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Assessment of Indoor and Outdoor Radiation Levels and Human Health Risk in Sheda Science and Technology Complex and its Environ, Abuja, Nigeria

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ABSTRACT: A study to assess the Indoor and Outdoor Background Ionizing Radiation (BIR) of Sheda Science and Technology Complex, Abuja has been conducted. An in-situ measurement using a portable factory calibrated radiation dose rate meter, Radiagem 2000, was used to ascertain the radiation level. The measured radiation dose rates were used to evaluate the radiological health hazards and radiation effective doses to different body organs using well established radiological relations. The results shows that the total Dose Rate (indoor and outdoor), the Total Annual Equivalent Dose (indoor and outdoor), total Annual Effective Dose Equivalent (indoor and outdoor) and the total Excess Lifetime Cancer Risk (indoor and outdoor) are 0.113±0.022 (μSv/h), 0.071±0.016 (μSv/h), 0.794±0.155 mSv/y, 0.0.124±0.074 mSv/y, 0.556±0.109 mSv/y, 0.087±0.020 mSv/y, 1.945±0.379, 0.304±0.104 respectively for the three zones. The dosage to organs received shows that the testes have the highest dose while the liver has the lowest dose (indoor and outdoor) for the three zones. Generally the study shows that the Annual Effective Dose Equivalents were within the permissible limits of 1 mSv/y for general public exposure recommended by the (ICRP). Also, the effective doses to different body organs are all below the recommended limits of 1 mSv/y. The calculated Excess Lifetime Cancer Risk values indicates that the chance of contacting cancer by workers and residents of the study area is not probable hence the study area could be said to be radiologically safe.

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We are all exposed to ionizing radiation from natural sources at all times. Natural background radiation is inevitably present in our environment. Natural Background radiation is the radiation of man's natural environment, consisting of what comes from Cosmic rays, the naturally radioactive elements of the earth and from within man's body (Nwankwo and Akoshile 2005, UNSCEAR 2000). Human beings are exposed to background radiation that stems both from natural and man-made sources. In general, approximately 85% of the annual total radiation dose of any person comes from natural radionuclides of both terrestrial and cosmogenic origin (Belivermis *et al.* 2010; UNSCEAR 2000). According to ((UNSCEAR 2000) the worldwide annual effective dose from natural sources is estimated to be 2.4 mSv. The earth's crust contains various radioactive isotopes such as uranium, thorium, radon, tritium, carbon, and potassium among others. These isotopes and their decayed products have differences in their half-lives, which emit various types of radiations such as alpha, beta and gamma rays. Additionally, cosmic radiation from the sun contributes to gamma rays surrounding the human body. Conversely, the controlled manmade-artificial background radiation results from several sources such as fallouts of weapons testing, radioactive waste, and the use of radioisotopes in radiation-therapy. Both controlled and uncontrolled sources of radiation may have undesired biological effects to living species (Orwa *et al*., 2012, James and Moses, 2014). Small traces of many naturally occurring radioactive materials are present in the human body. Radiation has been found to be beneficial on one hand and harmful on the other hand. An in-situ measurement of the background radiation level was carried out at the vicinity of three campuses of two major tertiary institutions in Minna, Niger State. The results of the investigation revealed that the average annual effective dose obtained was 0.189 mSv/y (Olarinoye *et al*., 2010). A study of the background radiation in Akwanga, Nasarawa State showed that the annual mean equivalent doses for indoor and outdoor backgrounds are 1.29±0.13 and 0.31±0.14 mSv/y respectively (Sadiq and Agba, 2011). Determination of Absorbed and Effective Dose from Natural Background Radiation around a Nuclear Research Facility was carried out in Zaria (Mohammad *et al*., 2011). It was observed that the estimated total annual effective dose outdoor for the sites range from 27.3-79.9 μSv/y. Also the natural background radiation

