PRINT ISSN 1119-8362
Electronic ISSN 1119-8362

Full-text Available Online at
https://www.ajol.info/index.php/jasem
http://ww.bioline.org.br/ja

J. Appl. Sci. Environ. Manage.
Vol. 24 (10) 1821-1826 October 2020

Assessment of Background Ionizing Radiation Dose Levels in Quarry Sites Located in Ebonyi State, Nigeria

ECHEWEOZO, EO; *UGBEDE, FO

Department of Physics with Electronics, College of Science, Evangel University, Akaeze, Ebonyi State, Nigeria.
**Corresponding Author Email: oghene4fred@yahoo.com; ugbedefred@evangeluniversity.edu.ng*

ABSTRACT: The study presents a radiometric survey of Background Ionizing Radiation (BIR) dose levels in ten quarry sites located in Ebonyi State, Nigeria. In-situ BIR dose rate measurements, by means of nuclear radiation survey meter, at 1 m above ground level were carried out at the excavation section (ES) and quarrying section (QS) of the investigated quarry sites. The obtained results indicated dose rates ranging from from 0.14 to 0.18 μSv/h with mean of 0.15±0.01 μSv/h at the ES and 0.16 to 0.19 μSv/h with mean value of 0.18±0.01 μSv/h at the QS. While the values obtained at the QS are respectively higher than those measured at the ES, they are all higher than the worldwide average value of 84 nSv/h signifying BIR elevated environments. The estimated mean annual effective dose (AED) and excess lifetime cancer risk (ELCR) are 0.27±0.03 mSv/y and 0.94×10^{-3} respectively at the ES and 0.31±0.02 mSv/y and 1.07×10^{-3} at the QS. The obtained AED values for all the sites are well above the outdoor worldwide average value of 0.07 mSv/y but lower than the International Commission on Radiological Protection recommended permissible limits of 1.0 mSv/y for the general public. Generally, the BIR levels of the quarry sites are within acceptable limits and no immediate radiological health threat may be derived from the current levels. However, long-term health effects due to continuous exposure to low-level radiation doses may manifested in future over a lifetime exposure of 70 years as indicated by the ELCR values.

DOI: https://dx.doi.org/10.4314/jasem.v24i10.17

Dates: Received: 15 August 2020; Revised: 22 September 2020; Accepted: 19 October 2020

Keywords: Background ionizing radiation, Dose rate, Annual effective dose, Quarry site**,** Ebonyi State.

Increasing demand of quarried products has stimulated investment surge in stone exploration/quarrying and production in both developed and developing nations, including Nigeria (Okeke, 2008). Over 33 solid mineral deposits have been found in Nigeria spreading across almost 400 locations which includes the Southeastern geopolitical zone that include Abia, Anambra, Imo, Enugu and Ebonyi States (Akpokodje, 1992; Lawal, 2010). Ebonyi State is associated with the occurrence of igneous intrusion with volcanic and sedimentary rocks (Chiadikobi *et al.,* 2011). Mineral deposits such as Lead, Zinc, Copper, Gypsum, Granite, Limestone, Marble stone, Aluminum, False gold, Uranium, Igneous rock, among others have been identified in Ebonyi state (Ebure and Ezeribe, 1997). Due to the geological formation of the state, there is a surplus supply of these natural resources (Edet *et al.,* 2011) with series of quarrying activities even as far back as 1950s (Chima *et al*., 2010). Mineral mining and quarrying activities are parts of anthropogenic activities identified as major contributors to background ionizing radiation (BIR) levels of the human inhibited environment (Mokobia and Balogun, 2004). The various mineral deposits listed above, by nature, contain naturally occurring radioactive materials (NORMs) with constituents of the series radionuclides of ^{235}U, ^{238}U and ^{232}Th and the single radionuclides ^{40}K (Ugbede and Akpolile, 2019). Usually, when mineral ores with naturally high concentrations of NORMs are mined from their natural depositions to the top surface, they redistribute the radiation levels of the immediate environment in a way that result to an elevation of the natural background level thus resulting in increased exposure of the general public. Consequent upon this, the BIR can therefore be considered as environmental pollution especially when it exceeds safe occupational and public limits (Agbalagba *et al.*, 2016). Although humans are known to be in constant interaction with background ionizing radiation (BIR) (UNSCEAR, 2000), the exposure to increase BIR within quarry site cannot be compared with those of normal environments. Internal exposure to radionuclides associated with the quarry products can also result owing to inadvertent ingestion within the mining/excavation pits, and inhalation of dust particles during quarrying. The continuous exposure by the workers can accumulate radionuclides within the internal body organs (Ugbede, 2018; Ugbede and Benson, 2018) and when in excess doses may result to various health challenges already listed in the literature (UNSCEAR, 1993; Taskin *et al.*, 2009; Jibiri

