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Original Research Article

Assessment of background ionizing radiation exposure levels in industrial buildings in Nnewi, Anambra State, Nigeria

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ABSTRACT

Background: Increased exposure from background radiations and the attendant health effects have in recent times drawn the attention of researchers. This study aimed to assess the indoor and outdoor background radiation levels in selected offices/industrial buildings in Nnewi, Anambra State, Nigeria.
Methods: Forty buildings in the four villages of Nnewi were surveyed using a calibrated international medicom CRM 100 radiation monitor. Radiation readings were obtained in counts per minute and converted to micro-sieverts per hour (µSv h-1). The indoor annual effective dose rate (IAEDR), outdoor annual effective dose rate, excess lifetime cancer risk, and organ doses were calculated using recommended occupancy and conversion factors.
Results: The mean IAEDR and OAEDR were respectively 0.8060±0.056 mSv y-1 and 0.2281±0.020 mSv y-1 with estimated ELCR of 2.822×10^{-3} and 0.799×10^{-3} respectively. The testes received the highest dose (0.843 mSv y-1) followed by bone marrow (0.710 mSv y-1).
Conclusions: The study revealed that the mean background radiation exposures in and outside offices in Nnewi, Anambra State were below the UNSCEAR and ICRP recommended doses for the general public.

Keywords: Annual effective dose rate, Background ionizing radiation, Indoor and outdoor, Offices/industrial buildings

INTRODUCTION

Man is exposed to radiation emitted from natural and man-made sources. The radiation contribution from these natural and artificial sources constitutes the background radiation. The total radiation dose taken at a location is recorded as background radiation if no specified radiation source is available.[1] The sources of background radiations include cosmic radiations (primary and secondary), terrestrial radiations (from natural radium, uranium, and thorium and their decay products; radon gas which is the largest natural source of radiation exposure to human beings) internal radiations (radioactivity in the body) and artificial or man-made sources such as from medical exposure, weapon testing, nuclear technologies and use of office equipment. An increase in the use of technological equipment in offices can also increase the background radiation levels.[2,3] Humans are inevitably exposed to background radiations both in work and public environments.[4] The level of exposure varies depending on latitude and longitude. According to Chad-Umorem et al chronic exposure to even low dose rates of nuclear radiations from an irradiated building has the potential to induce cytogenetic damage in human beings. In certain situations where the level exceeds the known average dose, the introduction of health protection measures needs to be considered.[5]

Increased exposure from background radiations and the attendant health effects have in recent times drawn the attention of researchers. Studies have shown exposure to indoor radon to be of greatest concern.[6-9] Apart from lung cancer, exposure to radon can lead to bronchial epithelial cancer, kidney cancer, bone marrow cancer and even stomach cancer due to radon in drinking water.[10] Positive association exists between radon exposure and leukaemia, multiple myeloma and chronic lymphocytic leukaemia with the highest mortality rate occurring among cigarette smokers.[11-14]

According to UNSCEAR report, the worldwide average annual effective dose from natural background radiation is 2.4 mSv.[15] The level is especially high in mines. It is observed that high levels of exposure from background radiation can also occur in areas other than mines and can reach such a level that cannot be ignored from the point of view of radiation protection.[6] Consequently, UNSCEAR classified the annual effective dose rate into four levels, namely, low: 5 mSv y-1 and below (or about twice the global average of 2.4 mSv y-1) , medium (5 – 20 mSv y-1), high: (20 – 50 mSv y-1) and very high: (> 50 mSv y-1).[6]

Background radiation levels have been established in many countries. In India and China, background radiation was reported to contribute about 2.29 mSv y-1 (96.7%) of the total annual effective dose of 2.393 mSv y-1.[16] In Greece, Stoulos et al[9] obtained a mean background exposure dose of 0.5 mSv y-1 and a mean radon exhalation rate of 3.24 Bq m-3 h-1. In Nigeria, many studies have been conducted to determine background radiations level and results from these studies showed variations in the levels of background radiation doses among states and different locations within a state.[17-27] From the literature search there was no study on background radiation exposure levels for Nnewi and Anambra State. This study aimed to assess the indoor and outdoor background ionizing radiation levels in selected industrial buildings in Nnewi North local government area of Anambra State, Nigeria and to estimate the excess lifetime cancer risks to the inhabitants.

METHODS

This was a cross-sectional survey conducted from August 2018 to September 2019 at Nnewi North local government area (LGA) located between Latitude 6.010 and 6.02^0 North and Longitude 6.95^0 and 6.91^0 East. Consent of the management of the Institutions studied was also obtained. Nnewi has a land area of about 1,076.9 square miles (2, 789 Km2) with a population of about 500, 000 in 2010.[28]

A total of sample size of 40 offices included this study was derived from the formula of unknown population given below;

$$n = Z\alpha 2pq \div d^2$$

Where, n=expected sample size, Zα=significant level usually set at 95% confidence level, Zα is 1.96 (two sided), p =proportion of the population with similar attributes under study=50% (0.5), d=margin of error tolerated or absolute error = 15.5% (0.155), q= 1-p=1-0.5 =0.5, Thus n was calculated to be ≈ 40.