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dose/dose rate has been investigated by many researchers in other parts of the world and a wide range of results are reported (Amiri et al., 2011). The 2011 Fukushima Daiichi nuclear disaster displaced thousands of people and its effects is still been felt even in places far from the site (Tanabe, 2011). The more radiation dose a person receives, the greater the chance of developing cancer. The cancer may not appear until many years after the radiation dose is received (typically 10-40 years) and there is no level below which we can say an exposure does not pose a risk to life (Avwiri *et al.,* 2010). Evaluation of hazard indices is of immense importance as it will be very useful in evaluating the radiological impact, by estimating the likelihood of developing various health effects (risks) associated with radiation exposure in the study area. This paper presents the indoor and outdoor background gamma radiation level, the annual effective dose equivalent rate (AEDE) and the excess life time cancer risk (ELCR) for the occupationally exposed and non-occupationally exposed workers working and living within Sheda Science and Technology Complex, Sheda and the general public living around the complex.

MATERIALS AND METHODS

*Study Area***:** This study was conducted in and around the Sheda Science and Technology Complex (SHESTCO), Abuja. It is located 70 km from the capital city Abuja. SHESTCO is located on Latitude 8^0 N and Longitude 7^0 E. The study area was delineated into 3 zones for easy coverage in the measurement with zone 1 and zone 2 classified as working area while zone 3 include both working and residential area as shown in Table 1.

*Instrumentation***:** An in-situ approach of background radiation measurement was adopted and preferred to enable samples maintain their original environmental characteristics. A portable Dose rate meter, Radiagem 2000 was used for the measurement. The Radiagem 2000 portable Dose rate Meter is an excellent, portable multipurpose radiation meter for a wide range of applications.it is a survey meter that includes an energy-compensated Geiger-Muller tube that measures the dose equivalent. It is especially designed for situations where accurate measurements at low dose rate levels are of importance. The assessment was achieved using a factory calibrated Radiagem 2000 portable survey meter (SN: 4423, Canberra, France). The monitor was suspended in air at one meter above the ground level. Readings were obtained between the hours of 1200 and 1600 hours since the exposure rate meter has a maximum response to environmental radiation within these hours as recommended by NCRP (1976). Five readings were taken at each indoor and outdoor location and the mean values were recorded.

Table 1: Location and Classification of study area

S/N	Location	Code	Classification
ZONE 1			
1	Gamma Irradiation Facility	GIF	working
2	Central Workshop	CWS	Working
3	Radioactive Waste management Facility	RWM	Working
4	New Instrumentation Laboratory	NIL	Working
5	Old Shestco Administrative Building	OSA	Working
6	Power Supply Station	PSS	Working
ZONE 2			
7	Warehouse	WHE	Working
8	New Shestco Administrative Building	NSA	Working
9	Researchers' Hostel and Conference Centre	RCC	Working
10	Staff Clinic	SFC	Working
11	Recreational Centre	RLC	Working
12	Gate House	GEH	Working
ZONE 3			
13	Chemistry Advanced Laboratory	CAL	Working
14	Physics Advanced Laboratory	PAL	Working
15	Biotechnology Advanced Laboratory	BAL	Working
16	Staff Quarters 1	SQ1	Residential
17	Staff Quarters 2	SQ2	Residential
18	Staff Quarters 3	SQ3	Residential

Radiation Health Risk Assessment: Different known radiation health hazard indices analysis is been use in radiation studies to arrive at a better and safer conclusion on the health status of a radiated or irradiated person and environment (Avwiri *et al*., 2012).

Equivalent Dose: The indoor and outdoor data obtained from the in situ measurement for the three zones within the study area were processed for mean value by adding up all the raw data obtained for each location and divided by the number of data taken to get the mean value for the location.

