EVALUATION OF INDOOR RADON AND IT'S HEALTH RISKS PARAMETERS WITHIN AZUABIE, TRANS-AMADI AND NKPOGU TOWNS, IN PORT HARCOURT, RIVERS STATE, NIGERIA

ABSTRACT

Evaluation of indoor radon level and its health risk parameters has been carried out in three communities Azuabie, Trans-Amadi and Nkpogu towns in Port Harcourt, Rivers State, Nigeria. A pocket sized Corentium Arthings digital radon detector meter was used to record the indoor radon concentration levels. The geographical coordinates were recorded using a hand-held geographical positioning system (GPS) for the various sample points. A total of 30 sample points were evaluated, with 10 sample points for each town respectively. The results of the concentration levels showed that for Azuabie (AZ) town, the concentration level varied from 6.660 Bqm^{-3} to 13.690 Bqm^{-3} with an average of 10.65±0.95Bqm^{-3}. Nkpogu (NK) town the results of the indoor concentration level ranged from 9.250 Bqm^{-3} to 18.870 Bqm^{-3} with an average of 13.32±1.02 Bqm^{-3}, Nkpogu (NK) town, the indoor concentration level ranged from 7.030 Bqm^{-3} to 20.350 Bqm^{-3} with an average of 12.25±1.34Bqm^{-3}. The annual absorbed dose for Azuabie, Trans-Amadi and Nkpogu varied as follows, 1.680 $mSvy^{-1}$ – 3.921 $mSvy^{-1}$, 2.334 $mSvy^{-1}$ – 47610 $mSvy^{-1}$ and 1.774 $mSvy^{-2}$ – 5.134 $mSvy^{-1}$ respectively. The annual effect dose rate for the three towns ranged from 0.403 $mSvy^{-1}$ – 0.941$mSvy^{-1}$, 0.560 $mSvy^{-1}$ - 1.143 $mSvy^{-1}$ and 0.426 $mSvy^{-1}$ – 1.143$mSvy^{-1}$. The excess life time cancer risk varied from 1.4117 – 3.294, 1.9607 – 3.999 and 1.4901 – 3.999 respectively. The results of the indoor concentration levels annual and the absorbed dose and the annual effective dose rate are all below the ICRP safe limit. However, the results of the excess life time cancer risk are all higher than the ICRP safe standard limit of 0.029×10^{-3} .

Key words: *Background Ionization Radiation, Annual Effective Dose,* Excess Life Cancer Risk

1.0 Introduction

Radon is a radioactive gas which is colourless, odourless and tasteless. It is predominantly found in rock samples, bedrock formations, soil and ground water all over the world, (Ojo and Ajayi, 2015). Radon-222 is the immediate decay product of radium- 226 during the decay series of Uranium – 238 which is the source of radon-222. It has a half-life of 3.81 days. Radon-222 decays to polonium – 298 with the release of an alpha particle and consequently to other progenies of radon or radon daughters. Radon has been classified by the international Agency for Research on cancer (I A R C, 1988) as a carcinogenic gas.

The World Health Organization (WHO, 1999) also classified radon as the second highest cause of lung cancer after cigarette smoking. It was estimated that radon-222 causes between 3% to 14% of all lung cancers. Radon is the main cause of lung cancer among non-smokers. It is the cause of about fifteen per cent of all lung cancer cases throughout the world, (WHO, 2009). People are exposed to high radon level in small houses than in bigger apartments (UNSCEAR, 2000).The entry routes of indoor into the houses includes, the door, the windows, cracks on the walls, sinks, basements, floors etc.

The health effects as a result of higher exposure to radon-222 radiation induced. Inhalation is the main route through which humans are exposure to radon radiation. The dose contribution to radon may be small, but the inhalation of the progenies of radon which have very short half-life can deposit non-homogenously in the human respiratory track and irradiate the bronchial epithelium which is usually very harmful.

Two of the radon progenies (daughters) Polonium-214 and Polonium-218 releases the highest amount of alpha radiation dose to the lungs (NCRP, 1994). When these radioactive particles settle in a person's lung, they can cause damage to the mucosa linings of the lungs. A prolonged exposure to radon-222 radiation can also lead to series of damage to the pulmonary mucosa which could result to lung cancer.

An individual's average radiation come from the decay products of radon -222 such as , polonium – 218 and polonium – 214. These products of radon – 222 are in the solid form. They could be attached or unattached to the surface of aerosols, dusts and smoke particles. They can adhere deeply or stick to the lungs where they irradiate and penetrate the cells of the mucosa membranes, bronchi and pulmonary tissues. The ionizing radiation which emanate from the radioactive decay of radon-222 begins the process of carcinogenesis in the human lungs.

It is estimated that about 90% of the radon progenies can attach to airborne particles (ICRP, 1993). Also, the unattached fraction of the particles which constitutes about 10% has a higher rate of deposition and is more efficient in delivering doses to the sensitive cells of the lungs (UNSCEAR, 1993). The more the concentration of radon in homes the greater the risk of lung cancer due to radon exposure. The risk of lung cancer increases for every100 Bq/m^3 increase in radon concentration, according to the World Health Organization (WHO, 2016).

However, there is no thresholds value below which radon exposure carries no risk of lung cancer. Therefore it is important that every country should set up a national reference level "AS Low As Reasonably Achievable" (ALARA) (Yeung, A.W.K., 2019).

