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ASSESSMENT OF EXCESS LIFETIME CANCER RISK FROM GAMMA RADIATION LEVELS AROUND SOKOTO CEMENT INDUSTRIAL AREA, NORTHWESTERN NIGERIA

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ABSTRACT
A study of the terrestrial gamma radiation dose rates (TGDRs) were measured directly at 1 meter above the ground levels to estimate the excess lifetime cancer risk around Sokoto cement company has been carried out, using a handheld nuclear radiation survey meter and a geographical positioning system (GPS) for GIS mapping. Monitoring of the terrestrial TGRD levels was carried out in September 2019, and the study was delineated into seven zones. The measured average exposure rates ranged from 80 to 130 nGyh^{-1}, with average of 97.1 nGyh^{-1}. Enhanced TGRDs ranged from 100 to 130 nGyh^{-1} These values were higher than the UNSCEAR world average of 59 nGyh^{-1}. The mean annual effective dose equivalent (AEDE) calculated was 0.61 mSvy^{-1} and calculated dose to organs showed that the testes have the highest organ dose of 0.34 mSvy^{-1}, while the liver has the lowest organ dose of 0.19 Svy^{-1}. However, this result is not expected to contribute significantly to the human health hazard from the point of view of radiation protection, as the ICRP recommended annual effective dose limit for members of the public is 1mSvy^{-1}. The average excess lifetime cancer risk (ELCR) was also 1.82E-03 more than the world average of 0.29E-03 but less the maximum permissible limit of 2.4E-03.

Keywords: Assessment Excess life cancer risk, Gamma radiation, Sokoto cement industrial area

INTRODUCTION
Human anthropogenic activities in the company's mines environs generate different forms of wastes, which when mismanaged may cause aesthetic nuisance, decrease the socio-economic value of the area and pose a radiation health burden on the populace. Additionally, the activities of cement plant including coal flaring and clinker grinding, oil spills from the ever busy heavy duty vehicles, spills of imported toxic chemicals and radionuclide materials for geological mapping, and other industrial activities can also increase the TGDR levels of the study area. Exposure to background radiation, which is known to be present everywhere on the Earth and in the atmosphere, may also add to radiation exposure levels that may cause detrimental health effects to residents (Garba *et al*., 2015).

Different literatures have shown that exposure to ionizing radiation can cause cancer and other health challenges including stunted growth and mental retardation in children of mothers exposed to radiation during pregnancy. According to National Research Council (NRC), 2006, high radiation doses may also cause other health effects as listed in BEIR VII PHASE 2. There is strong correlation between radiation exposure and health hazards among the populace and workers in a given environment (Odoh *et al*.; Inoue *et al*., (2020); Avwiri, Agbalagba and Enyinna 2007; Farai and Jibiri, 2000). Hence, TGDR can be considered to be a form of environmental contamination, especially when it exceeds safe occupational and public health limits. External TGDR comes from three major sources of background ionizing radiation (BIR): terrestrial radiation, cosmic radiation and anthropogenic radiation.

Ibrahim *et al*., (2015) carried out In-Situ background ionizing radiation (BIR) from indiscriminate dumpsites in Sokoto metropolis and the values obtained were in the range of 0.011 to 0.065 mRhr^{-1} and an average of 0.024 mRhr^{-1} against the global limit of 0.013 mRhr^{-1} with a significantly higher upper limit than the global average. However, the study concentrated only on dumpsites of medical wastes without considering to the dumpsite of Sokoto cement company. Odoh *et al*., (2019) mapped and assessed of terrestrial gamma radiation exposure in northern Zamfara state, an area under Sokoto basin where Sokoto cement was also located. The mean terrestrial gamma radiation exposure rate in the study area was found to be 32 nGyh^{-1}. Kaura Namoda local government area has the highest mean value of TGDR exposure rate of 38 nGyh^{-1}, while Bakura local government area has the lowest mean value of TGDR exposure rate of 28 nGyh^{-1}. Exposure and risk; outdoor annual effective dose rate, mean population weighted dose rate, annual collective effective dose, lifetime dose and excess lifetime cancer risk were computed as 0.04 mSvy^{-1}, 32.45 nGyh^{-1}, 59.33 Svy^{-1}, 2.75 mSv, and 1.38× 10^{-4}, respectively. These values were all below the world average values for the parameters. Even though, these adjudge radiological safety in terms of TGDR exposure rate, other areas under the Sokoto basin need to assessed especially Sokoto cement area. Farai and Jibiri reported the outdoor gamma radiation exposure dose rate for the eastern region of Nigeria to be between 25 and 80 nGyh^{-1}. Inoue *et al*., (2020) also reported the mean distribution the outdoor gamma radiation exposure dose rate for Vietnam 71 nGyh^{-1}.

