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Background Exposure Levels and Organ Doses in Abzat Quarrying Site in Keffi, Nasarawa State

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Abstract: In this study, the the background exposure levels in Abzat quarrying sites in Keffi, Nasarawa State has was investigated. An in-situ background exposure rate level for thirty (30) quarryng spots were carried out using a well calibrated portable halogen-quenched Geiger Muller (GM) detector (Inspector alert nuclear radiation monitor SN: 3544) placed 1 m above ground level. A Global Positioning System (GPS) was used to record the geopoints of the measured quarrying spot. Radiological health hazards parameters and radiation effective doses to different body organs were evaluated using the measured exposure rates values. The values of radiological hazard paramaters obtained were compared with recommended standards set by International Commission on Radiological Protection (ICRP) and United Nations Scientific Committee on the effect of Atomic Radiation (UNSCEAR) for hazard evaluation.. The mean values of the outdoor background exposure levels (0.0945 mRh^{-1}), absorbed dose rates (822.440 $nGyh^{-1}$) and excess lifetime cancer risk (3.530×10^{-3}) are higher than the recommended safe limits of 0.0130 mRh^{-1}, 84.000 $nGyh^{-1}$, 0.29×10^{-3} respectively as recommended by UNSCEAR and ICRP. The mean annual effective dose equivalent (1.00 $mSvy^{-1}$) is within the recommended permissible limits of 1.00 $mSvy^{-1}$ for general public exposure and the effective doses to different body organs are all below the recommended limits of 1.00 $mSvy^{-1}$. The background exposure level in Abzat quarrying sites is relatively safe with a potential of posing health risk on residence of the area in years to come due to doses accumulated.
Keywords: Background exposure level, Radiological hazard parameters, Inspector alert Nuclear radiation meter and Abzat quarrying site.

1 Introduction

Background radiation is the ionizing radiation present in the environment. It originates from both natural and artificial sources like cosmic radiation, and environmental radioactivity such as naturally occurring radioactive materials including radon, radium , and fallout from nuclear weapons testing and nuclear accidents [1]. Naturally occurring background radiation is the main source of exposure for most people [1, 2].

Man-made radionuclides have entered the environment from activities such as medical procedures that uses radionuclides to image the body and electricity generation that uses radioactive uranium as fuel [3]. Human beings are continuously irradiated by sources outside and inside their bodies. External sources include space radiation and terrestrial radiation while the internal sources include the radionuclides that enter the body through food, water and air. Whatever its origin, radiation is everywhere in the environment and is a public health concern [4, 5].

Radiation from beyond the solar system has enough energy to generate additional radiation as it passes through earth's atmosphere, creating either radionuclides in the air or secondary particles [4]. Some secondary particles reach the earth's surface most readily near the magnetic poles where the earth's magnetic field is weakest and at high altitudes where the earth's atmosphere is thinnest [6] .

Radionuclides created by space radiation are called cosmogenic radionuclides. They include tritium

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(hydrogen-3), beryllium -7, carbon-14, and sodium-22 [6]. Radiation that originates on earth is called terrestrial radiation. Primordial radionuclides (radioactive chemicals that were present when the earth formed about 4.5 billion years ago are found around the globe in igneous and sedimentary rock. From rocks, these radionuclides migrate into soil, water, and even air. Human activities such as uranium mining have also redistributed these radionuclides. Primordial radionuclides include the series of radionuclides produced when uranium and thorium decay, as well as potassium-40 and rubidium-87 [7]. We are surrounded by naturally-occurring radioactive elements in the soil and stones, and are bathed with cosmic rays entering the earth's atmosphere from outer space [8].

Exposure to high levels of radiation is known to cause cancer [9, 10]. But the effects on human health from very low doses of radiation such as the doses from background radiation, are very hard to determine because, there are so many other factors that can distort the effects of radiation [10]. The objective of this study is to determine the background exposre levels and organ doses in Abzat quarrying site in Keffi, Nasarawa.

2 Materials and methods

The background exposure levels measurement was carried out using a factory calibrated Inspector Alert Nuclear radiation meter (SN:35440, by SE international, Inc. USA). The meter's sensitivity 3500 CPM/ ($mR.h^{-1}$) referenced to Cs-137 and its maximum alpha and beta efficiencies are 18% and 33% respectively. It has a halogen-quenched Geiger-Muller detector tube of effective diameter of 45 mm and a mica window density of 1.50-2.00 $mg.cm^{-2}$ (Inspector alert operation manual).