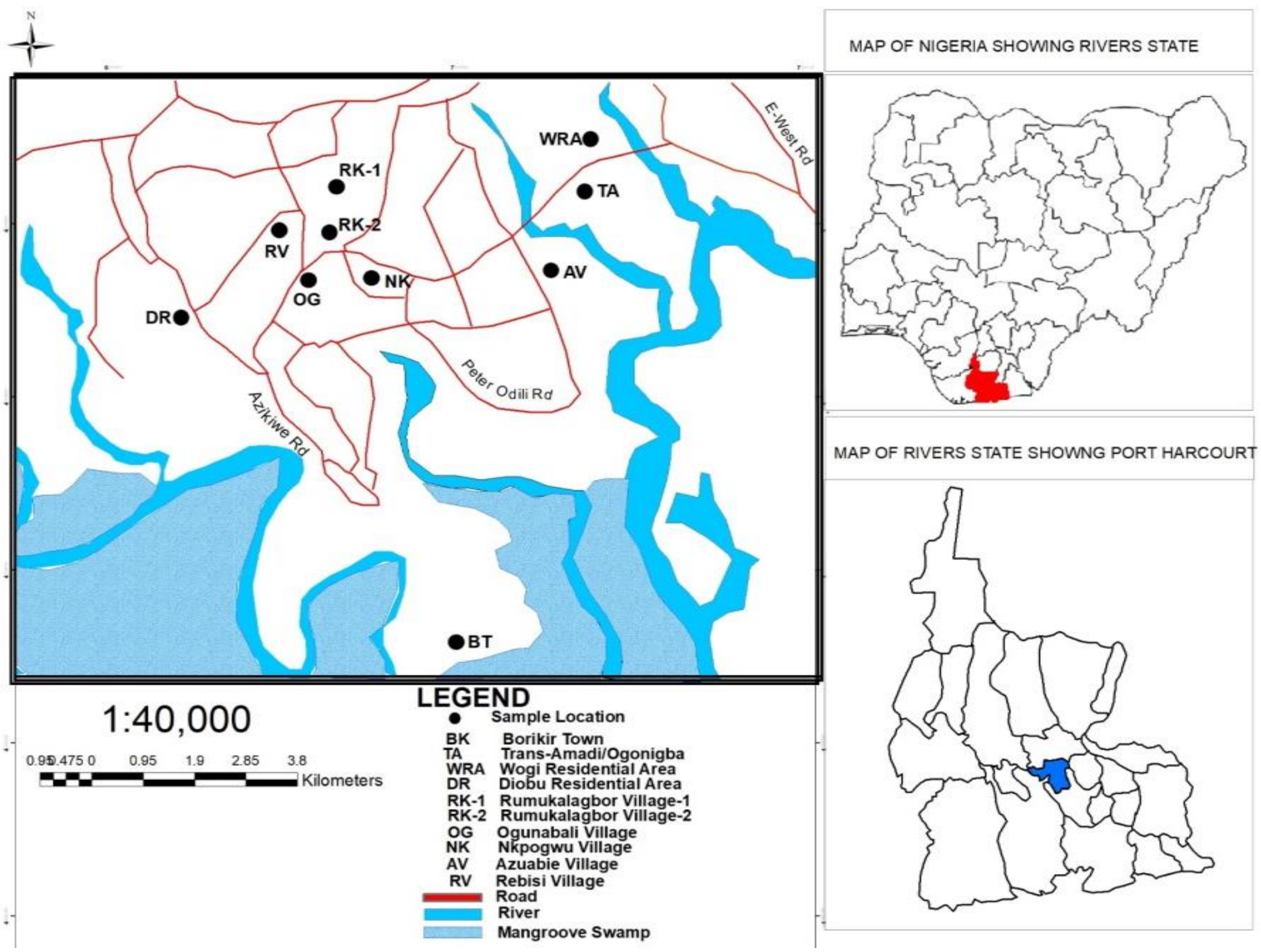

Figure 1: Map of Study Area

The reason for carrying out radon measurements in these towns is because radon-222 concentration level has not been done within Port Harcourt local government. Therefore, we wanted to find out the radon-222 concentration level and compare the results with international set standards. Also, measurement of radon-222 concentration level in these areas will provide baseline studies and literature for other researchers. It is well known fact that these areas are densely populated with building styles that are poorly ventilated therefore, it was necessary to find out if the residents of these towns are exposed to higher dose of radon-222 from their environment. Additionally, there has been incident of lung cancer cases within these areas in recent times even though not officially reported, therefore it was important to confirm if it was as a result of high level of radon exposure.

2.0 Materials and Methods

The radon detector used in this work is Airthings Corentium Digital Radon Detector designed in Oslo Norway in the year 2019. It is calibrated to measure radon-222 in picocurie per litre (pCi/L). The Airthings Corentium digital detector can be used to monitor radon concentration levels for a minimum period of 48 hours, for daily,, weekly, and monthly and yearly. The radon meter works on the principle that the radon diffuses into a detection chamber. As the atom decay they emit energetic alpha particles. The energetic alpha particles are detected by a silicon photodiode. The alpha particle generates a small signal current when it hits the photodiode. By the use of a low power amplifier stage, the signal current is converted into a large voltage signal. The maximum amplitude of the voltage signal is detected and sampled by an analog to digital converter (ADC). The amplitude of this signal is proportional to the energy of the alpha particle that hit the photodiode. The brain of the monitor is a micro-controller which registers the time and the energy of every detected particle. This information is used to calculate the mean Radon concentration for, daily, weekly, monthly and yearly periods.