MATERIALS AND METHODS
Location of the study area.

The study area was Sokoto cement industrial area (Figure 1). Sokoto cement company formally known as Cement Company of Northern Nigeria Plc (CCNN) was established in Kalambaina district, 10 km south-west outskirt of ancient city of Sokoto in 1960 by the then Northern Regional Government. It is the only cement production facility in Northwestern Nigeria. It falls under Sokoto Basin which is the southern extension of the lullemmeden Basin.

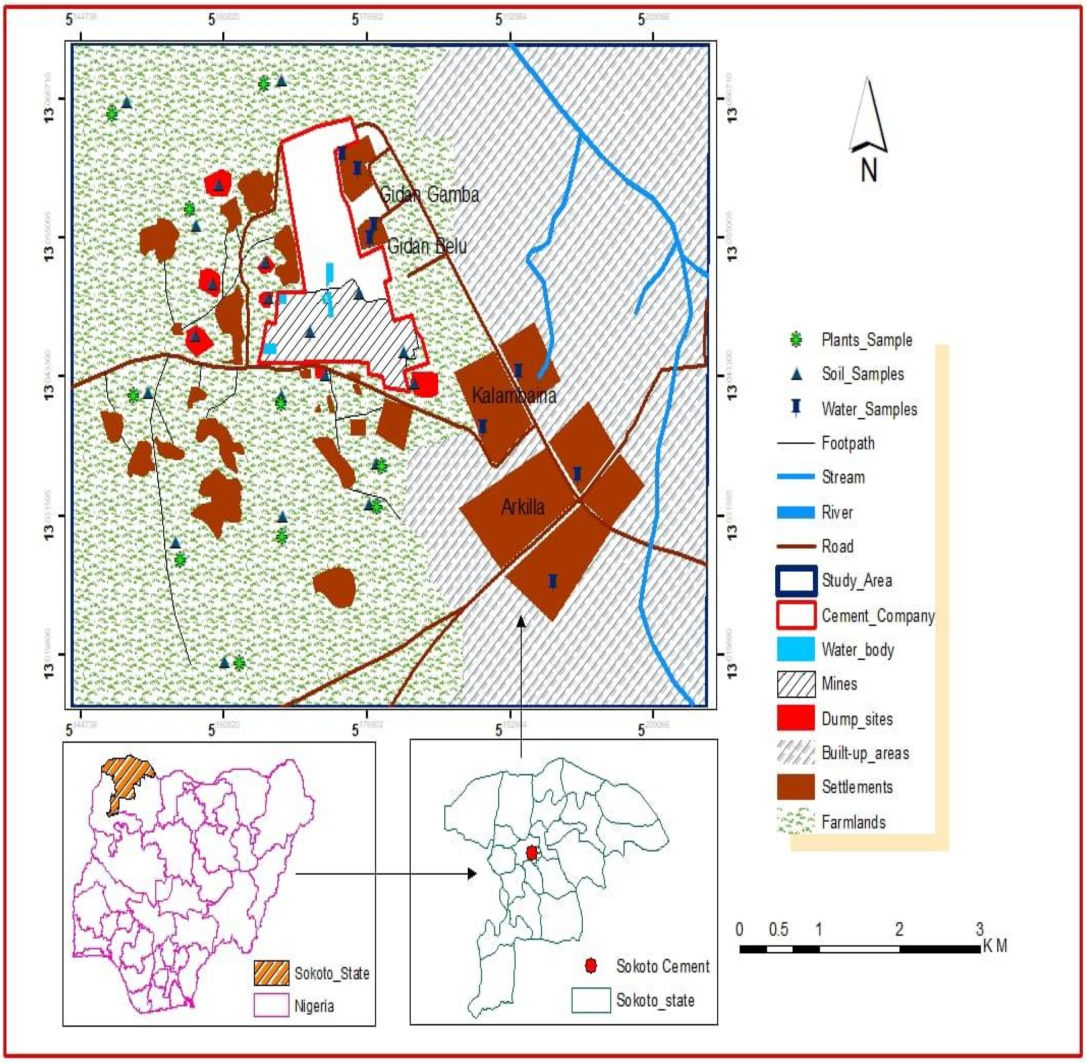

Figure 1: Map of the study area.

Picking of Kalambaina area as the location for siting the cement company was to take advantage of proximity to the required raw materials for cement production that are in abundance. The lullemmeden Basin is entirely a cratonic basin created by tectonic epirogenic movements or stretching and rifting of tectonically stabilized crust during the Palaeozoic (Yelwa *et al*., 2015). It is large synclinal structure trending NE-SE and it extends to Niger Republic, Mali, and Benin Republic (Albert *et al*., 2016). The study area is featured majorly with bared land and sparse vegetation. The climate is that of semi-arid with an annual average temperature of 28.3 °C (82.9 °F). The warmest months are February to April, where daytime temperatures can exceed 45 °C (113.0 °F). The wet season is usually from June to October. From late October to February, during the 'cold season', the climate is dominated by the harmattan wind blowing Sahara dust over the land. The rock type around Sokoto cement company is majorly phosphate rock which is primarily associated with the Sokoto Group of sediment comprising of shale, limestone and phosphate pellets (Albert *et al*., 2016; Obaje, 2009).

Measurement of terrestrial gamma dose rate (TGDR)