Ten largest-sized buildings with more business activities and a higher population of people in each of the four villages namely Otolo, Uraugu, Nnewi-Ichi, and Umudim that make up of Nnewi-North L.G.A (Figure 1), were selected using a stratified random sampling technique. The indoor and outdoor background radiation measurements of the selected buildings were taken using a well-calibrated International medicom CRM-100 digital radiation monitor (serial no.: 01697). The meter was calibrated at the National institute of radiation protection and research, university of Ibadan, Nigeria. This is a Nigerian secondary standard laboratory and a division of the Nigeria nuclear regulatory authority (NNRA) and certified by the International atomic energy agency (IAEA).

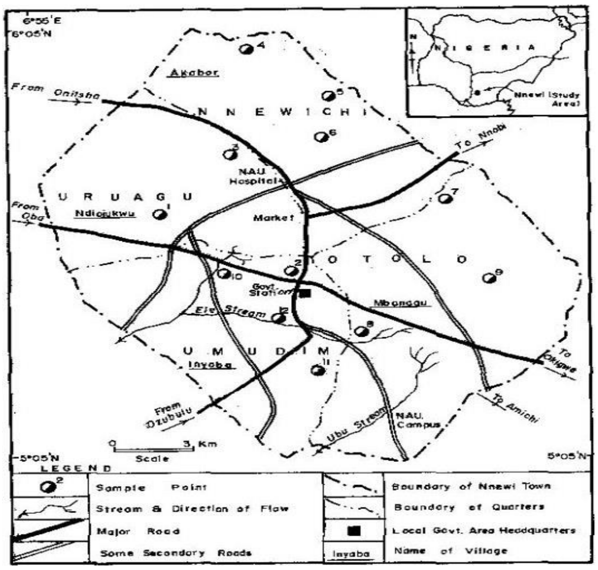

Figure 1: Map of Nnewi showing the four villages covered by the study.

The background radiation readings obtained in Counts per minute CPM was converted to µSv h-1 using the relation: (10 CPM = 0.10 µSv h-1 that is, 100 CPM = 1 µSv h-1 (CRM-100 guide). The radiation meter has a maximum response to environmental radiation during the hours of 1300 to 1600 hence the readings were taken during this period for optimum results.[29] The value of readings obtained and other details for each building were recorded in a purpose data capture sheet.

Radiation measurement procedure

An in situ background radiation measurement approach was adopted. The radiation measurements were made following standard procedure.[29] The readings were taken during working hours with the workers performing their usual daily work. For the indoor measurements, the radiation survey meter was held at a height of 1.0 meter above the floor and from the wall at each location. Four readings were taken at each point facing the wall of the room/apartment and the average recorded. The procedure was carried out for each of the four walls in turn. A similar procedure was used for the outdoor measurements but ensuring that the measurement location was as far as possible from the fence or wall of other nearby buildings. For each outdoor measurement location, three readings were taken and the average recorded. The relevant conversion was then done. The indoor annual effective dose rate (IAEDR) and the outdoor annual effective dose rate (OAEDR)(in mSv y-1) were computed using the respective recommended indoor and outdoor occupancy factors of 0.8 and 0.2.[15] The hourly dose rate (µSv h-1) was converted to the annual dose rate (mSv y-1) as in equations 1, 2, and 3.

$$\text{Annual dose rate (mSv y-1)} = X\ (\mu\text{Sv h-1}) \times T \times OF$$

Where; X=hourly dose rate, T=total number of hours in a year (8760 hrs) and OF=occupancy factor (indoor = 0.8 and outdoor=0.2). Based on 24 hours a day and 365 days in a year; the number of hours in a year was 24 x 365 = 8760 hours.

Hence:

$$\text{AIEDR (mSv y-1)} = X\ (\mu\text{Sv h-1}) \times 8760 \times 0.8 \times 10^{-3}$$

$$\text{AOEDR (mSv y-1)} = X\ (\mu\text{Sv h-1}) \times 8760 \times 0.2 \times 10^{-3}$$

The excess lifetime cancer risk, ELCR ($\times 10^{-3}$) was computed using below equation.[30]

$$\text{ELCR} = \text{AEDR} \times \text{DL} \times \text{RF}$$

Where; AEDR=total average annual effective dose (mSv y-1), DL=average duration of life (70 years), RF=risk factor per Sv. (RF=0.05 for public, stochastic effects), ELCR=a term used to estimate the difference between the proportion of persons who will develop or die of cancer (per sievert) in an exposed population compared to the people in a similar population that were not exposed to radiation.