Indoor radon concentration measurement were carried out in three communities in Port Harcourt using the Airthings digital radon detector while the geographical position system (GPS) was used for the measurement of the geographical coordinates of the sample points. A total of 30 sample points were measured for the three communities, 10 sample points for Azuabie town, 10 sample points for Nkpogu town and 10 sample points for Woji town.

The Airthings digital radon detector was placed in the dwelling room at a height of about 50cm above the ground and about 150cm from both the window and door and 25cm from the walls, (Kent, et al,2015). The detector was kept for a period of two days (48hrs.) in a given dwelling before relocating to another house or home.

The windows and doors were kept closed throughout the period of the measurement to ensure that the indoor air is not distorted to achieve accuracy within the period of 48 hours.

2.0 Radon Risk Parameters

2.1 Annual Absorbed dose from Radon Concentration

The annual absorb dose from the radon concentration is the magnitude of energy delivered in a tissue from exposure to ionizing radiation within a specified period. The physics of the equation employed in the computation of the annual absorbed dose rate due to report of United Nation`s Scientific Committee on the Effects of Atomic Radiation (UNSCEAR, 2000, ICRP, 1993) and is given as;

$$DRn(mSvy^{-1}) = CRn.\ D.H.T.F \qquad (1)$$

Where:

CRn = the measured concentration of indoor radon-222 in Bqm^{-3},
F = Radon-222 equilibrium indoor factor of (0.4)
T = Is the indoor-222 occupancy time 7000hr, (0.8 x 24 hr x 365)
H = Indoor radon-222 occupancy factor (0.4)
D = Dose conversion factor (9.0×10^{-6}mSv/hr per Bqm^{-3})

2.2 Annual Effective Dose Rate (AEDR) from Radon Concentration

The annual effective dose rate was calculated by applying a tissue and radiation weighting factor (ICRA 1991). The inhalation dose equation is given by;

$$AEDR\ (mSvy^{-1}) = DRn.\ WR.\ WT \qquad (2)$$

Where:

DRn = Indoor radon concentration
WR = Radiation weighting factor for alpha particles (20)
WT = Tissue weighting factor for the lung (0.12)

2.3 Excess Life Cancer Risk From Radon Concentration

The excess life time cancer risks (ELCR) is the potential carcinogenic effects, from the calculation based on probability of cancer induced incidence in a population. It indicates the chances of contracting a cancer from the exposure from radiation or toxic chemical substances for a specific life time. According to (ICRP, 2010), the excess life time risk was calculated from the equation.

$$ECLR = AEDR \times DL \times RF \quad (3)$$

Where:

DL = Average duration of life (70 years)
RF = Risk Factor 0.05×10^{-5}

2.4 Statistical Analysis

The mean values and standard deviation for the radon concentrations was computed using equations (4) and (5). This can also be computed with the aid of a histogram and contour maps showing the spatial distribution of radon concentration and its health risk parameters which will also be plotted with the aid of statistical package for social sciences (SPSS) version (22) and surfer – 8 contour map software.

Mean Value $\mu_x = \frac{\Sigma_i^n x}{n}$ . . ……… (4)

Standard Deviation (S.D) $= \sqrt{\frac{\Sigma_i^n (x_i \, \mu_x)^2}{n-1}}$ …………. (5)

3.0 Results and Discussion

The result of the indoor radon concentration and their geographical coordinates for the three towns; Azuabie, Trans-Amadi, and Nkpogu town are presented in Tables, 1 - 3 respectively. The indoor radon concentration was measured in PicoCuri per litre (PCi/L). Tables 4 – 9 represent the results of the concentration in Becqueri per metre cube with their health risk parameters.

Also, the indoor randon concentration level for Nkpogu town varied from 6.660Bq/m^3 to 13.690 Bq/m^3 with an average indoor radon concentration of 10.65±0.95 Bq/m^3 ; the result of indoor radon concentration level in Trans-madi varied from 9.250 Bq/m^3 to 18.870B/m^3 with an average of 13.32±1.02Bq/m^3 ; The indoor radon concentration level at Nkpogu town ranged from 7.030 to 20.350 Bq/m^3 with an average indoor concentration level of 12.25±1.34 Bq/m$^{3.}$ The annual absorbed dose for the indoor radon varied as follows; 1.68 mSv/yr-3.921 mSv/yr, 2.334 mSv/yr-4.761 mSv/yr, 1.774 mSv/yr-5.134 mSv/yr for Azuabie town, Trans-Amadi town and Nkpogu town respectively. The annual effective dose rate (AEDR) for the three towns which was calculated from the indoor radon concentration ranged from 0.403mSvm/yr- 0.941mSv/y; 0.560 mSv/yr-1.143mSv/yr; 0.426mSv/yr-1.143mSv/yr respectively. These values are all below the safe standard by International Commission on Radiological Protection (ICRP) . The Excess Life Time Cancer Risk calculated from the indoor radon concentration were; 1.4117-3.294;

1.9607-3.999 and 1.4901-3.999 for Azuabie, Trans- Amadi and Nkpogu respectively. The results of the Excess Life Time Cancer Risk for the three towns were all higher than the world average.

The mean annual absorbed dose for the three towns, Azuabie, Trans-Amadi and Nkpogu are 2.69±0.24mSv/yr, 3.36±0.26mSv/yr and 3.08±0.34mSv/yr. Also, the average Annual Absorbed Dose Rate (AEDR) for Azuabie town, Trans-Amadi town and Nkpogu town are 0.64±0.05mSv/yr, 0.81±0.06mSv/yr and 0.74±0.08mSv/yr respectively. The average Excess Life Time Cancer Risk calculated for Azuabie was $(2.26\pm0.20)\times10^{-3}$, Trans-Amadi was $(2.82\pm0.22)\times10^{-3}$, Nkpogu was $(2.60\pm0.28)\times10^{-3}$. These values are all higher than the world average. These results have been represented in their respective tables and barcharts. The excess life time cancer risk were calculated for the age duration of 70 ,60, 50,40 and 30 years. The result show that the higher the years the higher the risk of cancer due to exposure to rado-222.