The study area was depicted into seven zones for easy coverage during the measurement, with four zones classified as residential areas and one zone classified as an industrial zone (mines and dumpsites) because of the concentration of industrial activities in the area. The other zone was the farmlands around the company. An in-situ approach of TGDR measurement was adopted to enable samples to maintain their original environmental characteristics. A Digilert handheld nuclear radiation survey meter (RADOS-120 International, Inc., Finland) capable of detecting β-, γ- and X-rays, pre-set for γ-ray measurements, was used. It has linear energy responses to gamma radiation between 50 and 3 MeV, which are considered being acceptable for covering the majority of gamma ray emissions from major sources of ambient natural gamma radiation. Meanwhile, geographical positioning system (GPS Model 70 s) was used to measure the precise location of sampling.

The radiation survey metre was raised to a standard height of 1.0 m above the ground with its window facing the suspected source while the GPS reading was taken at that spot (Avwiri, Egieya, and Chinyere, 2013). Measurements were repeated three times at each sampling site to account for an error or any fluctuation in the environmental parameters. AS recommended by National Council on Radiation Protection (NCRP, 1993), readings were obtained between 1300 and 1600 h because the radiation metre has a maximum response to environmental radiation.

Determination of effective dose equivalent (AED).

The annual effective dose equivalent (AED) to the population due to the TGDR was calculated by summing up the outdoor and indoor annual effective doses to the population obtained using Equations 1 and 2 with the dose coefficient of 0.7SvGy^{-1} and the occupancy factors 0.2 for outdoors and 0.8 for indoors (Garba *et. al*., 2014; UNSCEAR, 2000).

$$OAE(mSvyr^{-1}) = TGDR(nGhr^{-1}) \times 24 \times 365 \times 0.2 \times 0.7 \times 10^{-6} \quad (1)$$

$$IAE(mSvyr^{-1}) = TGDR(nGhr^{-1}) \times 24 \times 365 \times 0.8 \times 0.7 \times 10^{-6} \quad (2)$$

$$\mathrm{AED}(mSvyr^{-1}) = \mathrm{OAE} + \mathrm{IAE} \quad (3)$$

where 0.7 is the conversion coefficient from absorbed dose in air to effective dose, 0.2 and 0.8 are occupancy factors for outdoor and indoor respectively (UNSCEAR, 2000).