**Corresponding Author Email: oghene4fred@yahoo.com; ugbedefred@evangeluniversity.edu.ng*

and Okeyode, 2012; Emelue *et al.*, 2014; Enyinna and Onwuka, 2014; Qureshi *et al.*, 2014; Suresh *et al.*, 2014; Rafique *et al.*, 2014; Ononugbo *et at.*, 2016). Notwithstanding the economic benefits of quarrying operations, it is imperative to assess and know the levels of background gamma radiation circulating within quarrying environments. By this, one can examine, quantify and qualify the radiation dose accruing to the workers and the general populace. On this fact, the present study was designed to measure the background ionizing radiation (BIR) dose levels of some quarry sites located in Ebonyi State, Nigeria.

MATERIALS AND METHODS

Study locations: Generally, the study location, Ebonyi State, Nigeria lies between 6°15'N and 8°05'E with low-lying to gentle undulating terrain of about 85-100 m above sea level and punctuated by few isolated low-hills (Ezepue *et al.*, 1984). The state is situated on the plains of Southeastern Savanna belt and southern end of the lower Benue trough of Nigeria (Chiadikobi *et al.,* 2011). The state is associated with the occurrence of igneous intrusion and volcanic with sedimentary rocks.

In achieving the objectives of the study, ten (10) quarry sites within the state were identified as indicated in Table 1. The sites were carefully selected in such a way as to cover all the local government areas of the state where quarrying is actively functional (Figure 1) and also to cover the different geological formations that exist in the state.

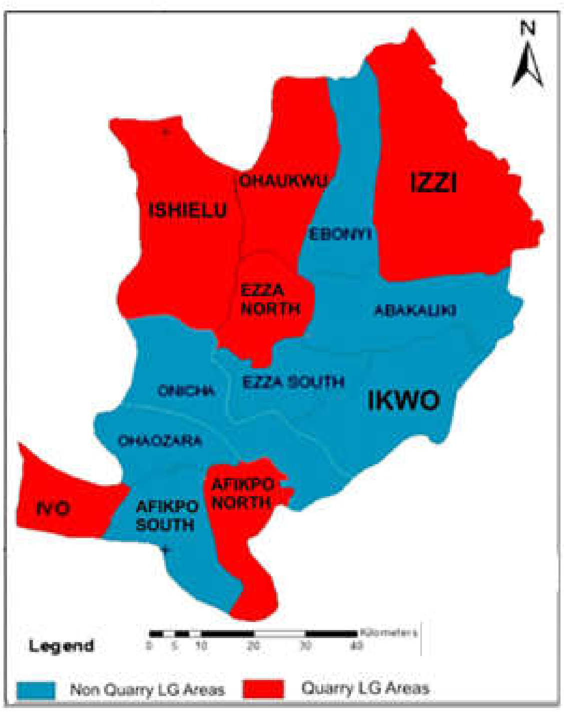

Fig 1: Map of Ebonyi State showing study locations

Table 1: Names and codes of Quarry sites

S/ No	Name Of Quarry Site	Quarry Site Code	Location
1	Julius Berger	JUB	Akpuoah
2	Setraco	SET	Amasiri
3	Crush Rock	CRR	Ishiagu
4	RCF Construction	RCF	Ngbo
5	Okposi Umuoghara Site	OUS	Ezza North
6	Green Field	GRF	Ishiagu
7	Afikpo South Sand	ASS	Edda
8	Jidech Mining Co. Ltd	JMC	Izzi
9	Jian ziang Quarry Company	JZQ	Ezillo
10	LOC metal Nig. Ltd	LOC	Ishiagu