A total of thirty (30) quarrying spot in Abzat quarry company in Keffi, Nasarawa State were randomly selected. Background exposure level measurement were taken in the quarry spots using an Inspector Alert Nuclear meter. The measurements were taken between the hours of 12.00pm and 4.00 pm because the radiation meter has a maximum response to radiation within these hours as recommended by the National Council on Radiation Protection and Measurements (National Council on Radiation Protection, 1993). An in-situ approach of measurement with the standard practice of raising the detector tube 1.0 m above ground level with its window facing the point under investigation was adopted to enable sample points maintain their original environmental characteristics [4, 11, 12]. The locations of each of the quaring spot were determined using a geographical positioning system (GPS). The exposure rate obtained were used to quantitatively assess the radiation health risk to the public in the quarrying site and radiation effective doses to different organs of the body by performing a number of radiological health hazard indices calculations using well established mathematical relations.

$$CMP = 10^{-3}\, Roentgen\ x\ F \qquad 1$$

where F is the quality factor, which is equal to 1 for external environments.

The absorbed dose is used to assess the potential for any biochemical changes in specific tissues. It quantifies the radiation energy that might be absorbed by a potentially exposed individual. The measured outdoor background exposure levels were converted to radiation absorbed dose rate in air using Equation 3 according to Agbalagba *et al*. [12] and Rafique *et al*. [13].

$$1\ \mu Rh^{-1} = 8.7\ \eta Gyh^{-1} = \frac{8.7x10^{-3}}{(1/8760y)}\ nGyy^{-1} \qquad 2$$

This implies that:

$$1mRh^{-1} = 8.7\ \eta Gyh^{-1}\ x\ 10^{3} = 8700\ nGyh^{-1} \qquad 3$$

The AEDE is used in radiation assessment and protection to quantify the whole body absorbed dose per year. It is used to assess the potential for long-term effects that might occur in the future. The AEDE per year received by workers and the population is obtained from equation 4 [4, 14].

$$AEDE(mSv.y^{-1})_{outdoor} = D(nGy.h^{-1})x\ 8760h\ x\ CF\ x\ OFx10^{-3} \qquad 4$$

where D is the absorbed dose rate in $nGyh^{-1}$, 8760h is the total hours in a year, CF is the dose conversion factor from absorbed dose in air to the effective dose in Sv/Gy (CF = 0.7 Sv/Gy), OF is the occupancy factor, the expected period the members of the population would spend within the study area. OF = 0.2 for outdoor as it is expected that human beings would spend 20 % of their time outdoors as recommended by UNSCEAR [14].

The organ dose (D_{organ}) estimates the amount of radiation dose intake to various body organs and tissues. The D_{organ} of the body due to inhalation was calculated using Equation 5 as given by idris *et al*. [4] and Ugbede & Benson [11].

$$D_{organ}(mSvy^{-1}) = AEDE\ x\ F\ x\ 10^{-3} \qquad 5$$

where F is the conversion factor of organ dose from air dose. The F value for whole body lungs, ovaries, bone marrow, testes, kidney, and liver as given by ICRP (1996) are 0.68, 0.64, 0.58, 0.69, 0.82, 0.62, and 0.46 respectively.

The excess lifetime cancer risk (ELCR) was evaluated using the AEDE values as shown in Equation 6 according to Idris *et al*. [4] and Rafique *et al*. [13].

$$ELCR = AEDE\ (mSvy^{-1})\ x\ DL\ x\ RF \qquad 6$$

where DL is average duration of life (70 years) and RF is the fatal cancer risk factor per sievert (Sv^{-1}). For lowdose background radiation, which is considered to produce stochastic effects, ICRP 103 uses a fatal cancer risk factor value of 0.05 for public exposure [10].

3 Results and Discussion

The backgroud outdoor exposure level measurements and the radiological health risk parameters associated with them are preseted in Table 1. Table 2 presents the effective dose results to some body organs in the stud+99y area. The radiological health hazards indices used in assessing the health status of the study area are ADR, annual AEDE,ELCR and D_{organ}.

The measured background exposure rate ranges from 0.013 to 0.190 mRh^{-1} with mean value of 0.0945 mRh^{-1}. The mean values exceeded the permissible recommended limit of 0.013 mRh^{-1} by UNSCEAR [14]. This could be attributed to the quaring activity and minig that are are being caried out within the area. The geological formation, geophysical characterization can be the secondary factors for the overal radiation level. The mean exposure level reported here is higher than 0.015±0.001mRh^{-1} and 0.018±0.004 mRh^{-1} value observed by Ugbede & Benson [11] in Emene Industrial Layout of Enugu State, Nigeria and Osimobi *et al*. [15] in solid mineral mining sites of Enugu State, Nigeria.