Radiation doses to some body organs/tissues such as the lungs, ovaries, bone marrow, testes, kidneys, liver and whole body due to inhalation were computed using equation mentioned below.

$$\text{Dorgan (mSv y-1)} = \text{AEDR(mSv y-1)} \times \text{CF}$$

Where; CF = the conversion factor of organ doses from air dose and CF = 0.64 for the lungs, 0.58 for ovaries, 0.69 for bone marrow, 0.82 for testes, 0.62 for kidneys, 0.46 for live and 0.68 for whole body.[31-32]

Statistical analysis

Data were analyzed using statistical package for social sciences (SPSS) version 21.0 (SPSS Inc. Chicago IL, USA). Descriptive statistics such as mean, standard deviations, tables, and charts were used for statistical analysis.

RESULTS

The total mean indoor and outdoor background ionizing radiation levels, annual effective dose rate and excess life cancer risk (ELCR) for office buildings in Otolo village Nnewi were highest in the Auditorium (0.2901±0.030 µSv h-1, 1.92±0.015 mSv y-1, and 2.086x10^{-3} per sievert respectively) and least in the Cafeteria (0.1801±0.020 µSv h-1, 0.7360±0.025 mSv y-1 and 1.288x10^{-3} per sievert respectively)(Table 1).The total mean indoor and outdoor background ionizing radiation levels, annual effective dose rate and excess life cancer risk (ELCR) of office buildings in Uruagu village Nnewi were highest at Keystone bank (0.3002±0.030 µSv h-1, 1.2097±0.158 mSv y-1 and 2.117 x 10^{-3} per sievert respectively) and least at First bank (0.2001 ±0.022 µSv h-1, 0.8241±0.049 mSv y-1 and 1.443 x 10-3 per sievert respectively)(Table 2).

The total mean indoor and outdoor background ionizing radiation levels, annual effective dose rate, and excess lifetime cancer risk (ELCR) of office buildings in Nnewi-Ichi Village Nnewi were highest at wave diagnostics Lab (0.2500±0.021 µSv h-1, 1.1738±0.077 mSv y-1 and 2.055x10^{-3} per sievert respectively) and least at NAUTH Staff Canteen (0.1602±0.002 µSv h-1, 0.6492±0.009 mSv y-1 and 1.136x10^{-3} per sievert respectively)(Table 3). The total mean indoor and outdoor background ionizing radiation levels, annual effective dose rate, and excess lifetime cancer risk (ELCR) of office buildings in Umudim village Nnewi were highest at FRSC license office block (0.3500±0.050 µSv h-1, 1.5068±0.245 mSv y-1 and 2.637 x 10-3 per sievert respectively) and least at LGA Sec. Block C (0.2002±0.002 µSv h-1, 0.8243±0.009 mSv y-1 and 1.443x10^{-3} per sievert respectively)(Table 4). The mean of IAEDR, OAEDR and AEDR for Otolo were (0.8410±0.007 mSv y-1, 0.2620±0.022 mSv y-1 and 1.0820±0.079 mSv y-1), (0.8550±0.072 mSv y-1, 0.2296±0.025 mSv y-1 and 1.0850±0.025 mSv y-1), (0.7291± 0.046 mSv y-1, 0.2000±0.010 mSv y-1 and 0.9289±0.056 mSv y-1) and (0.8200±0.046 mSv y-1, 0.0208±0.021 mSv y-1 and 1.0411±0.068 mSv y-1) for

Otolo, Uruagu, Nnewi-ichi and Umudim villages each respectively, (Figure 2) while the ICRP (1990) and UNSCEAR (2008) recommended annual dose level are 1.0 mSv y-1 and 2.4 mSv y-1 respectively.

Table 1: Mean indoor and outdoor background ionizing radiation levels, annual effective dose rate (IAEDR and OAEDR) and excess lifetime cancer risk for office buildings in Otolo village, Nnewi.

