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ASSESSMENT OF THE BACKGROUND IONIZING RADIATIONS (BIRS) LEVELS OF TWENTY SELECTED MOBILE PHONE BASE STATIONS

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Abstract: *Assessment of the background ionizing radiations (BIRs) levels of twenty selected mobile phone base stations to ascertain their radiological health risks was undertaken using the Radalert 100 radiation monitor and a Geographical Positioning System (Garmin etrex 10). An in-situ measurement of the (BIRs) in air at 1.0 meter above ground level was carried out at twenty different telecommunication base stations in Enugu metropolis. The mean BIR levels of the studied masts ranged from 0.0489 to 0.2306 µSv/h, and ten were higher than the ICRP recommended safe limit of 0.13 µSvh^{-1}(0.013mR/h) while the BIRs of the remaining ten were lower than the ICRP permissible standard. The estimated values of absorbed dose rate (ADR) ranged from 8.78nGy/h to 200.62nGy/h, ten also were above ICRP permissible limit of 84nGy/h, while ten fell below ICRP standard. In as much as the mean ADR of BIR levels of the ten masts were higher than the ICRP safety limit, it does not result to any instant radiological risk, evidenced by their estimated Annual effective dose equivalent (AEDE) values ranging from 0.011 to 0.246 mSv/y, all lower than the ICRP permissible limits of 1 mSvy^{-1}. For the associated excess lifetime cancer risk (ELCR), their values ranged from 0.038 $\times 10^{-3}$ to 0.861 $\times 10^{-3}$. Thirteen were observed to exceed the UNSCEAR recommended value of 0.29×10^{-3}, suggesting therefore, high probability of base station workers developing cancer or radiation-related ailments from the ages of 65 years and above. In as much as the studied base stations do not create immediate hazard both to human health and the environment, the result showed they undoubtedly do on the long run. It is recommended that consistent radiological checks be maintained, and the data taken as a radiological reference point for telecommunication masts in Enugu State.*

Keywords*: Telecommunication base stations, Background ionizing radiation (BIR), radiation health indices, Radalert-100 and radiological health risks.*

1: Introduction.

We live in environment constantly exposed to radiation, implying that every living organism including humans is continually and inescapably exposed daily to varying doses of ionizing radiation. This radiation called background ionizing radiation emanates from both natural and man – made sources. The natural sources of radiation are mainly due to cosmic rays and naturally occurring long – lived radioactive nuclides that originated from the earth's crust and are present everywhere in the environment, including the human body itself (UNSCEAR, 2008). It is an established fact that naturally occurring radionuclides contribute significantly to the exposures of humans to background ionizing radiation (Bamidele, 2013; Farai & Jibiri, 2003; Ibrahim, *et al.*, 2014). Among these radionuclides are the radioactive isotope of potassium ^{40}K and the radionuclides that originated from the decay of ^{238}U and ^{232}Th series, both widely spread in soil and rocks of the earth's crust, Ibrahim, Atta, and Zakaria, (2014). Radiation from these radionuclides mainly depends on geological and geophysical conditions of the environment and it is higher in igneous (e.g. granite) and lower in sedimentary rocks with the exception of shale and phosphate rocks which in some cases may have relatively high content of radionuclides (Enyinna & Onwuka, 2014). In addition to the natural sources, human activities also contribute to the radiation level of the environment.

The use of radionuclides and radioactive substances in nuclear reactors and power plants, medicine, industries and research institutions is usually accompanied by the release of radiation into the environment. The practice of radiation protection ensures that exposure to radiation should be kept to as low as reasonably achievable, called the ALARA principle. The estimation of exposure to ionizing radiation is therefore an important goal of regulatory authorities and radiation protection scientists (Osimobi, Agbalagba, Avwiri and Ononugbo, 2015). Because of the lethal effect of ionizing radiation, any area with perceived high radiation level is subjected to accurate assessment of the exposure level and quantification and categorization of the radiation dose in order to ensure that the ALARA principle is maintained