Annual Equivalent Dose (AEDR): The mean equivalent dose rate in μSv/h obtained from the processing of the in-situ measurement was used to calculate the corresponding annual equivalent dose rate in mSv/y using the mathematical relation given by (Tayyeb *et al*., 2012)

AEDR (mSv/y) = δ x μ x 24 x 365 x 10^{-3} (1)

Where: δ = Equivalent dose rate in micro Sievert per hour. μ= Occupancy factor

Hence for the calculation of the indoor and Outdoor of the annual equivalent dose rate we use the equations below
Annual Indoor Equivalent Dose Rate (mSv/y) = Indoor Equivalent dose rate (μSv/h) × 8760 (h/y) × 0.8 (indoor occupancy factor) × 0.001 (2)

Annual Outdoor Equivalent Dose Rate (mSv/**y) =** Outdoor Equivalent dose rate (μSv/h) × 8760 (h/y) × 0.2 (Outdoor occupancy factor) × 0.001 (3)

Annual Effective Dose Equivalent (AEDE): Radiation absorbed dose is a measure of the amount of energy absorbed per unit mass. It quantifies the radiation energy that might be absorbed by a potentially exposed individual as a result of a specific exposure. For whole body exposure, the quantity effective dose equivalent is used to measure the whole body absorbed dose. The annual effective dose equivalent (AEDE) is used in radiation assessment and protection to quantify the whole body absorbed dose per year. To estimate the AEDE the conversion factor (0.7 Sv/Gy) from absorbed dose rate in air in nGy/h to effective dose rate in mSv/y is used with indoor occupancy factor of 0.8 and outdoor occupancy factor of 0.2. The AEDE was calculated using the following formulae (UNSCEAR, 2000, Etuk et al., 2017):

AEDE (Indoor) (mSv/y) = D_{in} (nGy/h) x 8760 (h) x 0.8 x 0.7 Sv/Gy x 10^{-3} (4)

Where

$$D_{in}\left(\frac{nGy}{h}\right) = \frac{EDRI\ x\ (\mu S/y)\ x\ 10^{-3}}{Q} \qquad (5)$$

Similarly,
AEDE (Outdoor) (mSv/y) = D_{out} (nGy/h) x 8760 (h) x 0.2 x 0.7 Sv/Gy x 10^{-3} (6)

Where,

$$D_{out}\left(\frac{nGy}{h}\right) = \frac{EDRO\ x\ (\mu S/y)\ x\ 10^{-3}}{Q} \qquad (7)$$

Where Q is the quality factor which equals unity

Excess Lifetime Cancer Risk (ELCR): This gives the probability of developing cancer over a lifetime at a given exposure level. The ELCR has been calculated using the following equation (Darwish et al., 2015):

ELCR = AEDE x DL x RF (8)

Where DL is the duration of life (70 years average) and RF is the risk factor (Sv) i.e. fatal cancer risk per Sievert. For stochastic effects, the ICRP 106 used a value of RF = 0.05 for the public

Hence for the calculation of the Indoor and Outdoor ELCR we use the equations below

ELCR (indoor) = AEDE (indoor) x DL x RF (9)

ELCR (outdoor) = AEDE (outdoor) x DL x RF (10)

Effective dose rate (D_{organ}) to different body organs and tissues: The effective dose to organs (D_{organ}) estimates the amount of radiation dose intake to various body organs and tissues. The effective dose rate delivered to a particular organ can be calculated using the following relation (Darwich et al., 2015):
D_{organ} (mSv y^{-1}) =AEDE x F (11)

For the Indoor and Outdoor D_{organ} we use,

D_{organ} (mSv y^{-1}) = O x AEDE x F (12)

Where O is the occupancy factor 0.2 (indoor) and 0.8 (outdoor) and F is the conversion factor of organ dose from air dose.

RESULTS AND DISCUSSION

Equivalent Dose: The indoor and outdoor data obtained from the in situ measurement for the three zones within the study area were processed for mean value by adding up all the raw data obtained for each location and divided by the number of data taken to get the mean value for the location. The result is as shown in Tables 1-4.

Annual Equivalent Dose: The Annual Equivalent Dose rate for the three zones is shown in shown in (Tables 1-3). A summary of the Annual Equivalent Dose rate (Table 4) shows that the Indoor dose rate ranges from 0.102±0.021 μSv/h to 0.134±0.024 μSv/h with a mean of 0.113±0.022 μSv/h and Outdoor dose rate ranges from 0.062±0.021 μSv/h to 0.083±0.005 μSv/h with a mean of 0.071±0.016 μSv/h. These values are below the standard background radiation of 0.133 μSv/h.

