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EVALUATION OF RADIATION EXPOSURE OF SOME SELECTED URANIUM-ORE PITS WITHIN ZING, YORRO AND JALINGO LOCAL GOVERNMENT AREA OF TARABA STATE, NIGERIA

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ABSTRACT

This study's aim at assessing radiological exposure from abandoned uranium pits in Taraba State. The exposure level was made with the aid of a survey meter model GQ-GMC-500+ while the coordinates and elevation of each mine site were determined by a GPS. The mean values of background exposure levels (0.2691µSv/h) at the excavation point, (0.2493µSv/h) at 500m away from the mine pits, they are higher than the recommended safe limits of 0.13µSv/h (ICRP,2003). Absorbed dose rates (2.691E-04ηGyh-1) lower compare to 84ηGyh-1(UNSCEAR,2000). The mean annual effective dose equivalent (3.30E-04mSvy-1) is within recommended permissible limits of 1.00 mSvy-1 for general public exposure. Lifetime cancer risk value of 1.91E-02 is above the permissible benchmark value of 0.29x10-3 (UNSCEAR, 2000). Findings indicate exposure levels are above international safety thresholds, suggesting maximum current radiological risk, though periodic monitoring is recommended to safeguard public health. Generally, the study shows that Taraba mining spots are radiologically contaminated due to excavation and illegal mining operation. However, the contamination has no immediate radiological health risk on the inhabitants, but there is possibility of long-term health burden in the future, such as cancer, due to public exposure.

Keywords: Uranium ore pits, Radiation Exposure, Absorbed dose rate, Annual effective dose equivalent, Excess lifetime cancer risk

INTRODUCTION

The continuous excavation, extraction and processing of Uranium-ore in some selected Local Government Area of Taraba state enhances the environment radioactivity of the area. It has been discovered that all soil particles contain radio-active ^{238}U element (Farr *et al*., 2010). Public radiation exposure occurs via various pathways, such as ingestion, inhalation and skin Contact during radio-element decay procedure (Suleiman *et al*., 2025). The inhabitants of the selected area are traditionally popular in mining uranium ore, sapphires, gravel and other valuable buried stones mining in a crude form at commercial levels.

The local miners have potential to radiation exposure threat like ^{238}U, ^{232}Th and ^{40}K. Radon gas is also a major contributor of background ionizing radiation to human (Umma *et al*., 2020). The advent of illegal scooping of uranium ore and other solid minerals coupled with poor environmental management systems have resulted to the release of various forms of toxic, corrosive and radioactive contaminants into the immediate surrounding. The negative health implication of land excavation and mining operation within the study area has been a huge concern.

When toxics foreign particles are introduced into the system and the environment becomes unsecure, it affects man and his environment adversely (Avwiri et *al*., 2013). Radionuclides materials present in the body above the permissible threshold dose, irradiate distinctive organs with alpha particle, beta particles and gamma rays. Radiation has been discovered in our daily routine in many forms and intensities. Human health is harmed by high radiation levels and doses. Both Alpha and Beta particle ionize directly while gamma ray which is cheaply available indirectly ionize. When such radiation passes through a biological cell, it induces excitation as well as ionization, causing the cell's structure to be mutated (Emelue *et al*., 2014).

Cancer, cataracts, gene mutation, disintegration of bones and blood cells, and death are just a few of the negative consequences (Ogola *et al*., 2016). It is a usual practice to evaluate exposure levels and limit ionizing radiation exposure as low as reasonably achievable, called the ALARA principle (Ilugo *et al*.,2021). One of the radioactive element within us that can impact high grade of biological damage is radon. lung cancer issues are peculiar to radon irradiation either via intake or inhalation (Li *et al*., 2008). In order to control the health challenges of the populace against radiation threat originating from natural source of radiation, the measurement of radionuclide contents within the surroundings have become the focal point of concern by the IAEA in recent years.

Evaluation of health-related risk from exposure to background ionizing radiation is of immense importance. It gives insight on the radiological status of the mining area and the populace. It will form a base line for regulatory agencies because there is little or no data exist as at this period. The mining exercises will be put in proper checks in order to achieve low exposure levels to ionizing radiation and hence recommends measures of keeping the miners' in a safe healthy living standard.