From the result obtained, there is no appreciable difference between the different study areas, this is due to the fact that there is similarity in the building design, materials used in the building, ventilation pattern of the living houses and the life style of the people. These results obtained are comparable to the indoor radon concentration level for different types of buildings in covenant university, Nigeria (Usilan *et al.*, 2020). The mean radon concentration for the three different building types Glass, Brick house and Basement house were 14.96Bqm^{-3}, 10.74 Bqm^{-3} and 144,6Bqm^{-3} respectively.

The indoor radon concentration for the glass house ranged from 11.03 – 17.46Bqm^{-3}, the concentration level of brick house varied from 6.62 – 20.85Bqm^{-3}, while that for basement house ranged from 15.75 to 614.52Bqm^{-3}. However, the concentration level for the basement house was above the international safe standard, but the glass house and brick house indoor concentration levels were of the same range for the Azuabie, Trans-Amadi and Nkpogu locations in Port Harcourt. Also, the indoor radon level concentration measured by(Olusegun *et al.*, 2015) in Obasfemi Awolowo University Ile-Ife are similar to the indoor radon level measured in Azuabie, Trans-Amadi and Nkpogu town. The radon concentration level obtained from the offices varied from 0.0 - 5.3Bqm^{-3}. The average value obtained was 0.9 PCi/L.

Similarly, the health risk parameters, the annual absorbed dose , annul equivalent dose rate and the excess life time cancer risk agreed with the calculated value in Azuabie, Trans-Amadi and Nkpogu towns. The indoor radon level concentration measured at Azuabie, Trans-Amadi and Nkpogu towns is also comparable to the work done earlier by (Sokari, S.A. 2018) in Okirika local government area in River's state, Nigeria. The average concentration level was 19.36±Bqm^{-3} for mud house, while the overall average indoor radon concentration was 11.37±3.28Bqm^{-3} for Okirika local government.

These results are lower than the safe limit by ICRP. Also, the overall average of the annual absorb dose was 3.36±0.26mSv/yr , the mean annual effective dose rate was 0.15±0.42 mSv/yr while the overall excess life time cancer risk calculate from the indoor radon concentration level was $(0.52\pm0.15)\times10^{-3}$ and were all above the world standard of 0.029 $\times10^{-3}$.

Table 1. Radon Levels in Azuabie Town (AZB)

S/N	ZUABIE Town	GPS COORDINATES		RADON LEVELS IN PICO CURI PER LITRE (PC_I/L)
		LATITUDES	LONGITUDES	
1.0	AZB_1	$N4^{0}48^{1}35.832^{11}$	$E7^{0}3^{1}9.594^{11}$	0.18
2.0	AZB_2	$N4^{0}48^{1}39.914^{11}$	$E7^{0}3^{1}92.242^{11}$	0.22
3.0	AZB_3	$N4^{0}48^{1}34.32^{11}$	$E7^{0}3^{1}5.316^{11}$	0.32
4.0	AZB_4	$N4^{0}48^{1}26.136^{11}$	$E7^{0}3^{1}13.626^{11}$	0.26
5.0	AZB_5	$N4^{0}48^{1}.29.28^{11}$	$E7^{0}3^{1}13.404^{11}$	0.37
6.0	AZB_6	$N4^{0}48^{1}13.98^{11}$	$E7^{0}3^{1}4.902^{11}$	0.33
7.0	AZB_7	$N4^{0}48^{1}20.304^{11}$	$E7^{0}2^{1}59.154^{11}$	0.35
8.0	AZB_8	$N4^{0}48^{1}10.758^{11}$	$E7^{0}3^{1}1.374^{11}$	0.19
9.0	AZB_9	$N4^{0}48^{1}13.632^{11}$	$E7^{0}3^{1}2.388^{11}$	0.42
10.0	AZB_{10}	$N4^{0}48^{1}14.772^{11}$	$E7^{0}3^{1}1.824^{11}$	0.24

Table 2. Radon Levels in Trans-Amadi/Ogoniba Town

S/N	LOCATION, TRANS AMADI/OGONIGBA (TA)	GPS COORDINATES		RADON LEVELS IN PICO CURI PER LITRE (PC_I/L)
		LATITUDES	LONGITUDES	
1.0	TA_1	$N4^{0}49^{1}42.936^{11}$	$E7^{o}2^{1}22.878^{11}$	0.51
2.0	TA_2	$N4^{0}49^{1}40.818^{11}$	$E7^{0}2^{1}19.488^{11}$	0.25
3.0	TA_3	$N4^{0}49^{1}26.798^{11}$	$E7^{0}2^{1}29.934^{11}$	0.33
4.0	TA_4	$N4^{o}49^{1}21.252^{11}$	$E7^{o}2^{1}24.990^{11}$	0.34
5.0	TA_5	$N4^{o}48^{1}3.744^{11}$	$E7^{o}3^{1}25.836^{11}$	0.37
6.0	TA_6	$N4^{o}49^{1}33.492^{11}$	$E7^{o}2^{1}28.902^{11}$	0.31
7.0	TA_7	$N4^{0}49^{1}37.056^{11}$	$E7^{0}2^{1}25.506^{11}$	0.34
8.0	TA_8	$N4^{0}49^{1}34.374^{11}$	$E7^{0}2^{1}19.668^{11}$	0.28
9.0	TA_9	$N4^{0}49^{1}33.702^{11}$	$E7^{0}2^{1}28.308^{11}$	0.36
10.0	TA_{10}	$N4^{0}49^{1}39.006^{11}$	$E7^{0}2^{1}15.642^{11}$	0.32