Determination of excess life cancer risk (ELCR)

The resultant excess life cancer risk due to annual effective dose received estimates the probability of cancer incidence in a population of individuals for a specific lifetime. This was calculated using Equation 4 (Taskin *et al*, 2009; ICRP, 2007).

$$ELCR = AED \times LE \times RF \quad (4)$$

where LE is the life expectancy and RF is the risk factor. In this work LE of 55.12 reported by UNPD, 2021 and RF of 0.057 reported by ICRP, 2007 were used.

Determination of effective dose to organs

Effective dose rate to a particular organ was calculated using equation 5 (Abobneh, *et al*., 2010).

$$D_{organ}(mSvy^{-1}) = O \times AED \times F \quad (5)$$

where AED is annual effective dose, *O* is the occupancy factor 1 (for both indoor and outdoor) and *F* is the conversion factor for organ dose from ingestion. Organs considered in this study include lungs, ovaries, bone marrow, testes, kidneys, liver and whole body. Their respective F values are 0.64, 0.58, 0.69, 0.82, 0.62, 0.46 and 0.68 (ICRP, 1996).

RESULTS AND DISCUSSIONS

The results of measured terrestrial BIR, TGDR and consequential excess life cancer risk for all zones were presented in Tables 1-7. Table 8 presents the summary for Sokoto cement industrial area. The results from various point indicated that the lower and upper bounds TGDR were 80 and 130 nGyh^{-1}respectively. The upper bound value was obtained from dumpsite, farmlands and Arkilla. All averages of the seven various zones were higher than the world mean of 59 nGyh^{-1} (UNSCEAR, 2018). Average TGDR in Table 8 depicts enhanced value of 100 nGyh^{-1} was observed in farmlands. This could be attributed to large deposit of bedded phosphate and sandstone soils formations in the area which were reported commonly and occasionally carry high radioactive contain respectively. However, locations with relatively lower TGDRs are locations of large deposits of limestone, which is known to be of low radioactive contents (Hurley, 2009). On comparison with similar results from other studies in the same area covered by sedimentary Sokoto basin, result of the present study is well within the reported values. Ibrahim *et. al*., 2015, measured TGDRs from indiscriminate dumps sites within Sokoto metropolis, and values of range between 0.011 to 0.065 mR h^{-1}equivalent to 110 to 650 nGyh^{-1}were obtained. These values are quite higher than the results obtained from this study. However, results of terrestrial gamma radiation exposure in neighboring northern Zamfara state were 20 to 61 nGyh^{-1}, which are lower than the results obtained from this study (Odoh, *et al*., 2019). This showed that activities of Sokoto cement company interferes insignificantly to the TGDRs of the study area.

The annual effective dose equivalent (AED) to the population due to the TGDRs in the area was calculated using Equation 3 by summing up the outdoor effective dose (OAE) and indoor annual effective dose (IAE) to the population obtained using Equations 1 and 2. The results obtained were 0.11 mSvy^{-1} and 0.50 mSvy^{-1} respectively. OAE and IAE were sum together and obtained AED of 0.61 mSvy^{-1}. This value is higher than world average of 0.07 mSvy^{-1}(UNSCEAR, 2000). However, this result is not expected to contribute significantly to the human health hazard from the point of view of radiation protection, as the recommended annual effective dose limit for members of the public is 1mSvy^{-1} (ICRP, 2000).

Subsequently, excess life cancer risk (ELCR) was also estimated using Equation 4. The value obtained was 1.83E-03. Although, result of this study is higher than 0.14E-03 from neighboring Zamfara state and worldwide of 0.29E-03 but still less than the recommended limit of 2.4E-03 (Odoh, *et al*., 2019; ICRP, 2007).