MATERIALS AND METHODS

Sampler and Analytical Procedures

Twenty sampling points were carefully marked out for background ionizing radiation exposure measurement which covers the locations around the mining area. Each of the sampling point were assigned a code for easy referencing. An in-situ approach of measurement with the standard practice of keeping the meter beyond the ground state to reflect the abdominal point (1.0m) of the operator with its window facing the point under investigation was adopted to enable sample points maintain their original environmental characteristics (Agbalagba *et al*., 2016).

The sampling and measurements was done with the help of a well calibrated GQ GMC Geiger Counter radiation meter manufactured by GQ Electronics with GQ-GMC-500+ model. Instrument calibrated against Cs-137 (NPL traceable) on 2023-09-10; background = 0.040 ±0.002 µSv/h (30 min average).

This meter has an halogen quenched Geiger-Muller tube ± 45 mm effective diameter and mica window density of 1.5-2.0mg/cm^3. The Geiger tube produce a signal of electrical current each time radiation is imputed on the tube and create an ionization. Each signal is automatically detected and recorded as a count in a choice mode of the handler. The effective dose readings were taken in milli Roentgen per hour (mR/hr) directly from the display screen of the radiation meter. The results were then converted to micro-Sievert per hour (µSv/hr) and then finally converted to micro-Sievert per year (µSv/yr).

Four readings in count per minute (CPM) and Micro-sievert per hour (µSv/hr) were recorded at each point of the selected sampling field. The readings were acquired at the abandoned mine pits and 500m away from each of the mining field based on the dwellers population or the presence of an accessible foot path leading to the settlement(armlet) and the mining field. A geographical position system (GPS) was used to take the precise positions of the sampling points. The exposure dose rates in (µR/h) obtained in the study areas were converted into absorbed dose rate (nGy/h) using the conversion factor (Ilugo *et al*., 2021).