BIR dose rate measurement: Two sections, excavation section (ES) and quarrying section (QS), of each quarry site were delineated for BIR measurements. These two sections are referred to as the active sections (Akerblom and Mjones, 1994) of rock quarrying.

The excavation section is the central point of granite excavation which in most of the quarry sites is very deep and the quarrying section is the central point where the excavated granites are crushed to various sizes. Measurements of BIR dose rates in air were carried out using a portable hand survey GQ GMC-320 Geiger Counter nuclear radiation detector (GQ Electronics LLC, USA). The features and functionality of the meter were described in Ugbede and Benson (2018) and Ugbede (2018).

An in-situ approach of BIR measurements was adopted with the standard practice of positioning the meter at height of 1.0 m above ground level (Rafique *et al.*, 2014; Agbalagba *et al.*, 2016; Agbalagba, 2017; Ugbede and Benson, 2018). By this approach, the study areas can still retain their original environmental characteristics (Rafique *et al.*, 2014; Agbalagba *et al.*, 2016; Ugbede and Benson, 2018). The radiation detector window was positioned to facing suspected sources. Four repeated measurements, at interval of three minutes, for a period of twenty days was recorded for each location.

This was done to ensure that the fluctuating nature of background ionizing radiation occasioned by variation in environmental parameters and anthropogenic activities were accounted for (Agbalagba, 2017; Ugbede and Benson, 2018). The average of these repeated measurements was computed and presented in this report.

Estimation of annual effective dose (AED) and excess lifetime cancer risk (ELCR): The obtained average BIR dose rates in units of μSv/h were used to estimate the annual effective dose (AED) as given in Equ. 1

(Ramli *et al.*, 2014; Jindal *et al.*, 2018; Ibikunle *et al.*, 2019; Okeyode *et al.*, 2019).

$$\mathrm{AED\ (mSv/y)} = \mathrm{DR} \times \mathrm{T} \times \mathrm{OF} \times 10^{-3} \qquad 1$$

Where DR is the measured absorbed dose rate in µSv/h, T is the total hours per year (8760 h), and OF is the outdoor occupancy factor, defined as 0.2 (UNSCEAR, 2000).

In order to assess the cancer risk of the quarry workers resulting from the BIR exposure, excess lifetime cancer risk (ELCR) was estimated using well-established model given in Equ. 2 (Taskin *et al.*, 2009; Rafique *et al.*, 2014; Agbalagba *et al.*, 2016; Agbalagba, 2017; Ugbede and Benson, 2018; Jindal *et al.*, 2018). The ELCR is a radiological risk assessment parameter that predicts the probability of cancer development by an individual over a lifetime exposure to low-dose radiation (Darwish *et al.*, 2015; Ugbede and Benson, 2018).

$$\mathrm{ELCR} = \mathrm{AED} \times \mathrm{DL} \times \mathrm{RF} \qquad 2$$

Where DL is the average duration of life (70 years) and RF is the cancer risk factor per sievert (Sv^{-1}). For low-dose background radiation considered to produce stochastic effects, the International Commission on Radiological Protection (ICRP, 2007) recommended a cancer risk factor of 0.05 Sv^{-1} for general public exposure.

RESULTS AND DISCUSSION

Table 2 shows the obtained results for the average BIR dose rates measured at the excavation section (ES) and quarrying section (QS) of the studied quarry sites. The estimated values of the AED and ELCR are also presented in Table 2.