Table 1: measured TGDR from the company's mine site and calculated hazard indices

S/No.	Sample ID	Latitude (N)	Longitude (E)	TGDR (nGyh^{-1})	Effective Dose (mSvy^{-1})			ELCR
					OAE	IAE	AED	
1	MS1	13°03´38.4"	5°10´26.5"	90	0.10	0.44	0.54	1.70E-03
2	MS2	13°03´40.4"	5°10´30"	100	0.11	0.49	0.60	1.88E-03
3	MS3	13°03´42"	5°10´36"	80	0.99	0.39	0.48	1.50E-03
4	MS4	13°03´45.1"	5°10´33"	100	0.11	0.49	0.60	1.88E-03
5	MS5	13°03´39"	5°10´37"	100	0.11	0.49	0.60	1.88E-03
6	MS6	13°03´18.4"	5°10´34.5"	95	0.11	0.46	0.57	1.79E-03
7	MS7	13°03´17.1"	5°10´38.4"	100	0.11	0.49	0.60	1.88E-03
8	MS8	13°03´17.7"	5°10´40.2"	110	0.12	0.54	0.66	2.07E-03
9	MS9	13°03´29.9"	5°10´37.0"	100	0.11	0.49	0.60	1.88E-03
10	MS10	13°02´02.3"	5°12´0.9"	80	0.09	0.39	0.48	1.50E-03
		Average		**95.5**	**0.11**	**0.46**	**0.57**	**1.80E-03**
		World average		**59**	**0.07**	**0.34**	**0.41**	**0.29E-03**

Table 2: Measured TGDR from the company's dumpsites and calculated hazard indices

S/No.	Sample ID	Latitude (N)	Longitude (E)	TGDR ($nGyh^{-1}$)	Effective Dose ($mSvy^{-1}$)			ELCR
					OAE	IAE	AED	
1	DS1	13°01´32.9"	5°11´51.7"	100	0.11	0.49	0.60	1.88E-03
2	DS2	13°01´32"	5°11´52"	105	0.11	0.52	0.63	1.98E-03
3	DS3	13°01´30"	5°11´55"	90	0.10	0.44	0.54	1.57E-03
4	DS4	13°01´32.9"	5°11´50"	110	0.12	0.54	0.66	2.07E-03
5	DS5	13°02´35.9"	5°11´37"	100	0.11	0.49	0.60	1.88E-03
6	DS6	13°02´18.8"	5°11´22.2"	90	0.10	0.44	0.54	1.67E-03
7	DS7	13°02´42.2"	5°10´57.8"	80	0.09	0.39	0.48	1.50E-03
8	DS8	13°02´40"	5°10´52.3"	130	0.15	0.63	0.78	2.45E-03
9	DS9	13°02´60"	5°10´75.2"	90	0.10	0.44	0.54	1.67E-03
10	DS10	13°02´44"	13°10´51"	93	0.10	0.45	0.55	1.73E-03
		Average		**98.8**	**0.02**	**0.57**	**0.59**	**1.84E-03**
		World average		**59**	**0.07**	**0.34**	**0.41**	**0.29E-03**

Table 3: Measured TGDR from farmlands and calculated hazard indices

S/No.	Sample ID	Latitude (N)	Longitude (E)	TGDR ($nGyh^{-1}$)	Effective Dose ($mSvy^{-1}$)			ELCR
					OAE	IAE	AED	
1	FL1	13°02´44"	5°10´50.7"	110	0.12	0.54	0.66	2.07E-03
2	FL2	13°02´43.6"	5°10´52"	100	0.11	0.49	0.60	1.88E-03
3	FL3	13°02´48.4"	5°10´55.1"	80	0.09	0.39	0.48	1.50E-03
4	FL4	13°02´50"	5°10´58.5"	100	0.12	0.49	0.60	1.88E-03
5	FL5	13°02´38.4"	5°10´54.4"	110	0.12	0.54	0.66	2.07E-03
6	FL6	13°02´49.5"	5°10´59"	80	0.09	0.39	0.48	1.50E-03
7	FL7	13°02´47.8"	13°10´54"	100	0.11	0.49	0.60	1.88E-03
8	FL8	13°02´45.2"	5°10´58.9"	100	0.11	0.49	0.60	1.88E-03
9	FL9	13°02´44.1"	5°10´58.2"	90	0.10	0.44	0.54	1.67E-03
10	FL10	13°02´41.9"	5°10´59"	130	0.15	0.63	0.78	2.45E-03
		Average		**100**	**0.12**	**0.49**	**0.61**	**1.88E-03**
		World average		**59**	**0.07**	**0.34**	**0.41**	**0.29E-03**