Name of office	Mean±SD Indoor dose rate ($\mu Sv\ h^{-1}$)	IAEDR ($mSv\ y^{-1}$)	ELCR ($x\ 10^{-3}$)	Mean±SD Outdoor dose rate ($\mu Sv\ h^{-1}$)	OAEDR ($mSv\ y^{-1}$)	ELCR ($x10^{-3}$)	Total Mean±SD radiation level (IDR and ODR) ($\mu Sv\ h^{-1}$)	Total AEDR (IAEDR and ODAEDR) ($mSv\ y^{-1}$)	Total mean ELCR ($x10^{-3}$)
Office block, FHST, CHS NAU	0.1301± 0.020	0.9120± 0.140	3.192	0.1500± 0.010	0.2628± 0.018	0.920	0.2801± 0.03	1.1748± 0.158	2.056
Lecture hall block FHST, CHS NAU	0.1200± 0.001	0.8410± 0. 007	2.944	0.1501± 0.021	0.2630± 0.037	0.920	0.2701± 0.022	1.1040± 0.440	1.932
ETF lab, CHS NAU	0.1200± 0.00	0.8410± 0. 00	2.943	0.1302± 0.020	0.2279± 0.035	0.798	0.2502± 0.020	1.0690± 0.035	1.871
Auditorium, CHS, NAU	0.1300± 0.010	0.9110± 0.070	3.189	0.1601± 0.020	0.2805± 0.035	0.982	0.2901± 0.030	1.192± 0.015	2.086
Cafeteria, CHS, NAU, Okofia	0.0800± 0.010	0.5610± 0.007	1.962	0.1001± 0.010	0.1754± 0.018	0.614	0.1801± 0.020	0.7360± 0.025	1.288
Bch. lab, CHS, NAU	0.1200± 0.001	0.8410± 0.070	2.943	0.1501± 0. 020	0. 2630± 0.035	0.920	0.2701± 0.021	1.1040± 0.042	1.932
CHS, NAU library, Okofia	0.1100± 0.010	0.7709± 0.070	2.698	0.1300± 0.010	0.2278± 0.018	0.797	0.2400± 0.020	0.999± 0.088	1.748
Anatomy block, CHS, NAU	0.1201± 0. 011	0.842± 0. 077	2.946	0.1401± 0. 012	0.2455± 0.021	0.859	0.2602± 0.023	1.0880± 0.098	1.903
Physiology-block, CHS, NAU	0.1200± 0.002	0.841± 0.140	2.943	0.1502± 0. 002	0.2632± 0.004	0.921	0.2702± 0. 022	1.1042± 0.144	1. 932
Family care hospital Obiuno	0.1200± 0.001	0.8410± 0.007	2.943	0.1001± 0.001	0.1754± 0.002	0.614	0.2201± 0.002	1. 0164± 0. 009	1. 780
Mean±SD	0.1170± 0.008	0.8200± 0.059	2.87± 0.207	0.1502± 0.014	0.2620± 0.022	0.896± 0.078	0.2531± 0.021	1.0820± 0.079	1.850± 0.078

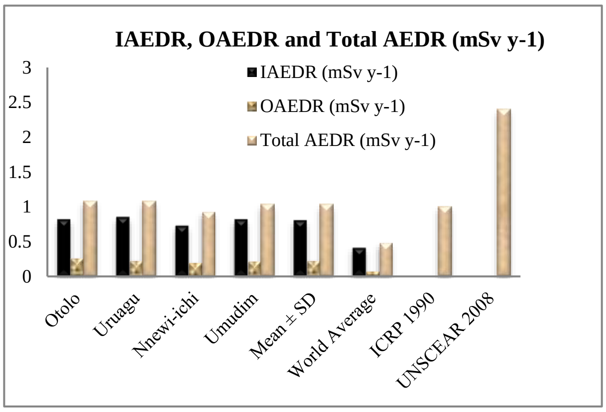

Figure 2: Annual indoor, outdoor and total effective dose rates ($mSv\ y^{-1}$) for Nnewi villages compared with recommended values.

The testes have the highest mean AEDR of 0. 843±0.021 mSv y-1 and ELCR of 2. 951 x 10-3 while the liver has the least AEDR of 0.473±0.012 mSv y-1 with ELCR of $1.656x10^3$. The overall AEDR to the four villages was 1.0284±0.103 mSv y-1 with ELCR of 3.599±0. $361x10^{-3}$ per sievert (Table 5).

DISCUSSION

In this study, the indoor annual effective dose rate (IAEDR) and the outdoor annual effective dose rate (OAEDR) were respectively computed and the result revealed that the IAEDR was significantly higher than the OAEDR for all the villages ($p<0.05$). This could be attributed to contributions from anthropogenic sources and also attenuation of the radiation by the materials used for the buildings. Among the villages, Uruagu has the highest background radiation level, which could be ascribed to the electronic devices used in the numerous financial institutions in Uruagu village when compared to other villages. This implies that inhabitants of this Uruagu village are likely to be at greater risk of cancer.

Table 2: Mean indoor and outdoor background ionizing radiation levels, annual effective dose rate (IAEDR and OAEDR) and excess lifetime cancer risk for office buildings in Uruagu village, Nnewi.