Table 2: Background ionizing radiation dose levels in quarry site of Enugu State

S/No.	Quarry site	Dose rate (µSv/h)		Annual effective dose (mSv/y)		Excess lifetime cancer risk ($\times 10^{-3}$)	
		ES	QS	ES	QS	ES	QS
1	JUB	0.14	0.16	0.25	0.28	0.86	0.98
2	SET	0.18	0.19	0.32	0.33	1.10	1.17
3	CRR	0.16	0.18	0.28	0.32	0.98	1.10
4	RCF	0.14	0.16	0.25	0.28	0.86	0.98
5	OUS	0.14	0.17	0.25	0.30	0.86	1.04
6	GRF	0.15	0.18	0.26	0.32	0.92	1.10
7	ASS	0.15	0.19	0.26	0.33	0.92	1.17
8	JMC	0.18	0.19	0.32	0.33	1.10	1.17
9	JZQ	0.14	0.16	0.25	0.28	0.86	0.98
10	LOC	0.16	0.17	0.28	0.30	0.98	1.04
Mean value		**0.15±0.01**	**0.18±0.01**	**0.27±0.03**	**0.31±0.02**	**0.94±0.09**	**1.07±0.07**

As shown, while the dose rates at the ES ranged from 0.14 to 0.18 µSv/h, that measured at the QS fluctuates between 0.16 and 0.19 µSv/h. Furthermore, the values obtained at the QS are all higher than those at the ES. The mean BIR dose rates were estimated to be 0.15 and 0.18 µSv/h for ES and QS, respectively with standard deviation of 0.01 µSv/h each. The noticeable difference in dose rates at the ES and QS can be attributed to high content of radioactive dust produced during quarrying/crushing of the excavated granitic rocks.

The radionuclides present in large rock size are dispersed alongside with dust particles into the immediate atmosphere. This observation is thus in consonance with Ugwu et al (2008) who reported high activity concentration of radionuclides ^{238}U, ^{232}Th and ^{40}K in quarry dust samples collected from quarry plants in urban area of Abakaliki, Nigeria. The variation of the BIR dose rates at the ES and QS are presented in Figure 2. This variation can be attributed to the geological location of the sites. As shown in Figure 2, the dose rates are higher than the worldwide average value of 84 nSv/h reported by UNSCEAR (2000). This indicates that the BIR dose levels of the examined quarry sites are elevated, signifying a radiological polluted environment. This is significant when discussing the radiological protection of the worker and the general public. While the current values are higher than those measured in some building types in Ondo State, Nigeria (Oladele *et al.*, 2018), along river Alaknanda and Ganges, India (Sharma *et al.*, 2014) and in Guilan Province, Iran (Basirjafari *et al.*, 2014), they are however within worldwide range of 20 – 200 nSv/h from different countries (UNSCEAR, 2000). Though the present dose rates in the quarry sites are elevated, they are still below the levels that can initiate immediate health effects to the workers (Sharma *et al.*, 2014). However, continuous exposure may result to accumulation of low-level radiation doses (Ugbede and Benson, 2018) which may present long-term health effects in future.

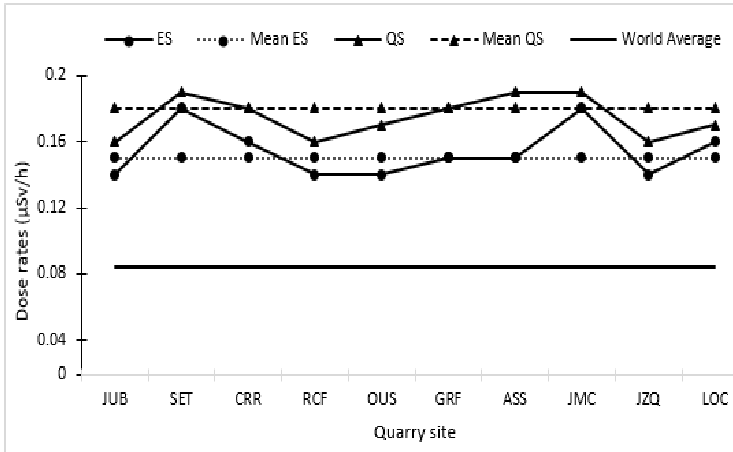

Fig 2: Variation of measured BIR dose rates in excavation and quarrying sections of the studied quarry sites