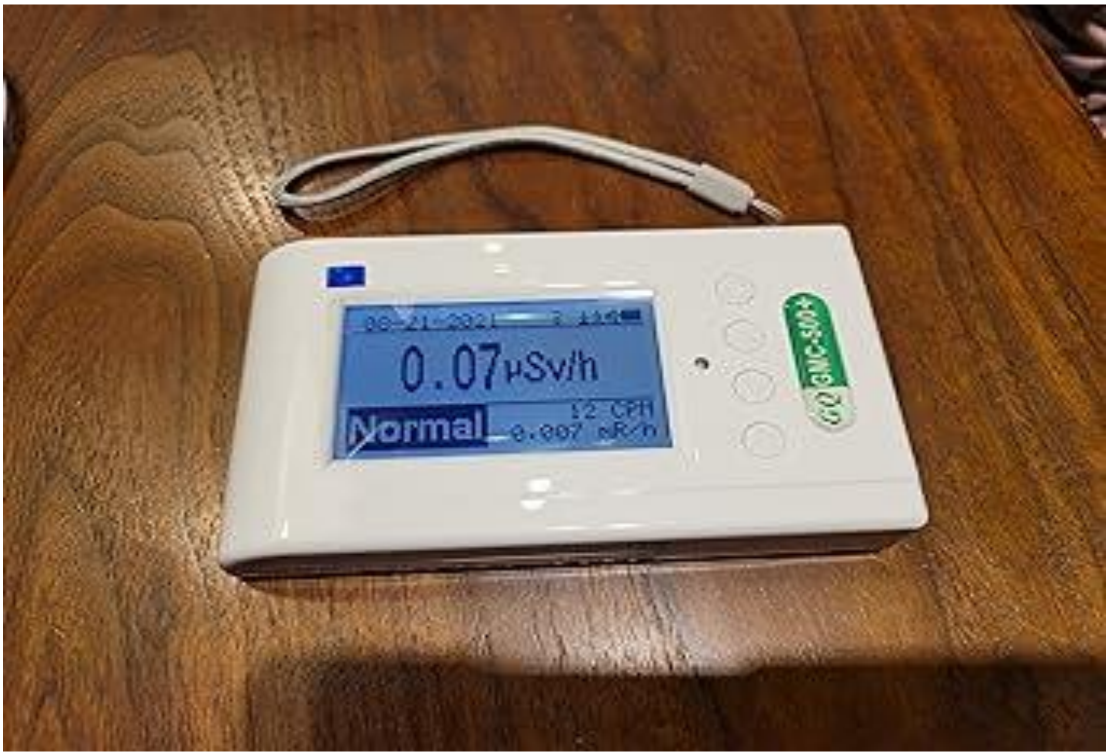

Figure 1: GQ-GMC-500+ model

Area of Investigation

The examined study area covers abandon mine pits within Yorro, Zing and Jalingo local government area of Taraba state. Yorro LGA is bounded to the east by Zing LGA and to the west by Jalingo LGA. The few selected mine pits are located in mika(kwaji chiefdom), popule, maraba-kuni, yorro, zing, monkin, kassa, Nyagai and mayo-gwoi. The area lies within latitude $08^{o}\ 46^{1}\ 03^{11}$– $09^{o}\ 13^{1}\ 20^{11}$N and longitude $11^{o}\ 20^{1}\ 58^{11}$ – $11^{o}\ 44^{1}\ 39^{11}$E and covered approximately 1,304km^2. The size of the dwellers is approximately 89,410 based on (NPC,2006). 90% of inhabitants are predominant farmers, miners and traders. The miners adopt crude tools (bare hands, hoes and digger) to unveil the bury precious stones. The three predominant uranium ore were discovered in Lau, Yorro and Zing LGAs of Taraba state (Orunoye and Ahmed, 2017). They exist in Arnotite, pitchblende and torbernite findings by the Nigerian Uranium Mining Company put up a reserve estimate of 52 metric tons (Oruonye and Ahmed, 2017).

Figure 1. Geographical map of Taraba state showing study area with neighboring state of the Country.

