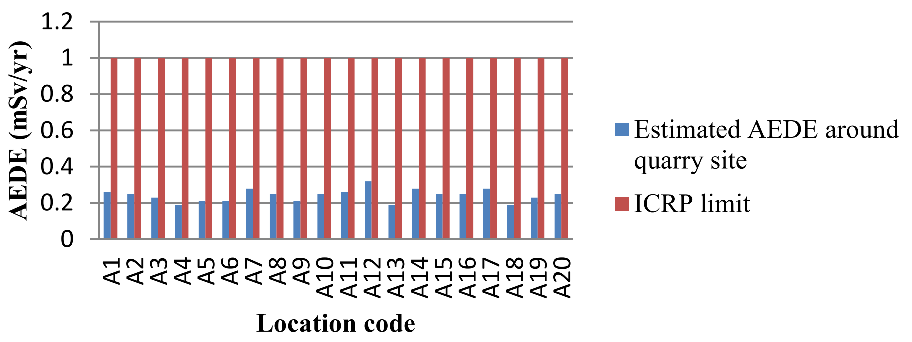


Figure 3: Graph of estimated AEDE around quarry site



As shown in Table 1, the absorbed dose rate within Okpoto quarry site ranges from 0.15 µSv/hr to 0.22 µSv/hr with mean absorbed dose rate of 0.19±0.02 µSv/hr. The estimated AEDE within the quarry site is between 0.26 $mSvy^{-1}$ and 0.39 $mSvy^{-1}$ with mean value of 0.32±0.04 $mSvy^{-1}$. These values are slightly higher than that measured around the quarry site which ranges between 0.11 µSv/hr and 0.18 µSv/hr with mean of 0.14±0.02 µSv/hr for the absorbed dose rate and 0.19 $mSvy^{-1}$ to 0.32 $mSvy^{-1}$ with mean value of 0.24±0.03 $mSvy^{-1}$ for the AEDE as depicted in Table 2. The difference in value may be due to high radionuclides concentration of ^{238}U, ^{232}Th and ^{40}K and their decay products which are widely spread in soil and rocks of the earth's crust within the quarry site than outside it. When naturally occurring deep buried rocks are excavated and crushed into various sizes, radionuclides associated with them are redistributed and this has the capability of enhancing the radiation level within the quarry site. In all, the measured absorbed dose rates are slightly lower than the 0.274 µSv/hr global average natural dose of background ionizing radiation (UNSCEAR, 2008; Okoye and Avwiri, 2013). The estimated mean AEDE of 0.32±0.04 $mSvy^{-1}$ and 0.24±0.03 $mSvy^{-1}$ for within and around Okpoto quarry site respectively are due to the enhanced concentration of natural radionuclides as radionuclides ^{238}U, ^{232}Th and ^{40}K and their decay products are widely spread in soil and rocks of the earth's crust (Ibrahim, et al, 2014). These radionuclides and radiation from them mainly depends on geological and geophysical conditions of the environment (Enyinna and Onwuka, 2014). As depicted in Figure 2 and 3, the values are lower than the permissible limits of 1.00 $mSvy^{-1}$ and 20.00 $mSvy^{-1}$ for individual in general public and occupational workers respectively within a year as recommended by ICRP (2007) and UNSCEAR (2008). This indicates that Okpoto quarry site is in good agreement with permissible limit and do not constitute any immediate radiological health effect on the workers, visitors and residents of host community due to absorbed dose from BIR.

The development of cancer due to exposure to ionizing radiation is not an immediate effect. It may take several years to develop if it develops at all. Temaugee et al (2014) pointed out that after exposure to radiation, cancer types may occur with some increasing frequency and can only be detected by epidemiological means. The period between radiation exposure and the detection of cancer is known as the latent period and this could take many years. Most cases, the cancer occurs only when the individual has reached an advanced age. The term 'excess lifetime cancer risk' (ELCR) is therefore defined as the probability that an individual will develop cancer over his lifetime of exposure to radiation. The calculated mean ELCR for within and around Okpoto quarry site are respectively 1.115×10^{-3} (Table 1) and 0.847×10^{-3} (Table 2). These values are higher than the average standard value of 0.29×10^{-3} (UNSCEAR, 2008; Avwiri et al, 2016). The implication of this is that the probability of one developing cancer over a life time in the quarry environment is very high.

4. Conclusion

This study designed to estimate the annual effective dose and excess lifetime cancer risk due to BIR levels within and around quarry Site in Okpoto-Ezillo, revealed that the mean BIR level and absorbed dose rates measured within the quarry site are slightly higher than those measured around the quarry site. The estimated mean AEDE for within and around the quarry site are less than 1.00$mSvy^{-1}$permissible limit. But the ELCR values for within and around the quarry site slightly exceed the average standard value of 0.29×10^{-3}. This is observed to be due to the enhanced concentration of radionuclides as a result of the excavation and quarrying/crushing activities going on in the area. The implication of the AEDE and ELCR values is that the quarry site is radiation safe for any immediate radiological health effects due to absorbed dose from BIR, but the probability of one developing cancer over a life time in the quarry environment is very high. It is however recommended that periodic BIR monitoring and evaluation and radioactivity concentration of radionuclides in soil and rocks of the area be carried out by local authority, management of the quarry company and interested researchers be carried out in other to access the absorbed dose by workers and people living within the area. In the same vein, the time spent in terms of hours by workers in the excavation and quarry/crushing section of the quarry site, buyers of the quarry products, and other persons who visit the site regularly for commercial activities and sightseeing should be minimized.

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