The estimated AED ranged from 0.25 to 0.32 mSv/y with mean of 0.27±0.03 mSv/y at the ES and 0.28 to 0.33 mSv/y with mean value of 0.31±0.02 mSv/y at the QS. The obtained AED values for all the sites are well above the outdoor worldwide average value of 0.07 mSv/y (UNSCEAR, 2000). This observation is illustrated in Figure 3. This further shows that the BIR levels of the studied quarry sites are quite elevated, an indication of a radiation contaminated environment. For radiological protection practices, ICRP (2007) recommended annual effective dose permissible limits of 20.0 mSv/y for occupational workers and 1.0 mSv/y for the general public. The present values are below these limits, thus indicating that the BIR levels of the studied quarry sites are still within acceptable limits and that no immediate radiological health threat may result from the current levels. However, as earlier noted, long-term health effects resulting from accumulative exposures may be manifested later at advanced age of the exposed individual. The reported AEDs are in similar range with means values of 0.288±0.045 mSv/y and 0.335±0.084 mSv/y in Okposi Okwu and Uburu salt lake areas respectively, both in Ebonyi State (Avwiri *et al.*, 2016). For the ELCR, the obtained values are ranged from 0.86×10^{-3} to 1.10×10^{-3} with mean of 0.94×10^{-3} at the ES and 0.98×10^{-3} to 1.17×10^{-3} with mean of 1.07×10^{-3}. These ELCR values are higher than the world average of 0.29×10^{-3} as documented by the United Nations Scientific Committee on the effects of Atomic Radiation (UNSCEAR, 2000). These values indicate probability of cancer incidence over a lifetime exposure of 70 years.

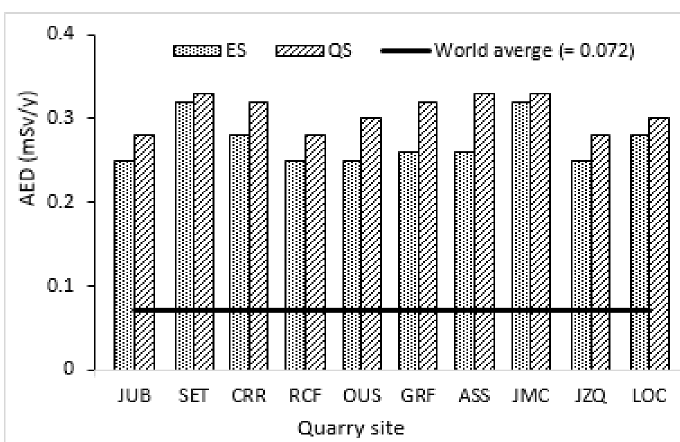

Fig 3: Comparison of AED of studied quarry sites with world average

Conclusion: Mineral mining and rock quarrying are parts of human activities that can elevate the background ionizing radiation (BIR) levels of the host environment. The present study has shown that the BIR dose levels of the investigated quarry sites in Ebonyi State are elevated, which suggest a radiation contaminated environment. While the current levels of BIR in the studied quarry sites are higher than the worldwide average. Long-term health effects due to accumulation of low-level radiation doses arising from prolonged and continuous exposures may be manifested in future.

REFERENCES

Agbalagba, EO (2017) Assessment of excess lifetime cancer risk from gamma radiation levels in Effurun and Warri City of Delta State, Nigeria. *J. Taibah Univ. Sci.* 11(3), 367–380.

Agbalagba, EO; Avwiri, GO; Ononugbo, CP (2016) GIS mapping of impact of industrial activities on the terrestrial background ionizing radiation levels of Ughelli metropolis and its Environs, Nigeria. *Environ. Earth Sci.* 75(21):1425

Akerblom, G; Mjönes, L (1994) Exposure to Workers in Swedish Quarrying, Stockholm. Swedish Radiation Protection Institute. ISBN 91-89230-00-0.