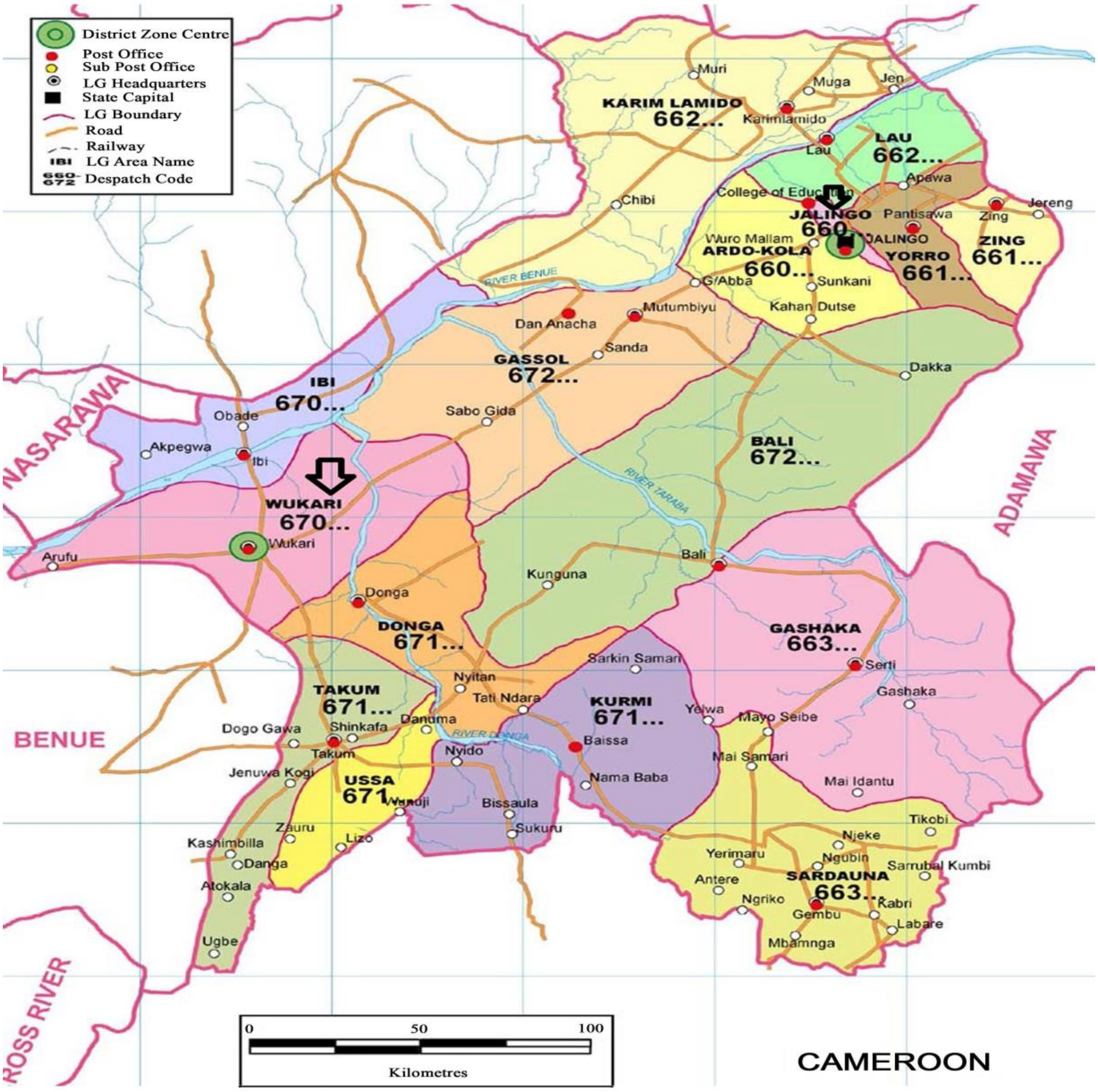

Figure 2: Map of Taraba State Showing the Study Area

Sampling Site Code
The randomized sampling spot was selected area from the assign study area and their tag codes are display in Table 1. The ten sites were selected due to high level of scattered ore pits (ditches and trenches) within the selected local government area.

Table 1: Mean Background Count within at the Source Point and 500m away from Mine Pits

S/N	Mine site	Latitude(°)	Longitude(°)	Elevation(m)	Excavation point (µSv/hr)	500m away from site (µSv/hr)
1	ZG	08 59 49	11 44 39	535	0.2145	0.1495
2	MKA	09 00 19	11 38 44	528	0.2715	0.2340
3	MKI	08 58 32	11 32 53	517	0.2515	0.2014
4	PPE	08 54 43	11 20 58	531	0.2080	0.2275
5	YRR	08 42 13	11 41 17	357	0.3120	0.2925
6	NGY	08 53 00	11 33 12	339	0.2570	0.2600
7	LKV	08 46 06	11 32 20	334	0.3055	0.2665
8	KPW	08 56 23	11 28 09	340	0.2925	0.2860
9	MON	08 46 42	11 43 16	536	0.3055	0.3185
10	MGI	08 47 15	11 30 23	334	0.2730	0.2573
	Min				0.2080	0.1495
	Max				0.3120	0.3185
	Mean				0.2691	0.2493

Note: ZG- Zing, MKA - Mika, MKI- Maraba-kuni, PPE-Popule, YRR- Yorro, NGY- Nyangai, LKV- Lankaviri, KPW-Kpantisawa, MON-Monking, MGI- Mayo-gwoi

Calculation of Radiological Hazards Indices

For detail compilation of the experimental data from irradiation state (in µSv/hr) to other hazard factors, the following mathematical tools were adopted.

The exposure (σ) recorded in µSv/h is transform to annual absorbed dose rate ADR in mSv/yr base on equation 1 (Idris *et al*., 2021; Etuk, *et al*., 2015).

$$ADR(msvy^{-1}) = \sigma(\mu svh^{-1}) \times OF \times 24hrs \times 365.25d \times 10^{-3} \quad (1)$$