Table 4: Measured TGDR from Arkilla and calculated hazard indices

S/No.	Sample ID	Latitude (N)	Longitude (E)	TGDR ($nGyh^{-1}$)	Effective Dose ($mSvy^{-1}$)			ELCR
					OAE	IAE	AED	
1	AR1	13°03´40.4"	5°11´58.7"	85	0.09	0.42	0.51	1.60E-03
2	AR2	13°04´0.6"	5°10´42.7"	80	0.09	0.39	0.48	1.50E-03
3	AR3	13°04´12.7"	5°10´42.7"	90	0.10	0.44	0.54	1.67E-03
4	AR4	13°04´10.5"	5°03´43.8"	110	0.12	0.54	0.66	2.07E-03
5	AR5	13°05´5.3"	5°03´43"	90	0.10	0.44	0.54	1.67E-03
6	AR6	13°05´58.7'	5°03´38"	100	0.11	0.49	0.60	1.88E-03
7	AR7	13°05´29.3"	5°03´6.2"	110	0.12	0.54	0.66	2.07E-03
8	AR8	13°05´29"	5°03´6"	95	0.11	0.46	0.57	1.80E-03
9	AR9	13°05´30.9"	5°03´4.4"	130	0.15	0.63	0.78	2.45E-03
10	AR10	13°02´40"	5°10´52.3"	80	0.09	0.39	0.48	1.50E-03
		Average		**97**	**0.09**	**0.49**	**0.58**	**1.82E-03**
		World average		**59**	**0.07**	**0.34**	**0.41**	**0.29E-03**

Table 5: Measured TGDR from Kalambaina and calculated hazard indices

S/No.	Sample ID	Latitude (N)	Longitude (E)	TGDR ($nGyh^{-1}$)	Effective Dose ($mSvy^{-1}$)			ELCR
					OAE	IAE	AED	
1	KL1	13°02´60"	5°10´75.2"	90	0.10	0.44	0.54	1.70E-03
2	KL2	13°02´44"	13°10´50.7"	95	0.10	0.45	0.55	1.73E-03

3	KL3	13°02´44"	5°10´50.7"	108	0.12	0.54	0.66	2.07E-03
4	KL4	13°02´43.6"	5°10´52"	100	0.11	0.49	0.60	1.88E-03
5	KL5	13°02´48.4"	5°10´55.1"	80	0.09	0.39	0.48	1.51E-03
6	KL6	13°02´50"	5°10´58.5"	100	0.11	0.49	0.60	1.88E-03
7	KL7	13°02´38.4"	5°10´54.4"	105	0.13	0.55	0.68	2.14E-03
8	KL8	13°02´49.5"	5°10´59"	80	0.09	0.39	0.48	1.51E-03
9	KL9	13°02´47.8"	13°10´53.6"	100	0.11	0.49	0.60	1.88E-03
10	KL10	13°02´47.8"	13°10´53.6"	80	0.09	0.39	0.48	1.51E-03
		Average		**93.8**	**0.11**	**0.46**	**0.57**	**1.78E-03**
		World Average		**59**	**0.07**	**0.34**	**0.41**	**0.29E-03**