Name of office	Mean±SD Indoor dose rate (μSv h^{-1})	IAEDR (mSv y^{-1})	ELCR ($x10^{-3}$)	Mean±SD Outdoor dose rate (μSv h^{-1})	OAEDR (mSv y^{-1})	ELCR (x 10^{-3})	Total Mean±SD Radiation level (IDR and ODR) (μSv h^{-1})	Total AEDR (IAEDR and ODAEDR) (mSv y^{-1})	Total mean ELCR ($x10^{-3}$)
FCMB	0.1400± 0.010	0.9811± 0.07	3.434	0.0800± 0.001	0.1402± 0.002	0.491	0.2200± 0.011	1.1213± 0.072	1.963
Keystone bank	0.1301± 0.010	0.9117± 0.14	3.191	0.1701± 0. 010	0.2980± 0.018	1. 043	0.3002± 0. 030	1.2097± 0.158	2.117
First bank	0. 0901± 0. 002	0.6314± 0. 014	2.210	0.1100± 0.020	0.1927± 0. 035	0.675	0.2001± 0.022	0.8241± 0.049	1.443
GT Bank	0.1201± 0. 010	0.8417± 0. 07	2. 946	0. 1800± 0. 030	0. 3154± 0. 053	1. 104	0.3001± 0.040	1.1571± 0. 123	2.025
Diamond bank	0.1301± 0.010	0.9117± 0.07	3.191	0.1300± 0.010	0.2278± 0.018	0.797	0.2601± 0.020	1.1395± 0.088	1.994
Access bank	0.1200± 0.001	0.841± 0.007	2. 943	0.1500± 0.020	0.2628± 0.035	0. 920	0.2700± 0.021	1.1038± 0.042	1. 932
Fire serv. /machine part	0.1300± 0.010	0.911± 0.070	3. 189	0. 0801± 0.001	0.1403± 0.002	0.491	0.2101± 0. 001	1.0513± 0.072	1. 840
Staff Room AGSS	0.1100± 0.010	0.7709± 0.07	2.698	0.1300± 0. 010	0.2278± 0. 018	0.797	0.2400± 0.020	0.9987± 0.088	1.748
SS2, AGSS	0.1300± 0.020	0.911± 0.014	3.189	0.1200± 0. 020	0.2102± 0.035	0. 736	0.2500± 0. 040	1.1212± 0.175	1.963
Admin block AGSS	0.1200± 0.010	0.841± 0. 070	2.943	0.1600± 0. 020	0.2803± 0.035	0.981	0.2800± 0.030	1.1213± 0.105	1.962
Mean±SD	0.1220± 0. 010	0.855± 0.072	2.993±0 . 252	0.1310± 0.014	0.2296± 0.025	0.804 ±0.088	0.2531± 0.025	1.0850± 0.097	1.899± 0. 340

The mean AEDR for the studied buildings is comparable with the IRCP recommended annual limit of 1.0mSv y-1 for the general public but well below the UNSCEAR recommended world average value of 2.4 mSv y-1.[6,30] This implies that the workers and people in those offices are radiologically safe. However, the high mean value of ELCR recorded in this study suggests an increased risk of developing cancer in the long run as a result of chronic exposure. This is more so because commonly consumed food items like rice, yam, garri, bean, groundnuts and vegetables are shown to contain a large concentration of Radium-226, Thorium-232, and Potassium-40[33] which can contribute to raise the ELCR. Compared with the UNSCEAR recommended world IAEDR of 0.41 mSv y^{-1} and OAEDR of 0.072 mSv y^{-1}, the mean IAEDR and OAEDR obtained for the villages in this study was respectively higher than the recommended values.[15] Compared with values from other parts of the world, the average AEDR from this study was greater than values obtained in countries such as Norway (0.15 mSv y^{-1}), Greece (0.5 mSv y^{-1}), Egypt (0.16 mSv y^{-1}), Iran (0.49 mSv y^{-1}) but less than values in China (2.393 mSv y^{-1}), Nairobi (2.763- 4.070 mSv y^{-1}), UK (> 100 mSv y^{-1}; 16 mSv y^{-1}).[9,16,35-42] While the greater AEDR in China and UK could be attributed to their being more industrialized than Nigeria, the greater AEDR values obtained at Nnewi than in countries like Egypt, Iran, Greece, and Norway could be ascribed to the different soil types in the various study areas. Nnewi soil is composed of sandy, silt, and clay in the ratio of 84.82: 2.45: 12.73.[43] It could be that the sandy soil of Nnewi contains large quantities of Uranium-238, Thorium-232, and Radium-226 as these radionuclides are known to contribute significantly to radiation doses.[16] From our study, the average values of IAEDR, OAEDR, and AEDR respectively, were greater than 0.258 mSv y^{-1} at Ibrahim Badamasi Babangida University, Lapai, Niger State Nigeria, 0.189 mSv y^{-1} at Minna in a study of two tertiary institutions, 0.155±0.006 mSv y^{-1} with ELCR of 0.54 x 10^{-3} at Emene industrial layout in Enugu State by Ugbede and Benson, 0.643±0. 115 mSv y^{-1} at Sheda science and technology, Abuja, 0.123 mSv y^{-1} in some Northern and Southern parts of Nigeria by Olalekan et al and 0.16±0.05 mSv y^{-1} at Effurun and Warri city of Delta State, Ezekiel.[17,18,23,45,46]

Table 3: Mean indoor and outdoor background ionizing radiation levels, annual effective dose rate (IAEDR and OAEDR) and excess lifetime cancer risk for office buildings in Nnewi-ichi village, Nnewi.