The arrival of global system on mobile (GSM) communication in Nigeria has been accompanied by several challenges especially with the attendant economic ties. One of the distinguished features that define the GSM increase in the country is the influx of telecommunication masts that are evidently seen all over the landscape. This gave rise to different concerns from different stakeholders, some are of the opinion that the telecommunication masts pose great health threat and others suggest that they do not. The advocates of the limited hazards to health by the telecommunication masts argue that such fears about mobile phone masts, power cables, and communication equipment generally are perpetuated by sensationalist newspapers and are often ill-conceived (Grasso, 2008; Ifc, 2007; Cherry, 2000; Bond & Wang, 2005; Hamblin & Wood, 2002). The opponents such as (Osibanjo, 2009) on the other hand, contend that there are certain aspects of the electromagnetic spectrum that are injurious to human health (e.g. ultraviolet rays, gamma radiation, extended exposure to x-rays), while others are safe and have no negative effect on our health.

As much as their contentions point to the fact that the extent of health threat posed by telecommunication masts rays are great at a minimal level compared with the ultraviolet rays from the sun, there still exist contingencies for health threats as a result of exposure to radiation masts rays (Hamblin & Wood, 2002). The result of (Nwachukwu A., Ikeagwuani, & Nwachukwu N., 2021) was that the excess lifetime cancer risk for the stations' users was all above the 0.29×10^{-3} world recommended value and therefore, concluded that there is a direct relationship between the base station workers (from the age of 65 years and above) and radiation-related illnesses. There are health effects from exposure to mast radiation, according to (Akintonwa, Busari, Awodele, & Olayemi, 2009). Halim *et al*., (2009) measured radiation using a Geiger-Mueller LND712 detector, Radiation Alert Monitor 4, calibrated by Cesium 137, once a month for a year to find the amount of background radiation that is naturally exposed to people near base stations. Measurements were made by Sabah (2013) in a research near cell towers in residential areas of Kirkuk, Iraq, and it was discovered that the radiation levels were higher than the recommended values. In their study, (Santini, Santini, Danze, Le Ruz, & Seigne, 2002) in France, found that those who resided closest to cellular antennas had the highest rates of the following conditions: fatigue, disturbed sleep, headaches, discomfort, difficulty concentrating, depression, memory loss, visual disturbances, irritability, hearing disturbances, skin

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issues, cardiovascular disorders, and dizziness. In Germany, Eger *et al*., (2004) looked at whether there was a higher chance of developing malignant tumors for those who lived close to cellular transmitter antennas. Based on medical records of residents living within 350 meters of a long-standing phone mast, Wolf and Wolf (2004) reported in Israel that there was a tenfold increase in the incidence of cancer among women compared to the locality further from the mast, and a fourfold increase in the incidence of cancer overall. In a study conducted in Spain, Oberfeld (2004) discovered a significant link between residing near two GSM mobile phone base stations and poor health. He discovered that the greatest five connections were cardiovascular issues, exhaustion, depressive tendencies, and sleeping disorders. People living within 50 to 300 meter radius as illustrated in figure 1, are in the high radiation zone and are more prone to ill-effects of electromagnetic radiation. Eneh (2015) establishes that there is a very great synergic relationship between location of telecommunication masts and the health of nearby residential and basic school premises.

The inherent issues of interest here are, whether radiations from telecommunication masts pose threats to human life, do their associated radiation health indices fall below, within, or above the International Commission on Radiation Protection (ICRP) safety standards. These considerations made a research of this nature relevant. Therefore, the need exists to determine the level of ionizing radiations generated by the dappling telecommunication masts in Enugu metropolis and the challenges these radiations pose to humans within the vicinity where these masts are sited.