Table 6: Measured TGDR from Gidan Gamba and calculated hazard indices

S/No.	**Sample ID**	**Latitude (N)**	**Longitude (E)**	**TGDR ($nGyh^{-1}$)**	**Effective Dose ($mSvy^{-1}$)**			**ELCR**
					OAE	**IAE**	**AED**	
1	GG1	13°02´50"	5°10´73"	90	0.10	0.44	0.54	1.70E-03
2	GG2	13°02´60"	5°10´75.2"	90	0.10	0.44	0.54	1.70E-03
3	GG3	13°02´44"	13°10´51'	93	0.11	0.44	0.55	1.73E-03
4	GG4	13°02´44"	5°10´50.7"	110	0.12	0.54	0.66	2.07E-03
5	GG5	13°02´43.6'	5°10´52"	100	0.11	0.49	0.60	1.88E-03
6	GG6	13°02´48.4'	5°10´55.1"	80	0.09	0.39	0.48	1.51E-03
7	GG7	13°02´50"	5°10´58.5"	100	0.11	0.49	0.60	1.88E-03
8	GG8	13°02´38.4'	5°10´54.4"	110	0.12	0.54	0.66	2.07E-03
9	GG9	13°02´49.5'	5°10´59"	80	0.09	0.39	0.48	1.51E-03
10	GG10	13°02´47.8'	13°10´54'	100	0.11	0.49	0.60	1.88E-03
		Average		**95.3**	**0.11**	**0.46**	**0.57**	**1.8E-03**
		World Average		**59**	**0.07**	**0.34**	**0.41**	**0.29E-03**

Table 7: Measured TGDR from Gidan Belu and calculated hazard indices

S/No.	**Sample ID**	**Latitude (N)**	**Longitude (E)**	**TGDR ($nGyh^{-1}$)**	**Effective Dose ($mSvy^{-1}$)**			**ELCR**
					OAE	**IAE**	**AED**	
1	GB1	13°02´63"	5°10´70"	110	0.10	0.54	0.66	2.07E-03
2	GB2	13°02´60"	5°10´75.2"	110	0.10	0.54	0.66	2.07E-03
3	GB3	13°02´44"	13°10´50.7"	100	0.11	0.49	0.60	1.88E-03
4	GB4	13°02´44"	5°10´50.7"	110	0.12	0.54	0.66	2.07E-03
5	GB5	13°02´43.6"	5°10´52"	100	0.11	0.49	0.60	1.88E-03
6	GB6	13°02´48.4"	5°10´55.1"	80	0.09	0.39	0.48	1.50E-03
7	GB7	13°02´50"	5°10´58.5"	110	0.12	0.54	0.66	2.07E-03
8	GB8	13°02´38.4"	5°10´54.4"	100	0.11	0.49	0.60	1.88E-03
9	GB9	13°02´49.5"	5°10´59"	80	0.09	0.39	0.48	1.51E-03
10	GB10	13°02´47.8"	13°10´53.6"	90	0.10	0.44	0.54	1.70E-03
		Average		**99**	**0.11**	**0.49**	**0.60**	**1.86E-03**
		World Average		**59**	**0.07**	**0.34**	**0.41**	**0.29E-03**

Table 8: Summary of the TGDR and the estimated hazard indices around Sokoto cement industrial area.

S/No	Zones	TGDR ($nGyh^{-1}$)	Effective Dose ($mSvy^{-1}$)			ELCR
			OAE	IAE	AED	
1	Company's mine site	95.5	0.11	0.46	0.57	1.80E-03
2	Company's dumpsite	98.8	0.12	0.47	0.59	1.84E-03
3	Farmlands	100	0.11	0.50	0.61	1.88E-03
4	Arkilla	97.0	0.12	0.46	0.58	1.82E-03
5	Kalambaina	93.8	0.11	0.46	0.57	1.78E-03
6	Gidan Gamba	95.3	0.11	0.46	0.57	1.80E-03
7	Gidan Belu	99.0	0.11	0.49	0.60	1.86E-03
	Average	**97.1**	**0.11**	**0.50**	**0.61**	**1.83E-03**
	World Average	**59**	**0.07**	**0.34**	**0.41**	**0.29E-03**

Effective dose rates delivered to the different organs under consideration were estimated using equation 5 and presented in Figure 2. The model of the annual effective dose to organs, thus, Equation 5 estimates the amount of radiation intake by a person that enters and accumulates in various body organs and tissues. Seven organs and tissues were examined, and the results show that the testes received the highest dose, with average value of 0.34 $mSvy^{-1}$, while the dose was found to be lowest in the liver, with average values of 0.19 $mSvy^{-1}$. The relatively higher dose to the testes and low dose intake to the liver is justified by the food nutrient absorption rate (Ababneh, *et al*., 2010) Although, results of this study depict higher values of estimated doses to the different organs examined than those obtained from Wari city, still these values were all below the international tolerable limits on dose to the body organs of 1.0 $mSvy^{-1}$ (Agbalagba,2017; WHO, 1993). This result shows that exposure to TGDRs around Sokoto cement industrial area contributes insignificantly to the radiation dose to these organs in adults and pose no immediate human health hazards from the point of view of radiation protection.