Name of office	Mean±SD Indoor dose rate (μSv h^{-1})	IAEDR (mSv y^{-1})	ELCR ($x10^{-3}$)	Mean±SD Outdoor dose rate (μSv h^{-1})	OAEDR (mSv y^{-1})	ELCR ($x10^{-3}$)	Total mean±SD radiation level (IDR and ODR) (μSv h^{-1})	AEDR (IAEDR and ODAEDR) (mSv y^{-1})	Total mean ELCR ($x10^{-3}$)
Radiology department NAUTH	0.1200± 0.010	0.8410± 0.070	2.943	0.1300± 0.020	0.2278± 0.035	0.797	0.2500± 0.030	1.0688± 0.105	1.870
Uzodike auditorium NAUTH	0.1101± 0.001	0.7716± 0.007	2.701	0.1200± 0.010	0.2102± 0.001	0.736	0.2301± 0.011	0.9818± 0.025	1.719
NAUTH staff canteen	0.0701 ± 0.001	0.4913± 0.007	1.719	0.0901± 0.001	0.1579± 0.002	0.553	0.1602± 0.002	0.6492± 0.009	1.136
A & E NAUTH	0.1001± 0.001	0.7015± 0.007	2.455	0.0701± 0.001	0.1228± 0.002	0.430	0.1702± 0.002	0.8243± 0. 009	1.443
School of nursing block NAUTH	0.1200± 0.020	0.8410± 0. 140	2.943	0.1300± 0.010	0.2278± 0.018	0.797	0.2500± 0.030	1. 0688± 0.158	1.870
Academic block NAUTH	0.1200± 0.010	0.8410± 0.070	2.943	0.1200± 0.001	0.2102± 0.002	0.736	0.2400± 0.011	1.0512± 0.025	1.840
Physiotherapy clinic NAUTH	0.0801± 0.001	0.5613± 0.007	1.965	0.1100± 0.010	0.1927± 0.018	0.675	0.1901± 0.011	0.7540± 0.025	1.32
CHS medical library	0.0600± 0.001	0.4205± 0.007	1. 472	0.1500± 0.001	0.2628± 0.002	2.;920	0.2100± 0.002	0.6833± 0.009	1.196
HO Qtrs NAUTH	0.1200± 0.001	0.8410± 0.007	2.943	0.1101± 0.001	0.1929± 0.002	0.675	0.2301± 0.002	1. 0339± 0.009	1.809
Waves diagnostic lab	0.1400± 0.020	0.9811± 0.140	3.434	0.1100± 0.001	0.1927± 0.007	0.675	0.2500± 0.021	1.1738± 0.027	2.055
Mean ± SD	0.1040± 0.007	0.7291± 0.046	2.55± 0.162	0.1140± 0.006	0.2000± 0.010	0.699± 0.030	0.2181± 0. 012	0.9289± 0.056	1.626± 0.098

Table 4: Mean indoor and outdoor background ionizing radiation levels, annual effective dose rate (IAEDR and OAEDR) and excess lifetime cancer risk (ELCR) for office buildings in Umudim village, Nnewi.

Name of office	Mean±SD Indoor dose rate (μSv h^{-1})	IAEDR (mSv y^{-1})	ELCR ($x10^{-3}$)	Mean±SD Outdoor dose rate (μSv h^{-1})	OAEDR (mSv y^{-1})	ELCR (x 10^{-3})	Total Mean±SD Radiation level (IDR and ODR) (μSv h^{-1})	Total AEDR (IAEDR and ODAEDR) (mSv y^{-1})	Total mean ELCR ($x10^{-3}$)
FRSC office block	0.1401± 0.010	0.9818± 0.070	3.436	0.1501± 0.010	0.2630± 0.020	0.920	0.2902± 0.020	1.2448± 0.090	2. 178
FRSC licence office block	0.1700± 0.030	1.1914± 0. 210	4.170	0.1800± 0.020	0.3154± 0.035	1.104	0.3500± 0. 050	1.5068± 0.245	2.637
EEDC district office	0.1001± 0.002	0.7015± 0.014	2.455	0.1201± 0.010	0.2104± 0.018	0.736	0.2202± 0.012	0.9119± 0.032	1.596
LGA secret. Block A	0.1101± 0.001	0.7716± 0.007	2.701	0.1000± 0.001	0.1752± 0.002	0.613	0.2101± 0.002	0.9468± 0.009	1.657

Continued.

Name of office	Mean±SD Indoor dose rate (µSv h^{-1})	IAEDR (mSv y^{-1})	ELCR ($x10^{-3}$)	Mean±SD outdoor dose rate (µSv h^{-1})	OAEDR (mSv y^{-1})	ELCR (x 10^{-3})	Total Mean±SD Radiation level (IDR and ODR) (µSv h^{-1})	Total AEDR (IAEDR and ODAEDR) (mSv y^{-1})	Total mean ELCR ($x10^{-3}$)
LGA secret. block B	0.1200± 0. 010	0.8410± 0.070	2.943	0.1000± 0.010	0.1752± 0.020	0.613	0.2200± 0.020	1.0162± 0.090	1.778
LGA secret. block C	0.0901± 0.001	0.6314± 0. 007	2,210	0.1101± 0.001	0.1929± 0.002	0.675	0.2002± 0.002	0.8243± 0.009	1. 443
Chicason office block	0.1200± 0.010	0.8410± 0.070	2.943	0.1500± 0.010	0.2628± 0.020	0.920	0. 2700± 0.020	1.1038± 0.020	1. 932
Innoson office block	0.1100± 0.001	0.7709± 0.007	2.700	0.1300± 0.030	0.2278± 0.053	0.797	0.2400± 0.031	0.9987± 0.060	1. 749
MTN office	0.1200± 0.010	0.8410± 0. 070	2,943	0.1100± 0.010	0.1927± 0.020	0.675	0.2300± 0.020	1.0337± 0.090	1. 809
Airtel office	0.0901± 0.001	0.6314± 007	2.210	0.1101± 0.020	0.1930± 0.035	0.675	0.2002± 0.021	0.8244± 0.042	1. 443
Mean±SD	0.1171± 0.007	0.8200± 0.046	2.871±0. 161	0.1260± 0.012	0.2208± 0.021	0.773± 0.074	0.2430± 0.019	1.0411± 0.068	1.822± 0.231