Recall,

1µR/h = 8.7nGy/h = 8.7 x 10^{-3}µGy/(1/8760)yr = 76.212nGyy^{-1}

1mR/h = (0.96x24x365)/100 mSv/y

1R /h =10µSv/hr

OF is the occupancy state (0.2) and imparted energy/mass is achieved in Gy/h from the observed irradiation in µSv/h using the expression below

$$ADR = \frac{0.2145\mu Sv}{h} \times 8{,}760\frac{h}{yr} \times 24hrs \times 365.25d \times 10^{-3} \times 0.2 = 0.376 \text{ mSv/yr}$$

$$D(nGyh^{-1}) = \sigma(\mu svh^{-1}) \div Q \times 10^{-3} \quad (2)$$

Q is the quality state =1.0 for exposure to gamma irradiation

$$D(nGyh^{-1}) = \frac{0.2145\mu Sv}{h} \div 1 \times 10^{-3} = 2.145E-04\ (nGyh^{-1})$$

The annual effective dose rate (AEDR) per year imputed on inhabitants is derived from equation 2 (UNSCEAR, 2000)

$$AEDR(msvy^{-1}) = D(nGyh^{-1}) \times 8760hr \times CF \times OF \quad (3)$$

Recall, that CF is given below

$$C.F = 0.7(svGy^{-1}) \quad (4)$$

OF is the occupancy Factor, OF = 0.2 for outdoor duration. Therefore, AEDR for outdoor is obtained from equations 4 (Idris *et al.*, 2021; Gupta and Chauhan, 2011)

$$AEDR = 2.145E-04 \times 8760hr \times 0.7(svGy^{-1}) \times 0.2 \times 10^{-3} = 2.63E-04 \text{ mSv/yr}$$

Effective Dose Rate (D_{organ}) to Different Organs/ Tissues

$$D_{Organ}(msvy^{-1}) = AEDR \times C.F \times O.F \quad (5)$$

$$D_{lungs} = 2.63E-04\text{mSv/yr} \times 0.64 \times 0.8 = 1.34E-04\text{mSv/yr}$$

OF is the occupancy Factor, OF = 0.8 Conversion Factor (C.F) values for lungs, ovaries, bone marrow, testes, kidneys, liver and whole body being 0.64, 0.58, 0.69, 0.82, 0.62, 0.46 and0.68 respectively (Ovuomarie-kevin *et al.*, 2018).

$$ECLR = AEDR \times D_L \times R_F \quad (6)$$

Where DL is life time spent (70 years) and RF is the risk factor. In stochastic effects ICRP 60 prescribed RF = 0.05 for the public safety standard (Taskin *et al.*, 2009).

$$ECLR = 2.63E-04\text{mSv/yr} \times 70yrs \times 0.05 = 9.2E-04$$

Table 2: Computed Radiological Hazard Component from Background Radiation within Taraba State

S/N	Mine site	Excavation point (µSv/hr)	500m away from site (µSv/hr)	ADR (mSv/yr)	D (nGy/h)	AEDR (mSv/yr)	ELCR
1	ZG	0.2145	0.1495	0.376	2.145E-04	2.63E-04	9.21E-04
2	MKA	0.2715	0.2340	0.476	2.715E-04	3.33E-04	1.16E-03
3	MKI	0.2515	0.2014	0.441	2.515E-04	3.08E-04	1.08E-03
4	PPE	0.2080	0.2275	0.365	2.080E-04	2.55E-04	8.93E-04
5	YRR	0.3120	0.2925	0.547	3.120E-04	3.88E-04	1.34E-03
6	NGY	0.2570	0.2600	0.451	2.570E-04	3.15E-04	1.10E-03
7	LKV	0.3055	0.2665	0.536	3.055E-04	3.74E-04	1.31E-03
8	KPW	0.2925	0.2860	0.513	2.925E-04	3.59E-04	1.26E-03
9	MON	0.3055	0.3185	0.535	3.055E-04	3.75E-04	1.31E-03
10	MGI	0.2730	0.2573	0.479	2.730E-04	3.34E-04	1.17E-03
	Min	0.2080	0.1495	0.365	2.080E-04	2.55E-04	9.21E-04
	Max	0.3120	0.3185	0.547	3.120E-04	3.88E-04	1.34E-03
	Mean	0.2691	0.2493	0.472	2.691E-04	3.30E-04	1.91E-02
	ICRP,2003	0.13	0.13	1.00	84.00	1.26	0.29E-03