The range of calculated absorbed dose rate value is between 113.1 $nGyh^{-1}$ and 1653 $nGyh^{-1}$ with a mean value of 822.44 $nGyh^{-1}$. The mean absorbed dose rate is

higher than the recorded world weighted average of 59.00 $nGyh^{-1}$ and recommended safe limit of 84.0 $nGyh^{-1}$ for outdoor exposure [4, 14, 16]. The mean dose rate from this study is higher than 126.15 ±5.10 $nGyh^{-1}$ dose rates reported by Ugbede & Benson [11] and 132.16±24.36 $nGyh^{-1}$ reported by Agbalagba *et al*. [12].

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The calculated values of AEDE range from 0.387 to 2.027 $mSvy^{-1}$ with mean value of 1.00 $mSvy^{-1}$. The values are higher than the world average value of 0.07 $mSvy^{-1}$ but within UNSCEAR and ICRP recommended permissible limits of 1.00 $mSvy^{-1}$ for the general public [10, 14]. The result indicates that Abzat quaring site is radiologically contaminated but still within the ICRP and UNSCEAR permissible limit. However, the radiological health effect on members of the public is not immediate. The AEDE from the present study are higher than those reported by Ugbede & Benson [11] in Emene Industrial Layout of Enugu State, Nigeria and Ononugbo and Mgbemere [17] in fertilizer producing area in Onne River State.

Table 1: Outdoor background exposure levels and related radiological health hazards indices in Abzat quarrying site in Keffi, Nasarawa State.

Sampling point code	Longitude	Latitude	E (mR.h^{-1})	ADR (nGy.h^{-1})	AEDE (mSv.y^{-1})	ELCR (x10^{-3})
P1	8^{0}51’58.254	7^{0}52’14.31	0.099	861.3	1.056298	3.697044
P2	8051’58.389	7052’14.671	0.079	687.3	0.842905	2.950167
P3	8051’58.356	7052’15.066	0.091	791.7	0.970941	3.398293
P4	805158.572	7052’15.924	0.180	1566.0	1.920542	6.721898
P5	8051’58.35	7052’17.604	0.020	174.0	0.213394	0.746878
P6	8051’58.308	7052’19.332	0.110	957.0	1.173665	4.107827
P7	8051’58.338	7052’20.716	0.170	1479.0	1.813846	6.34846
P8	8051’57.068	7052’20.424	0.067	582.9	0.714869	2.50204
P9	8051’58.972	7052’21.964	0.057	495.9	0.608172	2.128601
P10	8051’58.804	7052’21.222	0.083	722.1	0.885583	3.099542
P11	8051’58.212	7052’21.486	0.011	95.7	0.117366	0.410783
P12	8051’58.278	7052’22.744	0.130	1131.0	1.387058	4.854704
P13	8051’58.314	7052’22.134	0.012	104.4	0.128036	0.448127
P14	8051’58.404	7052’22.744	0.190	1653.0	2.027239	7.095337
P15	8051’58.656	7052’22.452	0.075	652.5	0.800226	2.800791
P16	8051’58.524	7052’22.722	0.120	1044.0	1.280362	4.481266
P17	8051’58.438	7052’22.810	0.091	791.7	0.970941	3.398293
P18	8051’58.212	7052’22.692	0.097	843.9	1.034959	3.622356
P19	8051’58.99	7052’22.844	0.013	113.1	0.138706	0.485470
P20	8051’58.894	7052’22.944	0.100	870.0	1.066968	3.734388
P21	8051’57.798	7052’22.806	0.067	582.9	0.714869	2.502040
P22	8051’57.636	7052’22.938	0.089	774.3	0.949602	3.323605
P23	8051’57.618	7052’22.732	0.180	1566.0	1.920542	6.721898
P24	8051’57.054	7052’22.822	0.089	774.3	0.949602	3.323605
P25	8051’57.826	7052’22.972	0.120	1044.0	1.280362	4.481266
P26	8051’57.844	7052’22.894	0.098	852.6	1.045629	3.659700
P27	8051’57.79	7052’22.516	0.090	783.0	0.960271	3.360949
P28	8051’56.264	7051’21.84	0.130	1131.0	1.387058	4.854704
P29	8051’56.826	7052’21.24	0.078	678.6	0.832235	2.912823
P30	8051’56.994	7052’21.072	0.100	870.0	1.066968	3.734388
Mean			0.095	822.4	1.00864	3.530241

Table 2: Dose to different organs of the body in Abzat quarrying site in Keffi, Nasarawa State..