Table 3. Radon Levels in Nkpogwu Town (NK)

S/N	NKPOGWU Town	GPS COORDINATES		RADON LEVELS IN PICO CURI PER LITRE (PC_I/L)
		LATITUDES	LONGITUDES	
1.0	NK_1	$N4^{0} 48^{1} 3. 921080^{11}$	$E7^{0} 1^{11} 15.12055^{11}$	0.51
2.0	NK_2	$N4^{0} 48^{1} 5.732280^{11}$	$E 7^{0} 1^{1} 13.724620^{11}$	0.33
3.0	NK_3	$N4^{0} 48^{1} 6.435790^{11}$	$E7^{0} 1^{1} 16.291020^{11}$	0.28
4.0	NK_4	$N4^{0} 48^{1} 6.293740^{11}$	$E7^{0} 1^{1} 11.700480^{11}$	0.26
5.0	NK_5	$N4^{0} 48^{1} 3.573170^{11}$	$E7^{0} 1^{1} 806956000^{11}$	0.29
6.0	NK_6	$N4^{0} 48^{1} 5.524240^{11}$	$E7^{0} 1^{1} 28. 163170^{11}$	0.55
7.0	NK_7	$N4^{0} 48^{1} 3.3 89317^{11}$	$E7^{0} 0^{1} 59.070420^{11}$	0.19
8.0	NK_8	$N4^{0} 48^{1} 3.292 538^{11}$	$E7^{0} 059.9982000^{11}$	0.32
9.0	NK_9	$N4^{0} 48^{1} 12. 93592^{11}$	$E7^{0} 1^{1} 9.1599200^{11}$	0.34
10.0	NK_{10}	$N4^{0} 48^{1} 4.817770^{11}$	$E7^{0} 1^{1} 18.051850^{11}$	0.24

Table 4. Computed values of annual effective dose and annual equivalent dose rate of Azuabie Town (AZB)

S/N	S/Pts	CRN (PCi/L)	CRN (Bq/m3)	DRn (mSvy-1)	AEDR (mSvy-1)
1.0	AZB1	0.18	6.6600	1.6802	0.403
2.0	AZB2	0.22	8.1400	2.0536	0.493
3.0	AZB3	0.32	11.8400	2.9871	0.717
4.0	AZB4	0.26	9.6200	2.4270	0.582
5.0	AZB5	0.37	13.6900	3.4538	0.829
6.0	AZB6	0.33	12.2100	3.0804	0.739
7.0	AZB7	0.35	12.9500	3.2671	0.784
8.0	AZB8	0.19	7.0300	1.7736	0.426
9.0	AZB9	0.42	15.5400	3.9206	0.941
10.0	AZB10	0.24	8.8800	2.2403	0.538
AVERAGE		**0.29 ± 0.02**	**10.65 ± 0.95**	**2.69 ± 0.24**	**0.64 ± 0.05**

Table 5. Computed values of excess lifetime cancer risk for ages of 70(Std), 60, 50, 40 and 30 yrs of Azuabie Town (AZB)

S/N	S/Pts	ELCR x10-3 70 yrs(Std)	ELCR x10-3 60 yrs	ELCR x10-3 50 yrs	ELCR x10-3 40 yrs	ELCR x10-3 30 yrs
1.0	AZB1	1.412	1.210	1.008	0.807	0.605
2.0	AZB2	1.725	1.479	1.232	0.986	0.739
3.0	AZB3	2.510	2.151	1.792	1.434	1.075
4.0	AZB4	2.039	1.747	1.456	1.165	0.874
5.0	AZB5	2.902	2.487	2.072	1.658	1.243
6.0	AZB6	2.588	2.218	1.848	1.479	1.109
7.0	AZB7	2.745	2.352	1.960	1.568	1.176
8.0	AZB8	1.490	1.277	1.064	0.851	0.638
9.0	AZB9	3.294	2.823	2.352	1.882	1.411
10.0	AZB10	1.882	1.613	1.344	1.075	0.807
AVERAGE		**2.25± 0.20**	**1.94 ± 0.17**	**1.61 ± 0.14**	**1.29 ± 0.11**	**0.97 ± 0.08**

Table 6. Computed values of annual effective dose and annual equivalent dose rate of Trans-Amadi/Ogoniba Town

S/N	S/Pts	CRN (PCi/L)	CRN (Bq/m3)	DRn (mSvy-1)	AEDR (mSvy-1)
1.0	TA1	0.51	18.8700	4.7607	1.143
2.0	TA2	0.25	9.2500	2.3337	0.560
3.0	TA3	0.33	12.2100	3.0804	0.739
4.0	TA4	0.34	12.5800	3.1738	0.762
5.0	TA5	0.37	13.6900	3.4538	0.829
6.0	TA6	0.31	11.4700	2.8937	0.694
7.0	TA7	0.34	12.5800	3.1738	0.762
8.0	TA8	0.28	10.3600	2.6137	0.627
9.0	TA9	0.36	13.3200	3.3605	0.807
10.0	TA10	0.32	18.8700	4.7607	1.143
AVERAGE		0.34 ± 0.03	13.32 ± 1.02	3.36 ± 0.26	0.81 ± 0.06