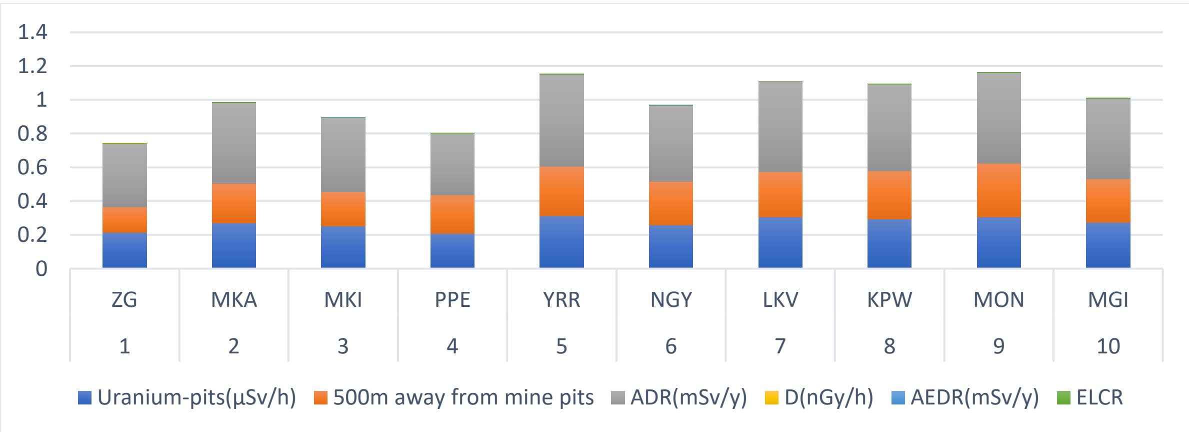

Figure 3: Graphically Display the Outcome of Radiological Burden within the Uranium-ore Pits

Table 3: Computed Effective Dose Rate($D_{organ/tissues}$) from Background Exposure within Taraba State

S/N	Mine site	AEDR (mSv/yr)	D_{lungs} (mSv/yr)	$D_{ovaries}$ (mSv/yr)	$D_{Bone\ marrow}$	D_{testes} (mSv/yr)	D_{kidney} (mSv/yr)	D_{liver} (mSv/yr)	$D_{whole\ body}$
1	ZNG	2.63E-04	1.34E-4	1.2E-4	1.5E-4	1.7E-4	1.3E-4	9.6E-5	1.4E-4
2	MKA	3.33E-04	1.7E-4	1.5E-4	1.8E-4	2.1E-4	1.7E-4	1.2E-4	1.8E-4
3	MKI	3.08E-04	1.6E-4	1.4E-4	1.7E-4	2.0E-4	1.5E-4	1.1E-4	1.7E-4
4	PPE	2.55E-04	1.3E-4	1.2E-4	1.4E-4	1.7E-4	1.3E-4	9.4E-5	1.4E-4
5	YRR	3.88E-04	2.0E-4	1.8E-4	2.1E-4	2.5E-4	1.9E-4	1.4E-4	2.1E-4
6	NGY	3.15E-04	1.6E-4	1.5E-4	1.7E-4	2.0E-4	1.6E-4	1.2E-4	1.7E-4
7	LKV	3.74E-04	1.9E-4	1.7E-4	2.1E-4	2.5E-4	1.9E-4	1.4E-4	2.0E-4
8	KPW	3.59E-04	1.8E-4	1.6E-4	2.0E-4	2.4E-4	1.8E-4	1.3E-4	1.9E-4
9	MON	3.75E-04	1.9E-4	1.7E-4	2.1E-4	2.5E-4	1.9E-4	1.4E-4	2.0E-4
10	MGI	3.34E-04	1.7E-4	1.5E-4	1.8E-4	2.2E-4	1.7E-4	1.2E-4	1.8E-4
	Min	2.55E-04	1.3E-4	1.2E-4	1.4E-4	1.7E-4	1.3E-4	9.6E-5	1.4E-4
	Max	3.88E-04	2.0E-4	1.8E-4	2.1E-4	2.5E-4	1.9E-4	1.4E-4	2.1E-4
	Mean	3.30E-04	1.7E-4	1.5E-4	1.8E-4	2.2E-4	1.7E-4	1.2E-4	1.8E-4
	ICRP, 2003	0.07	1.00	1.00	1.00	1.00	1.00	1.00	1.00