Akpokodje, EG (1992) Properties of some Nigerian rock aggregates and concrete. *J. Min. Geo.*, (23):185–190.

Avwiri, GO; Nwaka, BU; Ononugbo, CP (2016) Radiological Health Risk Due to Gamma Dose Rates Around Okposi Okwu and Uburu Salt Lakes, Ebonyi State. *Int. J. Emerg. Res. Manage. Technol.* 5(9):36–46.

Basirjafari, S; Aghayari, S; Poorabas, SM; Moladoust, H; Asadinezhad, M (2014) Assessment of outdoor gamma radiation dose rates in 49 cities of Guilan province, Iran. *Iranian J. Med. Phys.* 11(1):168-174

Chiadikobi, KC; Beka, FT; Chiaghanam, OI (2011) Structural attributes of igneous intrusive in Ishiagu area of Ebonyi State, Nigeria. *Arch. Appl. Sci. Res.* 3(5):390–403.

Chima, GN; Nwaugo, VO; Ezekwe, IC (2010) The impact of rock quarrying on Akwukwo tributary of Ivo River in Ishiagu, Ebonyi State. *J. Appl. Environ. Sci.* 6(2):68–73.

Darwish, DAE; Abul-Nasr, KTM; El-Khayatt, AM (2015) The assessment of natural radioactivity and its associated radiological hazards and dose parameters in granite samples from South Sinai, Egypt. *J. Radiat. Res. Appl. Sci.* 8:17–25.

Ebure, CI; Ezeribe, IE (1997) Geology of Ishiagu area, Eastern Nigeria. Unpublished B.Sc Project, University of Nigeria, Nssuka.

Edet, A; Nganje, AJ; Ekwere, AS; Ukpong, AJ. (2011) Groundwater chemistry and quality of Nigeria: A Status Review. *Afri. J. Environ. Sci. Technol.* 5(13):1152–1169.

Emelue, HU; Jibiri, NN; Eke, BC (2014) Excess lifetime cancer risk due to gamma radiation in and around Warri refining and petrochemical company in Niger Delta, Nigeria. *Bri. J. Med. Med. Res.* 4(13):2590–2598.

Enyinna, PI Onwuka, IM (2014,) Investigation of the radiation exposure rate and noise levels within crush rock quarry site in Ishiagu, Ebonyi State, Nigeria. *Int. J. Adv. Res. Phys. Sci.* 1(6):56–62.

Ezepue, MC (1984) Geologic setting of lead–zinc deposit at Ishiage, South-Eastern Nigeria. *J. Afr. Earth Sci.* 2:97–101.

Ibikunle, SB; Arogunjo, AM; Lajuwomi, JT (2019) Isodose mapping and its radiological implications in Lagos state, Nigeria. *Int. J. Radiat. Res.* 17(3):429–437

ICRP (2007) The 2007 Recommendations of the International Commission on Radiological Protection. ICRP publication 103. Annals of the ICRP, Vol. 37

Jibiri, NN; Okeyode, IC (2012) Evaluation of radiological hazards in the sediments of Ogun River, South-Western Nigeria. *Radiat. Phys. Chem.* 81:103–112

Jindal, MK; Sar, SK; Singh, S; Arora, A (2018) Risk assessment from gamma dose rate in Balod District of Chhattisgarh, India. *J. Radioanal. Nucl. Chem.* 317(1):387–395.

Lawal, MO (2010) Constraints to small-scale mining in Nigeria: Policies and strategies for development. Centre for Energy Petroleum Minerals Law and Policy- Annual Review. The Dundee Year Book of International National Resources and Energy Law and Policy Pp: 205-210

Mokobia, CE; Balogun, FA (2004) Background gamma terrestrial dose rate in Nigerian functional coal mines. *Radiat. Prot. Dosim.* 108(2):169–173.

Okeke, CN (2008) Geology and mineral resource. Blessing or Curse? *J. Int. Law.* 42(1):193–210.