Table 7. Computed values of excess lifetime cancer risk for ages of; 70(Std), 60, 50, 40 and 30 yrs of Trans-Amadi/Ogoniba Town

S/N	S/Pts	ELCR $x10^{-3}$ 70 yrs(Std)	ELCR $x10^{-3}$ 60 yrs	ELCR $x10^{-3}$ 50 yrs	ELCR $x10^{-3}$ 40 yrs	ELCR $x10^{-3}$ 30 yrs
1.0	TA_1	4.000	3.428	2.856	2.285	1.714
2.0	TA_2	1.961	1.680	1.400	1.120	0.840
3.0	TA_3	2.588	2.218	1.848	1.479	1.109
4.0	TA_4	2.667	2.285	1.904	1.523	1.143
5.0	TA_5	2.902	2.487	2.072	1.658	1.243
6.0	TA_6	2.431	2.083	1.736	1.389	1.042
7.0	TA_7	2.667	2.285	1.904	1.523	1.143
8.0	TA_8	2.196	1.882	1.568	1.255	0.941
9.0	TA_9	2.823	2.420	2.016	1.613	1.210
10.0	TA_{10}	2.510	2.151	1.792	1.434	1.075
AVERAGE		**2.67 ± 0.54**	**2.29 ± 0.47**	**1.90 ± 0.39**	**1.52 ± 0.10**	**1.14 ± 0.23**

Table 8. Computed values of annual effective dose and annual equivalent dose rate of Nkpogwu Town (NK)

S/N	S/Pts	C_{RN} (PCi/L)	C_{RN} (Bq/m3)	D_{Rn} (mSvy-1)	AEDR (mSvy-1)
1.0	NK_1	0.51	18.8700	4.7607	1.143
2.0	NK_2	0.33	12.2100	3.0804	0.739
3.0	NK_3	0.28	10.3600	2.6137	0.627
4.0	NK_4	0.26	9.6200	2.4270	0.582
5.0	NK_5	0.29	10.7300	2.7071	0.650
6.0	NK_6	0.55	20.3500	5.1341	1.232
7.0	NK_7	0.19	7.0300	1.7736	0.426
8.0	NK_8	0.32	11.8400	2.9871	0.717
9.0	NK_9	0.34	12.5800	3.1738	0.762
10.0	NK_{10}	0.24	8.8800	2.2403	0.538
AVERAGE		**0.33 ± 0.04**	**12.25± 1.34**	**3.08 ± 0.34**	**0.74± 0.08**

Table 9. Computed values of excess lifetime cancer risk for ages of 70(Std),60, 50, 40 and 30 yrs of Nkpogwu Town (NK)

S/N	S/Pts	ELCR x10^{-3} 70 yrs(Std)	ELCR x10^{-3} 60 yrs	ELCR x10^{-3} 50 yrs	ELCR x10^{-3} 40 yrs	ELCR x10^{-3} 30 yrs
1.0	NK_1	4.000	3.428	2.856	2.285	1.714
2.0	NK_2	2.588	2.218	1.848	1.479	1.109
3.0	NK_3	2.196	1.882	1.568	1.255	0.941
4.0	NK_4	2.039	1.747	1.456	1.165	0.874
5.0	NK_5	2.274	1.949	1.624	1.299	0.975
6.0	NK_6	4.314	3.697	3.080	2.464	1.848
7.0	NK_7	1.490	1.277	1.064	0.851	0.638
8.0	NK_8	2.510	2.151	1.792	1.434	1.075
9.0	NK_9	2.667	2.285	1.904	1.523	1.143
10.0	NK_{10}	1.882	1.613	1.344	1.075	0.807
AVERAGE		**2.59± 0.28**	**2.23± 0.24**	**1.85± 0.20**	**1.48± 0.16**	**1.11 ± 0.12**