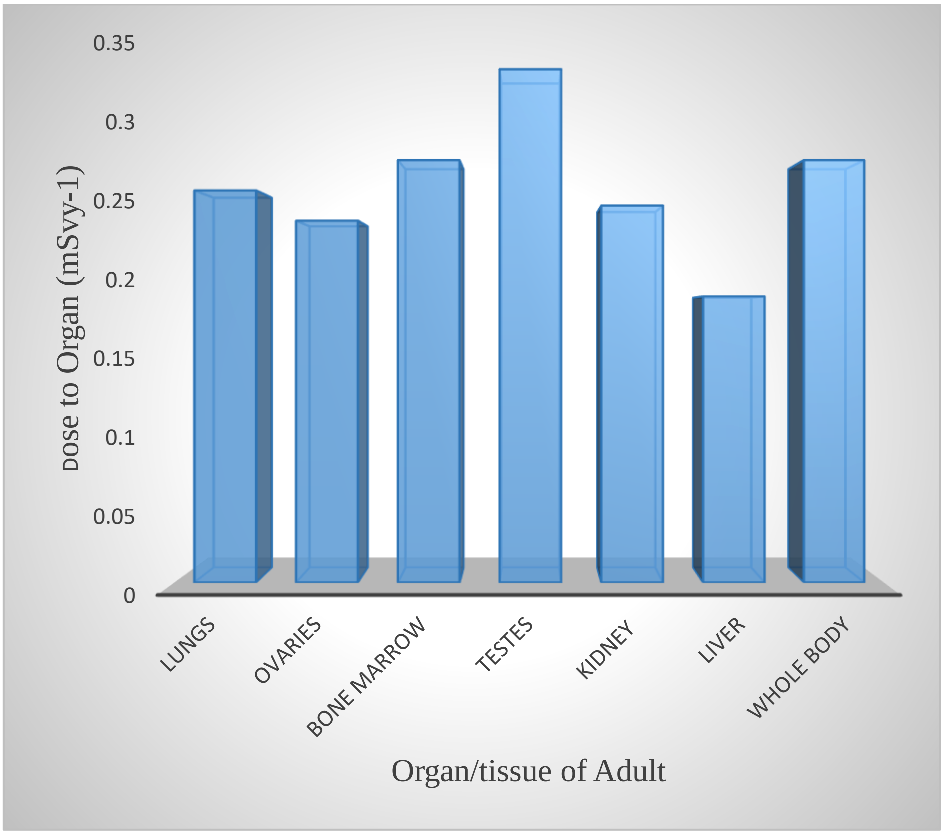

Figure 2: Effective dose to different organs/tissues

CONCLUSION

The TGDRs of Sokoto cement industrial area, were measured and found to be between 80 to 130 $nGyh^{-1}$ and average of 97.1 $nGyh^{-1}$. The result was compared with different studies from within and outside Nigeria. The consequential annual effective dose equivalent rate was 0.61 $mSvy^{-1}$ and not exceeding the radiation safety limit of 1.0 $mSvy^{-1}$ recommended by UNSCEAR. The estimated excess lifetime cancer risk revealed that the chance of contracting cancer for inhabitants of the study area who will spend all of their lives in the area is low, and the effective doses from the current exposure rate to the adult organs investigated are also insignificant. However, it is recommended that prolonged exposure in the farmlands and Gidan Belu zones should be limited to avoid future health risks. Also, the ALARA (as low as reasonably achievable) principle is recommended for Sokoto cement company and all other cement companies operating in Nigeria.

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