Sampling location code	D_{organ}						
	Whole body	Lung	Ovaries	Bone marrow	Testes	Kidney	Liver
P1	0.000718	0.000676	0.000613	0.000729	0.000866	0.000655	0.000486
P2	0.000573	0.000539	0.000489	0.000582	0.000691	0.000523	0.000388
P3	0.000660	0.000621	0.000563	0.000670	0.000796	0.000602	0.000447
P4	0.001306	0.001229	0.001114	0.001325	0.001575	0.001191	0.000883
P5	0.000145	0.000137	0.000124	0.000147	0.000175	0.000132	0.000098
P6	0.000798	0.000751	0.000681	0.000810	0.000962	0.000728	0.000540
P7	0.001233	0.001161	0.001052	0.001252	0.001487	0.001125	0.000834
P8	0.000486	0.000458	0.000415	0.000493	0.000586	0.000443	0.000329
P9	0.000414	0.000389	0.000353	0.000420	0.000499	0.000377	0.000280
P10	0.000602	0.000567	0.000514	0.000611	0.000726	0.000549	0.000407
P11	0.000079	0.000075	0.000068	0.000081	0.000096	0.000072	0.000054
P12	0.000943	0.000888	0.000804	0.000957	0.001137	0.000860	0.000638
P13	0.000087	0.000082	0.000074	0.000088	0.000105	0.000079	0.000058
P14	0.001379	0.001297	0.001176	0.001399	0.001662	0.001257	0.000933
P15	0.000544	0.000512	0.000464	0.000552	0.000656	0.000496	0.000368
P16	0.000871	0.000819	0.000743	0.000883	0.00105	0.000794	0.000589
P17	0.00066	0.000621	0.000563	0.000670	0.000796	0.000602	0.000447
P18	0.000704	0.000662	0.000600	0.000714	0.000849	0.000642	0.000476
P19	0.000094	0.000089	0.000080	0.000096	0.000114	0.000086	0.000063
P20	0.000726	0.000683	0.000619	0.000736	0.000875	0.000662	0.000491
P21	0.000486	0.000458	0.000415	0.000493	0.000586	0.000443	0.000329
P22	0.000646	0.000608	0.000551	0.000655	0.000779	0.000589	0.000437
P23	0.001306	0.001229	0.001114	0.001325	0.001575	0.001191	0.000883
P24	0.000646	0.000608	0.000551	0.000655	0.000779	0.000589	0.000437
P25	0.000871	0.000819	0.000743	0.000883	0.00105	0.000794	0.000589
P26	0.000711	0.000669	0.000606	0.000721	0.000857	0.000648	0.000481
P27	0.000653	0.000615	0.000557	0.000663	0.000787	0.000595	0.000442
P28	0.000943	0.000888	0.000804	0.000957	0.001137	0.00086	0.000638
P29	0.000566	0.000533	0.000483	0.000574	0.000682	0.000516	0.000383
p30	0.000726	0.000683	0.000619	0.000736	0.000875	0.000662	0.000491