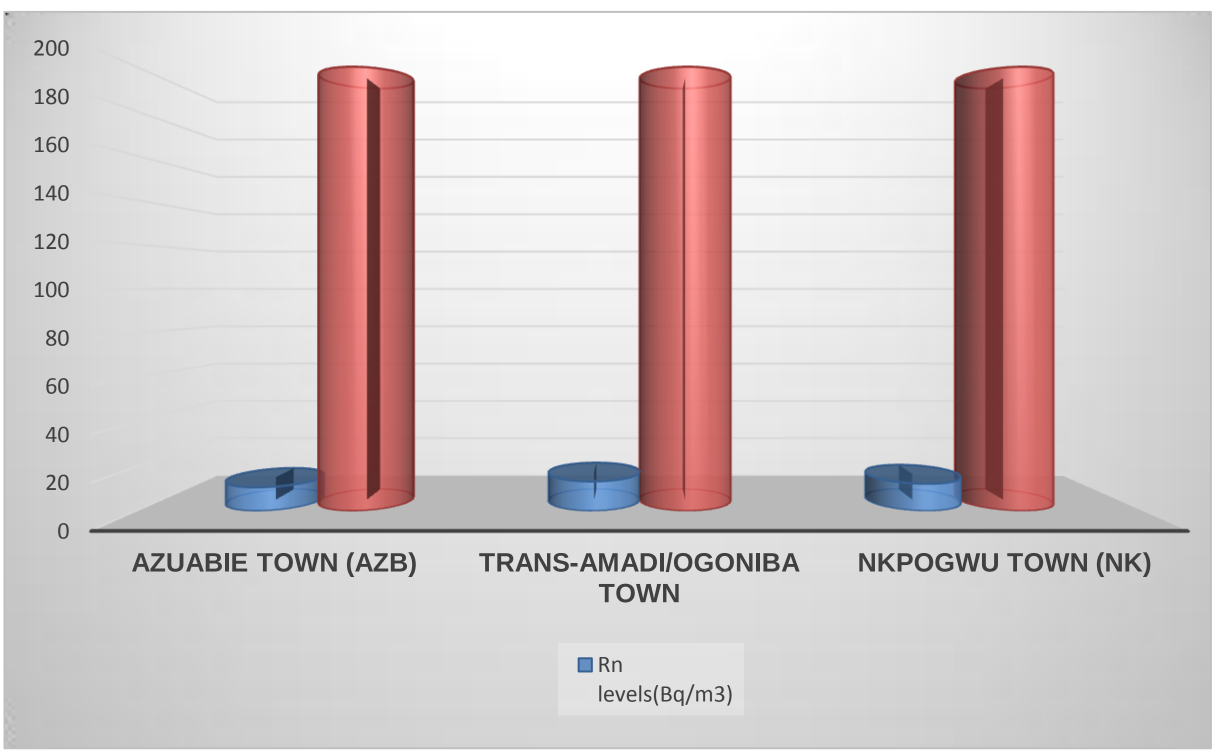

Figure 4. Average Indoor Radon Level of sample locations and ICPR reference level