Annual Effective Dose Equivalent (AEDE): The AEDE for the three zones is shown in shown in (Tables 1-3) and a comparison with the internationally recommended limit is shown in Figure 1. A summary of the AEDE (Table 4) shows that the Indoor AEDE ranges from 0.502±0.101 mSv/y to 0.656±0.120 mSv/y with a mean of 0.556±0.109 mSv/y and Outdoor AEDE ranges from 0.076±0.026 mSv/y to 0.101±0.006 mSv/y with a mean of 0.087±0.020 mSv/y. These values are lower than the ICRP recommended limits of 1.0 mSv/y for the public and 20 mSv/y for occupationally exposed workers. This indicates that the studied areas are in good agreement with permissible limit and do not constitute any immediate radiological health effect on the workers and the general public due to background ionizing radiation (BIR) exposure. However, periodic assessment of activity concentration of natural radionuclides and BIR levels in the study area should be carried out in order to ensure that exposure to radiation within the areas is kept to as low as reasonably achievable.

Excess Lifetime Cancer Risk (ELCR): The excess lifetime cancer risk is used in radiation protection assessment to predict the probability of an individual developing cancer over his lifetime due to low radiation dose exposure, if it will occur at all. The ELCR for the three zones is shown in shown in (Tables 1-3) and a comparison with world average shown in Figure 2. A summary of the ELCR (Table 4) shows that the Outdoor ELCR ranges from 0.266 x 10^{-3} to 0.355 x 10^{-3} with a mean of 0.304 x 10^{-3} which is 1.05 times higher than the world's average of 0.29 x 10^{-3} (Qureshi et al., 2014). The Indoor ELCR ranges from 1.756 x 10^{-3} to 2.295 x 10^{-3} with a mean of 1.945 10^{-3} which is 1.68 times higher than the world's average of 1.16 x 10^{-3} (Qureshi et al., 2014). The total (ELCR) ranges from 2.075 10^{-3} to 2.0561 x 10^{-3} with a mean of 2.249 x 10^{-3} which is 1.55 times higher than the world's average of 1.45 x 10^{-3} (Qureshi et al., 2014). These low values for excess lifetime cancer risk indicates that the probability of cancer development by workers and residents who wish to spend all their life time in the area is very low. The ELCR values reported in this study are lower than those reported for industrial areas of Warri and Effurun, Delta State, Nigeria (Agbalagba. 2017), and also lower than those for the salt lake environment of Okposi Okwu and Uburu of Ebonyi State, Nigeria (Avwiri et al., 2016). It is also lower than the values from Emene Industrial Layout, Enugu (Ugbede and Benson, 2018), highly populated motor parks in Enugu State, Nigeria (Benson and Ugbede, 2018), Unity park, Uyo, Akwa Ibom state, Nigeria (Etuk et al., 2017) and river sediments from Northern Pakistan (Qureshi et al, 2014).

Effective dose rate (D_{organ}) to different body organs and tissues: The result of the effective dose rate delivered to the different organs is presented in Figure 3, with the F values for Lungs, Ovaries, Bone marrow, Testes, Kidneys, Liver and Whole body as 0.64, 0.58, 0.69, 0.82, 0.62, 0.46 and 0.68 respectively**,** obtained from ICRP [1996]. The estimated average D_{organ} values for the lungs, ovaries, bone marrow, testes, kidney, liver and whole body due to radiation exposure and inhalation in the study area are 0.071, 0.064, 0.077, 0.091, 0.069, 0.051, 0.076 for indoor and 0.045, 0.040, 0.048, 0.057, 0.043, 0.032, 0.047 for outdoor respectively. These results are all below the international tolerable limits of 1.0 mSv/y (Agbalagba, 2017, Ugbede and Benson, 2018) which further shows that the radiation levels do not constitute any immediate health effect on workers and residents of the study area. From the results, it is concluded that the testes and liver have highest and lowest sensitivity to radiation respectively for indoor and outdoor. The relatively higher dose to the testes and low dose intake to the liver is justifiable from food nutrient absorption rate (Zaid et al., 2010). This show that the impact of exposure to BIR levels in the study area contributes insignificantly to the radiation dose to these organs of the adult. Similar conclusion has also been made by Darwish et al. (2015), Agbalagba (2017) and Ugbede and Benson, (2018).