Table 5: Effective dose to some organs (D_{organ}, mSv y^{-1}) from exposure to background radiation in offices in Nnewi, Anambra State, Nigeria.

Villages	Names of offices	Mean AEDR (mSv y-1)	Lungs	Ovaries	Bone marrow	Testes	Kidneys	Liver	Whole body
OTOLO 6.0085° N 6.9538° E	Office block, FHST, CHS NAU	1.1748± 0.158	0.752	0.682	0.811	0.964	0.729	0.541	0.799
	Lecture hall block FHST, CHS NAU	1.1040± 0.440	0.707	0.640	0.762	0.905	0.685	0.508	0.751
	ETF Lab, CHS NAU	1.0690± 0.035	0.684	0.620	0.738	0.877	0.633	0.492	0.727
	Auditorium, CHS, NAU	1.192± 0.015	0.763	0.691	0.823	0.977	0.739	0.548	0.811
	Cafeteria, CHS, NAU, Okofia	0.7360± 0.025	0.471	0. 427	0.508	0.604	0.456	0.339	0.501
	Bch. Lab, CHS, NAU	1. 1040± 0.042	0.707	0.640	0.762	0.905	0.685	0.508	0.751
	CHS, NAU Library, Okofia	0.999± 0.088	0.640	0.680	0.690	0.820	0.620	0.460	0.680
	Anatomy block, CHS, NAU	1. 0880± 0.098	0.696	0.631	0.751	0.892	0.675	0. 501	0.740
	Physiologyblock, CHS, NAU	1. 1042± 0.144	0. 707	0. 640	0.762	0. 905	0. 685	0. 508	0.751
	Family Care hospital Obiuno	1.0164± 0.009	0. 650	0. 589	0. 701	0. 833	0. 630	0.467	0. 691

Continued.

Villages	Names of offices	Mean AEDR (mSv y-1)	Lungs	Ovaries	Bone marrow	Testes	Kidneys	Liver	Whole body
URUAGU 6.0228º N 6.9142º E	FCMB	1.1213± 0.072	0.717	0.650	0. 774	0. 919	0. 695	0. 516	0. 762
	Keystone bank	1.2097± 0.158	0. 774	0. 702	0. 835	0. 992	0. 750	0. 557	0. 828
	First bank	0.8241± 0. 049	0. 527	0. 478	0. 569	0. 676	0. 511	0. 379	0. 560
	GT Bank	1.1571± 0.123	0. 741	0. 671	0. 798	0. 949	0. 717	0. 524	0. 787
	Diamond bank	1.1395± 0.088	0. 730	0. 661	0. 787	0. 935	0. 707	0. 524	0. 775
	Access bank	1.1038± 0.042	0. 707	0. 640	0. 762	0. 905	0. 685	0. 508	0. 751
	Fire serv. /machine part	1.0513± 0.072	0. 673	0. 610	0. 725	0. 862	0. 652	0. 484	0. 715
	Staff room AGSS	0.9987± 0.088	0.640	0.580	0.690	0. 820	0. 620	0.460	0. 680
	SS2,AGSS	1.1212± 0.175	0. 717	0.650	0.774	0. 919	0. 695	0. 516	0. 762
	Admin block AGSS	1.1213± 0.105	0. 717	0. 650	0. 774	0. 919	0. 695	0. 516	0.762
NNEWI-ICHI 6.0479º N 6.9075º E	Radiology department NAUTH	1.0688± 0.105	0. 684	0. 620	0. 738	0. 877	0. 663	0. 492	0. 727
	Uzodike auditorium NAUTH	0.9818± 0.025	0. 629	0. 570	0. 678	0. 805	0. 609	0. 452	0. 668
	NAUTH staff canteen	0.6492± 0. 009	0. 415	0. 376	0. 448	0. 532	0. 402	0. 299	0. 441
	A & E NAUTH	0.8243± 0.009	0. 527	0. 478	0. 569	0. 676	0. 511	0. 379	0. 560
	School of nursing block NAUTH	1.0688± 0.158	0. 684	0. 620	0. 738	0. 877	0. 663	0. 492	0. 727
	Academic block NAUTH	1.0512± 0. 025	0. 673	0. 610	0. 725	0. 861	0. 652	0. 484	0. 715
	Physio-therapy clinic NAUTH	0.7540± 0.025	0. 483	0. 437	0. 520	0. 618	0. 468	0. 347	0. 513
	CHS medical library	0.6833± 0.009	0. 437	0. 396	0. 471	0. 560	0. 424	0. 314	0. 464
	HO Qtrs NAUTH	1.0339± 0.009	0.662	0. 600	0. 713	0. 848	0. 641	0. 476	0. 703
	Waves diagnostic lab	1.1738± 0. 027	0. 751	0. 681	0. 810	0. 963	0. 728	0. 540	0. 798
UMUDIM 6.0105º N 6. 9103º E	FRSC Office block	1.2448± 0.090	0. 797	0. 722	0. 859	1. 021	0. 772	0. 573	0. 847
	FRSC Licence office block	1.5068± 0.245	0. 965	0. 874	1.040	1.236	0. 934	0. 693	1. 025
	EEDC District office	0.9119± 0.032	0. 584	0. 529	0. 629	0. 748	0. 565	0. 420	0.620
	LGA secret. block A	0.9468± 0.009	0. 606	0. 549	0.653	0. 777	0. 587	0. 436	0. 644
	LGA secret. block B	0.10162± 0.090	0. 650	0. 589	0. 701	0. 833	0. 630	0. 467	0. 691