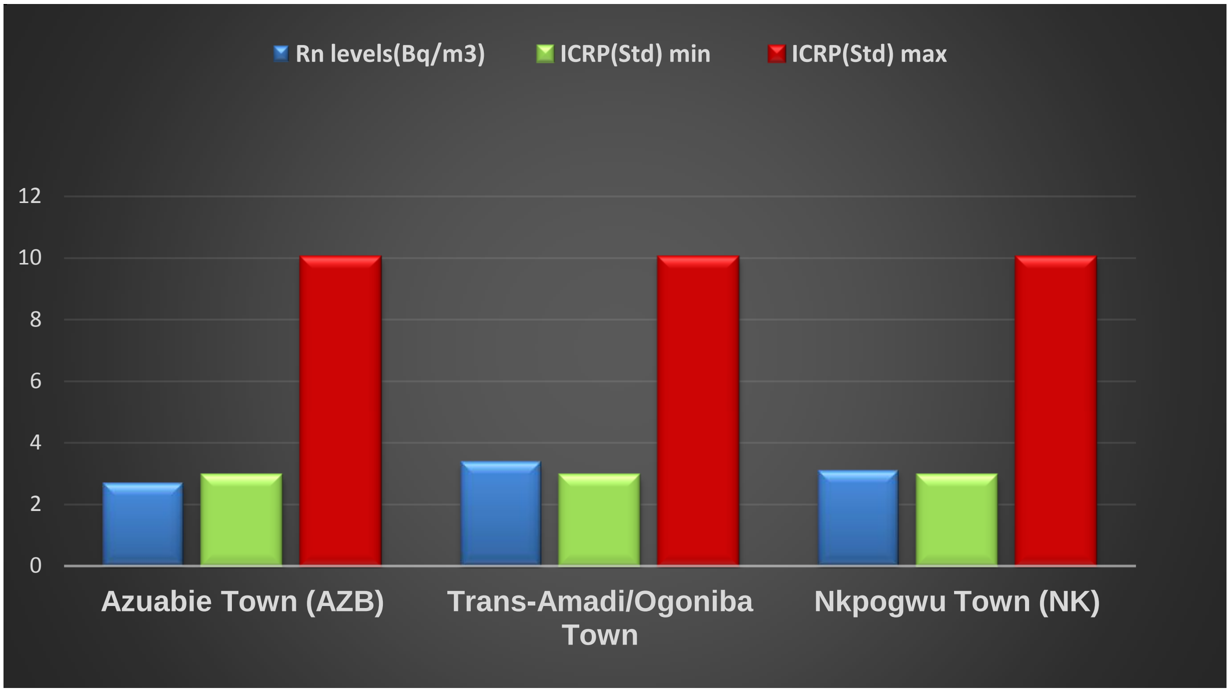

Figure 5. Annual Absorbed Dose of sample locations and ICRP Standard

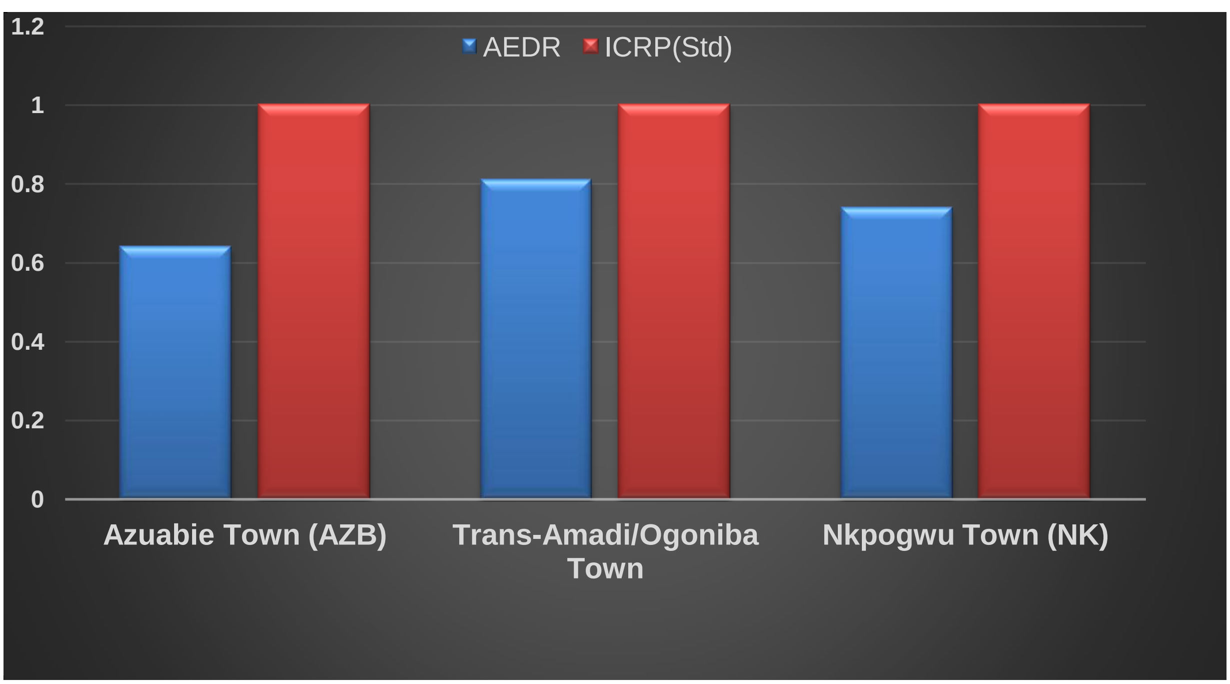

Figure 3. Annual Effective Dose Rate (AEDR) and ICRP Standard

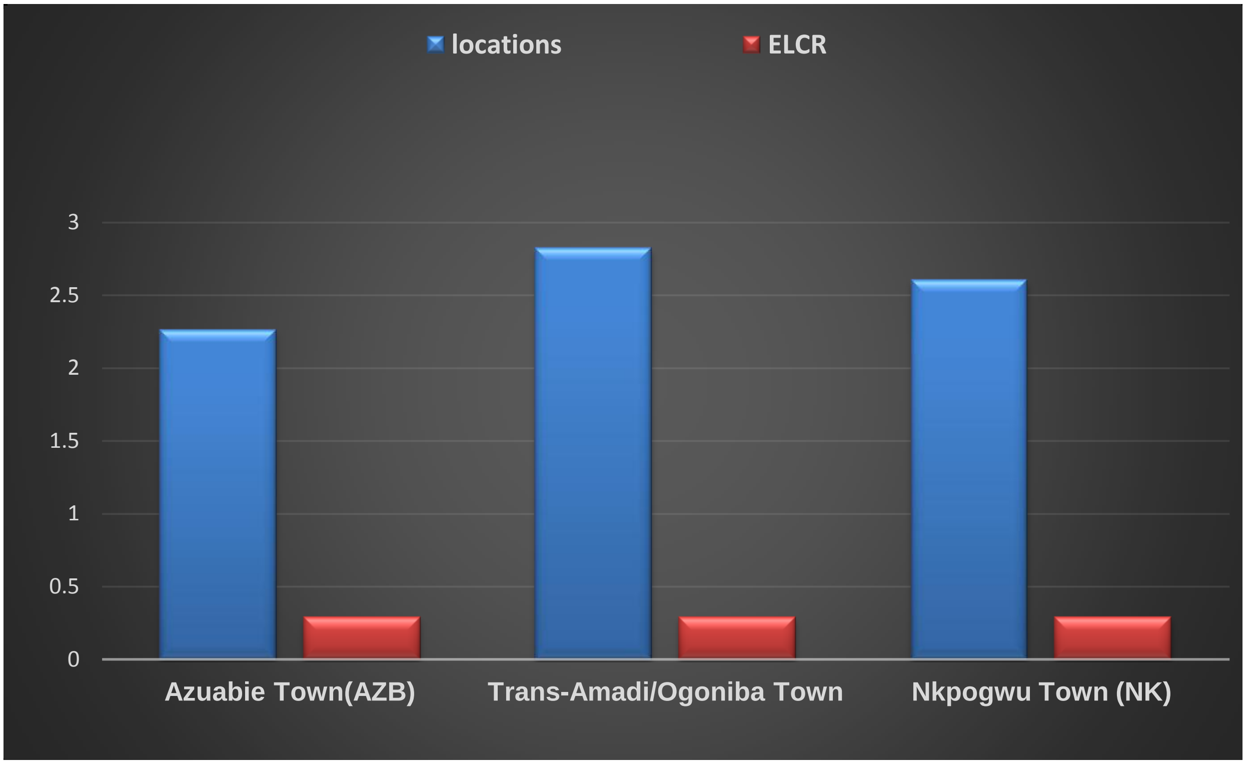

Figure 6. Excess Life Time Cancer Risk (ELCR) of sample locations with World Standard

4.0 Conclusion

The evaluation of indoor radon concentration level and its health risk parameters has been done in Azuabie town, Nkpogu town and Trans-Amadi in Port Harcourt, Rivers State, Nigeria using the Corentium Arthings radon digital detector. The concentration levels measured for the three towns were all below the action level of 200-600 Bq/m^3 given by the International Commission on Radiological Protection (ICRP). However, the excess life time cancer risk for all the three towns were all higher than the world average. It was also observed that there was no appreciable difference in the indoor radon concentration level between the three towns of Azuabie, Trans-Amadi, Nkpogu. This is because of the similarities in the building styles, materials used for the buildings, the life style of the people and the ventilation method.

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