Table 1: Measured indoor and Outdoor Dose Rate and Calculated Hazard Indices in Zone (1)

	Location Code	AIDR (μSv/h)	AODR (μSv/h)	AEDI mSv/y	AEDO mSv/y	AEDEI (mSv/y)	AEDEO (mSv/y)	ELCRI ($x10^{-3}$)	ELCRO ($x10^{-3}$)
1	GIF	0.090	0.080	0.631	0.140	0.4415	0.0981	1.5453	0.3434
2	CWS	0.090	0.080	0.631	0.140	0.4415	0.0981	1.5453	0.3434
3	RWM	0.090	0.080	0.631	0.140	0.4415	0.0981	1.5453	0.3434
4	NIF	0.102	0.082	0.715	0.144	0.5004	0.1006	1.7513	0.3520
5	OSA	0.099	0.082	0.692	0.144	0.4847	0.1006	1.6964	0.3520
6	PSS	0.143	0.092	1.002	0.161	0.7015	0.1128	2.4553	0.3949
	Mean Value	0.102±0.021	0.083±0.005	0.717±0.144	0.145±0.144	0.502±0.101	0.101±0.006	1.756	0.355

AIDR = Average Indoor Dose Rate, AODR = Average outdoor Dose Rate, AEDI = Annual Equivalent Dose (Indoor); AEDO = Annual Equivalent Dose (Outdoor), AEDEI = Annual Effective Dose Equivalent indoor; AEDEO = Annual Effective Dose Equivalent outdoor; ELCRI = Excess Lifetime Cancer Risk indoor, ELCRO = Excess Lifetime Cancer Risk outdoor,

Table 2: Measured indoor and Outdoor Dose Rate and Calculated Hazard Indices in Zone (2)

	Location Code	AIDR (µSv/h)	AODR (µSv/h)	AEDI mSv/y	AEDO mSv/y	AEDEI ıSv/y)	AEDEO (mSv/y)	ELCRI ($x10^{-3}$)	ELCRO 0^{-3})
1	WHE	0.110	0.090	0.771	0.158	0.5396	0.1104	1.8887	0.3863
2	NSA	0.144	0.056	1.009	0.098	0.7064	0.0687	2.4724	0.2404
3	RHC	0.176	0.080	1.233	0.140	0.8634	0.0981	3.0218	0.3434
4	SFC	0.120	0.032	0.841	0.056	0.5887	0.0392	2.0604	0.1374
5	RLC	0.132	0.064	0.925	0.112	0.6475	0.0785	2.2664	0.2747
6	GHE	0.120	0.050	0.841	0.088	0.5887	0.0613	2.0604	0.2146
	Mean values	0.134±0.024	0.062±0.021	0.937±0.167	0.109±0.037	0.656±0.120	0.076±0.026	2.295	0.266

Table 3: Measured indoor and Outdoor Dose Rate and Calculated Hazard Indices in Zone (3)

	Location Code	AIDR (µSv/h)	AODR (µSv/h)	AEDI mSv/y	AEDO mSv/y	AEDEI (mSv/y)	AEDEO (mSv/y)	ELCRI ($x10^{-3}$)	ELCRO ($x10^{-3}$)
1	CAL	0.090	0.034	0.631	0.060	0.4415	0.0417	1.5453	0.1459
2	PAL	0.130	0.098	0.911	0.172	0.6377	0.1202	2.2320	0.4207
3	BAL	0.080	0.060	0.561	0.105	0.3924	0.0736	1.3736	0.2575
4	SQ1	0.115	0.085	0.806	0.149	0.5641	0.1042	1.9745	0.3649
5	SQ2	0.084	0.056	0.589	0.098	0.4121	0.0687	1.4422	0.2404
6	SQ3	0.124	0.075	0.869	0.131	0.6083	0.0920	2.1290	0.3219
	Mean values	0.104±0.022	0.068±0.023	0.728±0.153	0.119±0.040	0.509±0.107	0.083±0.028	1.783	0.292