2: Methodology

The study was carried out in Enugu city, Enugu State of South Eastern Nigeria. Enugu city is located between longitudes 7º6′E and 7º54′E and latitudes 5º56′N and 6º52′N (Amalu & Ajake, 2014). The state shares boundaries with, Ebonyi State to the East, Anambra to the West, Abia State and Imo State to the south, Benue State to the North-East and Kogi State to the Northwest. It is 2545m above the mean sea level, with an area of about 79.25 square kilometers. Assessment of health effects of background ionizing radiations of telecommunication masts in Enugu Metropolis was carried out at 20 different base stations in Enugu Metropolis using radiation meter, a Geographical Positioning System (GPS), and 1m metre rule. The radiation meter used in this work to measure background ionization radiation (BIR) was the Radalert-100. The radiation meter was chosen owing to its portability, sensitivity and response which are suitable since the radiation measurement is for low radiation field (Agbalagba *et al.*, 2016). The Radalert 100 uses a Geiger-Muller tube to detect α, β, γ, and x-rays. A pulse of electrical current is produced by the Geiger tube any time radiation passes through it and results in ionization which the CPU registers as counts and is displayed on the screen. The Radalert 100 displays the readings in micro Sieverts per hour (μSv/hr) as the used SI units. The procedure for calibration is as reported in the monitors' operating manual (International Medcom, Radalert 100 Nuclear Radiation Monitor Operating Manual, 2013). Measurements from the Radalert-100 monitor were recorded in units of micro Serviet per hour (μSv/hr).

The method of radiation measurement used in this work was the direct observation and measurement of radiation levels from the base stations studied with the above-mentioned detector. The detector was held one meter above the ground surface with the aid a metre rule at each base stations and readings were taken. Each reading was recorded as it varied at intervals to compensate for any error due to fluctuation in the environment parameters (Rafique *et al.*, 2014). For each of the selected base stations, the mean background ionizing radiation (BIR) reading of each set of 10 and 15 measurements or readings was obtained and denoted as mean BIR exposure rate (average dose rate) for each point. The radiation absorbed dose rates (ADR) were evaluated using equation below

$1\mu R/h = 8.7\eta Gy/h$ 1

And $1\mu Sv/h = 870\eta Gy/h$; (note: $1R/h = 0.01Sv/h$ and $1\mu R/h = 0.01\mu Sv/h$)

The recommended ICRP dose limit of background ionizing radiation is $0.013mRh^{-1}$ (Nwachukwu *etal.*, 2021) which is equivalent to $0.00013mSvh^{-1}$ ($0.13\ \mu Svh^{-1}$)

The computed absorbed dose rates were used to calculate the annual effective dose equivalent (AEDE) using equation (2) below.

$AEDE = ADR\ (\eta Gy/h) \times 8760h \times 0.7\ Sv/Gy \times 0.2$ in mSv/y 2

ADR equals the absorbed dose rate in ηGy/h, 8760 equals the total hours in a year, 0.7Sv/Gy equals the dose conversion factor from absorbed dose in the air to the effective dose using an occupancy factor of 0.2 for outdoor exposure as recommended by UNSCEAR.

The excess lifetime cancer risks were evaluated using the annual effective dose values by employing equation (3).

$ELCR = AEDE\ (mSv/y) \times DL \times RF$ 3

Where AEDE is the annual effective dose equivalent, DL is the average duration of life (70 years) and RF is the fatal cancer risk factor per sievert (Sv^{-1}). For low-dose background radiation, which is considered to produce stochastic effects, ICRP 103 uses a fatal cancer risk factor value of 0.05 for public exposure (Paquet, Bailey, Leggett *et al.*, 2019).

The locations of each base stations which are majorly Enugu North and Enugu East Local Government Areas of Enugu State, include Okpara Avenue, Park Avenue, Railway Crossing, Fire Service, Emene Junction, Thinkers' Corner and Emene were measured with the aid of a global positioning system (GPS). Quantities measured were the longitudes, latitudes and altitudes (elevations). GPS is a space-based satellite navigation system that provides location and time information in all weather conditions, anywhere on or near the earth. It is maintained by the United States Government and is freely accessible to anyone with a GPS receiver.

3: Results and Discussions.

3.1: Results

The results of the BIR exposure level measurements for the 20 telecommunication base stations studied were presented in tables 1 and 2 respectively below and their calculated health radiological health parameters or indices were presented in tables 3 and 4 respectively below.