RESULTS AND DISCUSSION

The mean background ionizing radiation exposure rate obtained were quantitatively used to assess the radiation health impact to dwellers in the immediate environments by performing a number of radiological health indices calculations such as absorbed dose rate, annual effective dose equivalent and excess lifetime cancer risk using the necessary relations given by (Agbalagba, 2017). The average exposure rate, absorbed dose, annual effective dose equivalent and the excess life cancer risk from the in-situ measurement of the selected sites are computed using equation one to six and indicated in Table 2.

Annual Effective Dose Equivalent

The outdoor background exposure rate measured ranges from 0.2080 to 0.3120µSv/hr with mean value of 0.2691µSv/hr at the excavation point. Additionally, at 500m away from the mine pits, the exposure rate ranges from 0.1495µSv/h to 0.3185µSv/h with a mean value of 0.2493µSv/h. The mean exposure count rate for this studied exceeded the permissible recommended limit of 0.13µSv/hr (ICRP,2003). The high background ionizing radiation level could be attributed to the geological formation, geophysical structure and human activities. It could also be link to the continuous land excavation in search of uranium ore and abandonment of used mining pits. The radiation count rates also depend on factors such as location, altitude and temperature.

The results of ADR spanned between 0.365mSv/yr to 0.547mSv/yr, while the computed AEDR ranged between 2.55 x 10^{-4}mSv/yr to 3.88 x 10^{-4}mSv/yr. The values put together in Table 2 reveal that annual effective dose level is quite below the benchmark of 1.0mSv/yr, (ICRP, 2003; NNRA, 2006). The evaluated background radiation counts together with its associated computed radiological analysis from the various location within the abandoned Uranium-ore pits were display in Figure one.

In brief the background ionizing radiation value from this study was found to be lower than the results reported by researchers like Ayua, *et al.* (2017), (Avwiri & Olatubosun, 2014) but commensurate with values reported by Mgbeokwere, *et al.* (2023).

The calculated effective dose rates delivered to different organs in human are presented in Table. 3. It was shown that the testes recorded the highest dose of 2.2E-4mSvy^{-1} while the liver recorded the least value with mean value of 1.2E-4mSvy^{-1}. These results indicate that the estimated doses to the different organs are below the permissible threshold on radiation dose to body organs of 1.0 mSvy^{-1}(ICRP,2003).

Excess Life Cancer Risk (ELCR) Outdoor for the Various Mine Pits

The computed value of ECLR ranges between 8.93 x 10^{-4} to 13.37 x10^{-4} with a mean value of 0.89 x 10^{-3} which is above the world benchmark of 0.29x10^{-3} (Taskin *et al.,* 2009). This result indicate that the dwellers are at risk of carcinogenic. This reveal that there is residual radioactivity within the selected mining area which could be from the radionuclides of potassium(K), Uranium(U), Radium(Ra) and Thorium (Th) contain in the Nuclear substances (Michael *et al.,* 2010). The lifetime cancer risk is quite high and the possibilities of cancer growth by inhabitants who wish to spend all their life time in their ancestral home is imminent. The ELCR values in this work is beyond the outcome reported by (Ugbede, 2018; Idris *et al.*, 2021)

CONCLUSION

The radiation exposure levels in some selected deserted mine pits in Taraba State, Nigeria have been investigated in order to determine the radiological effects to dwellers. The outcomes reveal that all the radiological parameters evaluated fall within the permissible level of 1mSv/yr (UNSCEAR, 2000) for public exposure but the lifetime cancer risk from the immediate surrounding is quite above the tolerance level of 0.00029 (ICRP,2003). The high radiation exposure levels and life cancer risk indicate that the environment is radiologically unhealthy and contaminated for the general public. The cancer risk calculated revealed the probability of contracting cancer is high but the effective radiation doses to the various organs calculated are below the tolerance limit and insignificant. However, to keep the radiation level under check, authorized agency and radiation regulated bodies must conduct routine surveillance.

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