Continued.

Villages	Names of offices	Mean AEDR (mSv y-1)	Lungs	Ovaries	Bone marrow	Testes	Kidneys	Liver	Whole body
UMUDIM 6.0105º N 6. 9103º E	LGA secret. block C	0.8243± 0. 009	0. 527	0. 478	0. 569	0. 676	0. 511	0. 379	0. 560
	Chicason office block	1.1038± 0. 020	0. 707	0. 640	0. 762	0. 905	0. 685	0. 508	0. 751
	Innoson office block	0.9987± 0.060	0. 640	0. 580	0. 690	0. 820	0.620	0.460	0.680
	MTN office	1.0337± 0.090	0. 662	0. 600	0.713	0.848	0.641	0. 476	0.703
	Airtel office	0.8244± 0.042	0. 527	0. 478	0. 569	0. 676	0. 511	0. 379	0. 560
	Mean±SD	1.0284± 0.103	0. 658	0. 596	0.710	0. 843	0.638	0.473	0.699
	ELCR ($x10^{-3}$)	3.599± 0.361	2.303	2.086	2.485	2.951	2. 233	1.656	2.447

However, the dose rates obtained from our study were lower than dose values obtained at some other places in Nigeria such as 1.04 mSv y^{-1} to 1.75 mSv y^{-1} at Akwanga, Nasarawa State 1.29+0.13 mSv y^{-1} and 0.31+0.04 mSv y^{-1}(for Akwanga) and 1.08+0.15 mSv y^{-1} and 0.25+0.04 mSv y^{-1}(for Keffi) of Nasarawa State and 1.3055 mSv y^{-1}, 1.438 mSv y^{-1}, 1.227 mSv y^{-1}, and 1.3289 mSv y^{-1} respectively for the four locations in Gokana LGA, Rivers State by Avwiriet al.[19-21] The dose values in this study was also lower than values of 65.28 µSv y^{-1} and 29.80 µSv y^{-1} for refuse dump sites in Owerri, Imo State, and Lagos State respectively, 1.56±0.3 mSv y^{-1} in Ondo State, 1.54 mSv y^{-1} (IAEDR), and 0.44 mSv y^{-1} (OAEDR) from the laboratory premises of Plateau State University, Bokkos in Jos, Plateau State and 2.733 mSv y^{-1} and 2.435 mSv y^{-1} for the laboratory buildings.[22-27] The mean dose from our study was comparable with 0.88±0.28 mSv y^{-1} obtained at Asaba, Delta State and 0.9746±0.201 mSv y^{-1} at Makurdi, Benue State.[34,47]

The difference between the dose rates obtained in this study and those obtained from other parts of the country could be a result of a difference in location and soil type. The high level of background radiation at Nnewi calls for similar studies to be done in other parts of Anambra State. This will be important as it will alert the State to the presence of high background radiation that may require intervention to avert possible danger with the present rate of industrialization in the state. Our results also showed that there were high doses to some body organs. The implication is the possibility of cancer development over a long time especially on the testes and bone marrow. The ELCR obtained for each of the organs in table 5 was higher than what was obtained in other parts of Nigeria such as Delta State, ($0.61x10^{-3}$), Southwestern Nigeria ($4.10x10^{-3}$), Enugu State ($0.54x 10^{-3}$) and in India (0.375- 0.662 x 10-3).[42,46-49] The ELCR to the organs was however comparable to the value of $3.21x10^{-3}$ obtained for Northern Pakistan where the researcher reported numerous deaths from cancer.[50] This again calls for further investigations for Nnewi and Anambra State with emphasis on the radionuclide contents of the soils.

CONCLUSION

The mean background radiation exposure levels in office buildings in Nnewi and its environment were below the values from many other parts of Nigeria and also below the UNSCEAR and ICRP recommended dose for the general public. Therefore, the workers and people in the environment of those offices are radiologically safe at the moment.

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