Okeyode, IC; Oladotun, IC; Alatise, OO; Bada, BO; Makinde, V; Akinboro, FG; Mustapha, AO; Al-

Azmi, D (2019) Indoor gamma dose rates in the high background radiation area of Abeokuta, South Western Nigeria. *J. Radiat. Res. Appl. Sci.* 12(1):72–77.

Oladele, BB; Arogunjo, AM; Aladeniyi, K (2018) Indoor and outdoor gamma radiation exposure levels in selected residential buildings across Ondo state, Nigeria. *Int. J. Radiat. Res.* 16(3):363–370.

Ononugbo, CP; Avwiri, GO; Tutumeni, G (2016) Measurement of Natural Radioactivity and Evaluation of Radiation Hazards in Soil of Abua/Odual Districts Using Multivariable Statistical Approach. *Bri. J. Environ. Sci.* 4(1):35–48.

Qureshi, AA; Tariq, S; Ud Din, K; Manzoor, S; Calligaris, C; Waheed, A (2014) Evaluation of excessive lifetime cancer risk due to natural radioactivity in the rivers sediments of Northern Pakistan. *J. Radiat. Res. Appl. Sci.* 7(4):438–447.

Rafique, M; Saeed, UR; Muhammad, B; Wajid, A; Iftikhar, A; Khursheed, AL; Khalil, AM (2014) Evaluation of excess life time cancer risk from gamma dose rates in Jhelum valley. *J. Radiat. Res. Appl. Sci.* 7(1):29–35.

Ramli, AT; Aliyu, AS; Agba, EH; Saleh, MA (2014) Effective dose from natural background radiation in Keffi and Akwanga towns, central Nigeria. *Int. J. Radiat. Res.* 12(1):47–52.

Sharma, P; Meher, PK; Mishra, KP (2014) Terrestrial gamma radiation dose measurement and health hazard along river Alaknanda and Ganges in India. *J. Radiat. Res. Appl. Sci.* 7(4):595-600.

Suresh, GM; Ravisankar, R; Rajalakshmi, A; Sivakumar, S; Chandrasekaran, A; Anand, DP (2014) Measurements of natural gamma radiation in beach sediments of north east coast of Tamilnadu, India by gamma ray spectrometry with multivariate statistical approach. *J. Radiat. Res. Appl. Sci.* 7(1):7–17.

Taskin, H; Karavus, M; Ay, P; Topuzoglu, A; Hindiroglu, S; Karahan, G (2009) Radionuclide concentrations in soil and lifetime cancer risk due to the gamma radioactivity in Kirklareli, Turkey. *J. Environ. Radioact.* 100:49–53.

Ugbede, FO (2018) Measurement of background ionizing radiation exposure levels in some selected farms in communities of Ishielu LGA, Ebonyi State, Nigeria. *J. Appl. Sci. Environ. Manage.* 22(9):1427–1432.

Ugbede, FO; Benson, ID (2018) Assessment of outdoor radiation levels and radiological health hazards in Emene Industrial Layout of Enugu State, Nigeria. *Int. J. Phys. Sci.* 13(20):265–272.

Ugbede, FO; Akpolile, AF (2019) Determination of specific activity of ^{238}U, ^{232}Th and ^{40}K and radiological hazards assessment of Tuomo River sediments in Burutu, Delta State, Nigeria. *J. Appl. Sci. Environ. Manage.* 23(4):725–731.

Ugwu, EI; Agwu, KO; Ogbu, HM (2008) Assessment of Radioactivity content of quarry dust in Abakaliki, Nigeria. *The Pac. J. Sci. Technol.* 9(1):208–211.

UNSCEAR (1993). United Nations Scientific Committee on the Effects of Atomic Radiation. Sources, Effects and Risks of ionizing radiation. Report to United Nations General Assembly, New York.

UNSCEAR (2000). United Nations Scientific Committee on the effect of Atomic Radiation: Exposures from natural radiation sources. Report to General Assembly, with Scientific Annexes. United Nations, New York.