Table 4: Summary of Measured indoor and Outdoor Dose Rate and Calculated Hazard Indices for the three Zones

Location Code	AIDR (µSv/h)	AODR (µSv/h)	AEDI mSv/y	AEDO mSv/y	AEDEI (mSv/y)	AEDEO (mSv/y)	ELCRI ($x10^{-3}$)	ELCRO ($x10^{-3}$)	TOTAL ELCR
ZONE 1	0.102±0.021	0.083±0.005	0.717±0.144	0.145±0.144	0.502±0.101	0.101±0.006	1.756	0.355	2.111
ZONE 2	0.134±0.024	0.062±0.021	0.937±0.167	0.109±0.037	0.656±0.120	0.076±0.026	2.295	0.266	2.561
ZONE 3	0.104±0.022	0.068±0.023	0.728±0.153	0.119±0.040	0.509±0.107	0.083±0.028	1.783	0.292	2.075
Mean	0.113±0.022	0.071±0.016	0.794±0.155	0.0.124±0.074	0.556±0.109	0.087±0.020	1.945±0.379	0.304±0.104	2.249±0.271

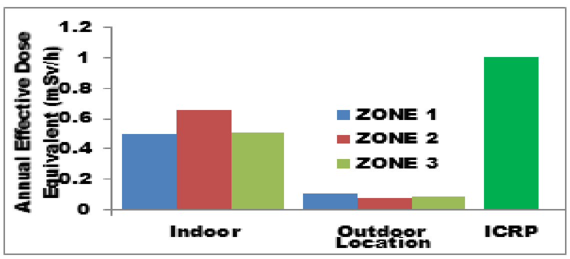

Fig 1: Annual Effective Dose Equivalent for Indoor and Outdoor for the three Zones

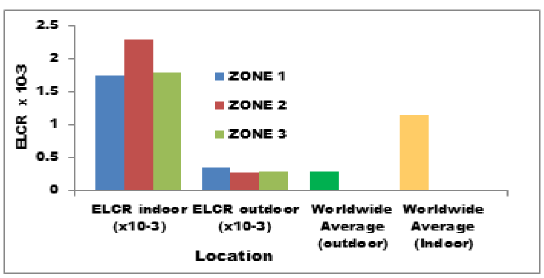

Fig 2: Excess Lifetime Cancer Risk for Indoor and Outdoor

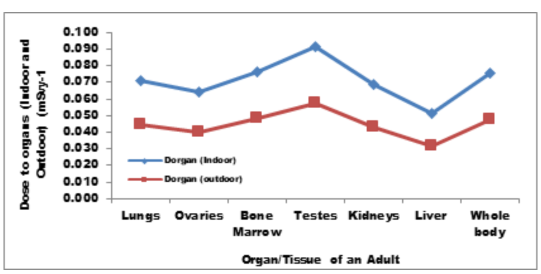

Fig 3: Effective Dose Rate to different Organs/Tissue

Conclusion: The qualitative and quantitative assessment of radiation exposure level and doses within an environment is an important aspect of radiation protection since human exposure to natural background radiation is a continuous and unavoidable feature of human existence. The present study has been designed in this regard to quantitatively assess the indoor and outdoor background radiation levels around Sheda Science and Technology Complex (SHESTCO) and its environ and to estimate their radiological impact on the workers, residents and the environment. The radiological assessment shows that the study area does not constitute any immediate radiological health effect on the workers and the general public due to BIR exposure. We recommend that a periodic assessment of activity concentration of natural radionuclides and BIR levels in the study area should be carried out to keep the radiation level to as low as reasonably achievable.

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