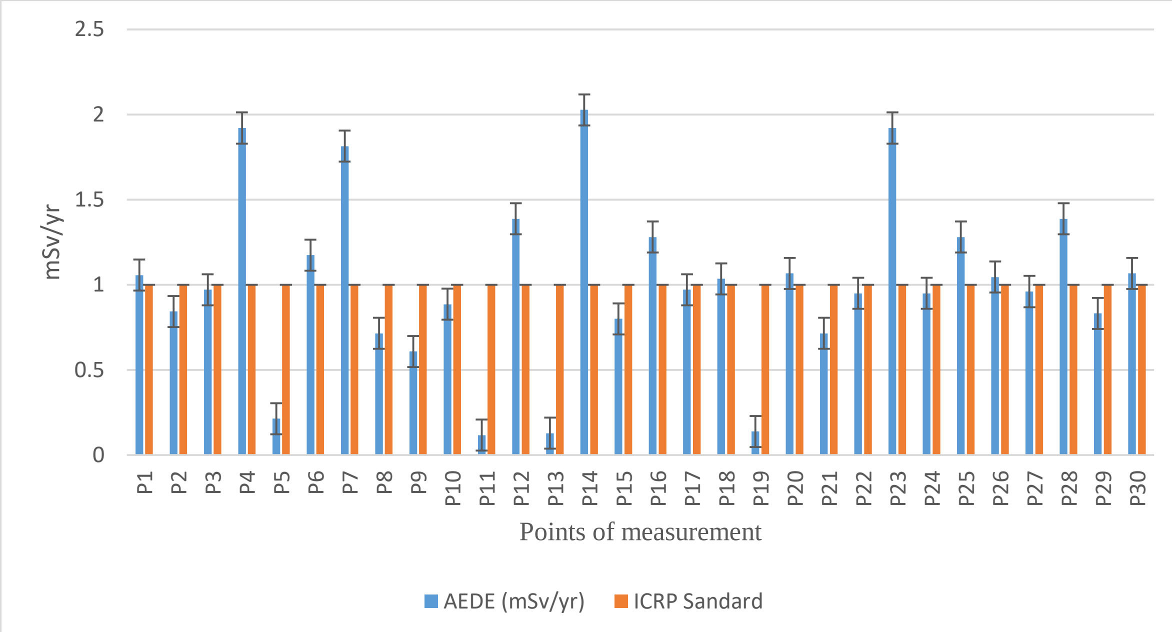

Fig. 1: Comparison between the annual effective dose equivalent (AEDE) rate in the study area and permissible safe limit.

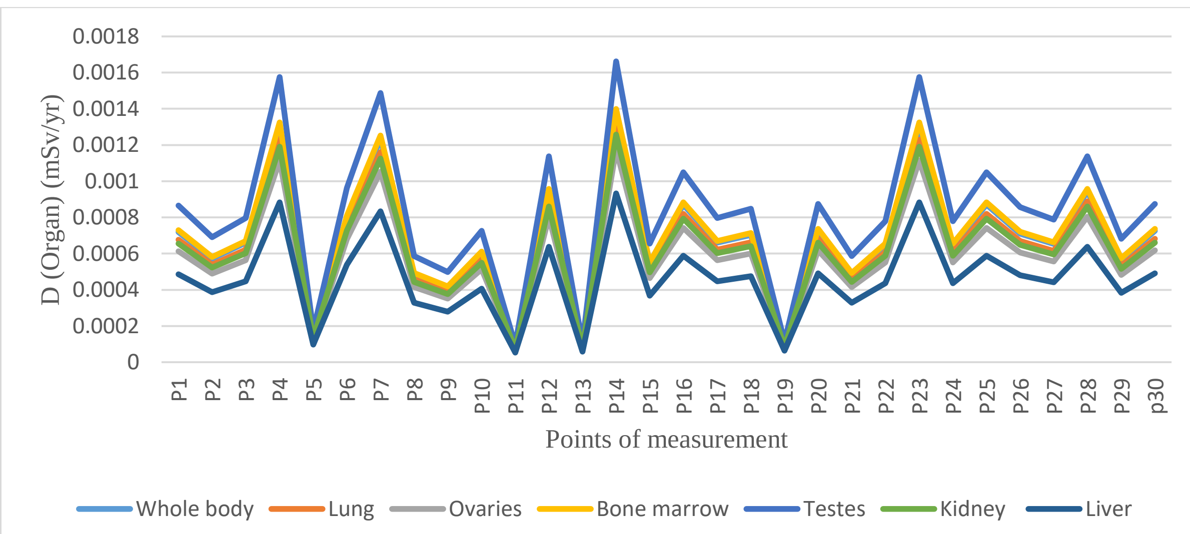

Fig. 2: Comparison of the doses to different body organs.

The highest and lowest of calculated values of ELCR are 0.485×10^{-3} to 7.095×10^{-3} respectively with mean value of 3.53×10^{-3}. This mean value is higher than the world average value of 0.29×10^{-3}. This lifetime cancer risk is quite high and the possibilities of cancer development by the public who reside or work in the quarrying site is imminent. The ELCR values reported in this study is lower than those reported by Uburu Salt Lake environments of Ebonyi State, Nigeria reported by Avwiri *et al*. [3] and Agbalagba *et al*. [12].

4 Conclusions

This study was carried out to examine the radiological impact of background exposure level of Abzat quarrying site in Keffi, Nasarawa State, Nigeria. The radiation level investigated in this study is quite higher than the recommended dose limits and the world average value reported by ICRP and UNSCEAR. Generally, the study shows that Abzat quaring site may not be radiologically safe which could be attributed to the quaring and mining activity in the study area. The secondary factors could be attributed to geological formation of the area. The background radiation level may pose risk of cancer that is not immediate on workers. The results from this study provides the baseline information for the assessment of any environmental radioactive contamination of the area in foreseeable near future.

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