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3.1.1: Background Ionizing Radiations (BIRs) of the Twenty Telecommunication Base Stations (Masts 1-10 and Masts 11-20) and their associated Health Indices

Table 1: Results of Background Ionizing Radiations (BIRs) of the different Telecommunication Masts1 – 10

S/No	Mast1	Mast2	Mast3	Mast4	Mast5	Mast6	Mast7	Mast8	Mast9	Mast10
1	0.144	0.144	0.036	0.288	0.036	0.072	0.144	0.432	0.144	0.288
2	0.072	0.08	0.028	0.192	0.057	0.096	0.072	0.216	0.072	0.144
3	0.048	0.172	0.048	0.144	0.072	0.108	0.048	0.144	0.096	0.216
4	0.036	0.192	0.041	0.155	0.082	0.086	0.1	0.108	0.1	0.23
5	0.028	0.185	0.094	0.115	0.072	0.072	0.115	0.115	0.086	0.216
6	0.024	0.18	0.058	0.096	0.08	0.082	0.096	0.12	0.072	0.205
7	0.041	0.192	0.048	0.082	0.086	0.9	0.123	0.123	0.102	0.216
8	0.036	0.172	0.043	0.126	0.104	0.112	0.1	0.144	0.9	0.208
9	0.032	0.17	0.039	0.288	0.096	0.1	0.112	0.157	0.112	0.187
10	0.028	0.156	0.06	0.172	0.08	0.091	0.1	0.18	0.1	0.188
Mean	**0.0489**	**0.1643**	**0.0495**	**0.1658**	**0.0765**	**0.1719**	**0.101**	**0.1739**	**0.1784**	**0.2098**

Table 2: Results of Background Ionizing Radiations (BIRs) of the different Telecommunication Masts11 – 20

S/N	Mast11	Mast12	Mast13	Mast14	Mast15	Mast16	Mast17	Mast18	Mast19	Mast20
1	0.288	0.144	0.108	0.048	0.072	0.144	0.144	0.036	0.144	0.288
2	0.144	0.094	0.115	0.072	0.192	0.288	0.096	0.086	0.096	0.192
3	0.096	0.072	0.120	0.086	0.144	0.336	0.180	0.072	0.072	0.216
4	0.072	0.086	0.102	0.096	0.195	0.252	0.144	0.061	0.057	0.172
5	0.086	0.072	0.090	0.102	0.096	0.288	0.168	0.072	0.072	0.192
6	0.072	0.061	0.960	0.108	0.082	0.264	0.205	0.064	0.061	0.164
7	0.061	0.054	0.100	0.096	0.072	0.246	0.216	0.057	0.054	0.162
8	0.054	0.048	0.117	0.129	0.064	0.252	0.224	0.065	0.048	0.192
9	0.048	0.043	0.108	0.13	0.072	0.24	0.216	0.084	0.043	0.172
10	0.056	0.052	0.990	0.12	0.065	0.216	0.209	0.077	0.052	0.170
11	0.091	0.048	0.113	0.121	0.060	0.196	0.192	0.082	0.048	0.156
12	0.084	0.055	0.105	0.113	0.088	0.192	0.172	0.086	0.044	0.155

13	0.088	0.061	0.108	0.105	0.082	0.188	0.174	0.099	0.041	0.164
14	0.092	0.067	0.11	0.108	0.086	0.185	0.163	0.093	0.048	0.172
15	0.086	0.072	0.104	0.101	0.081	0.172	0.153	0.096	0.063	0.162
Mean BIR	**0.0945**	**0.0686**	**0.2233**	**0.1023**	**0.0967**	**0.2306**	**0.1770**	**0.0753**	**0.0628**	**0.1819**

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Table 3: Radiation Health Indices associated with BIR of different Telecommunication Masts.

			Radiation Health Indices			
Masts	**Location Name**	**Geographical Location**	**Mean BIR**	**ADR (nGy/h)**	**AEDE (mSv/y)**	**ELCR $\times 10^{-3}$**
1	30 ATANI ST., ABAKPA	N06°29'0389" E007°31'0774"	0.0489	42.543	0.0521	0.1826
2	32 NKPOR ST, ABAKPA	N06°29'0690" E007°0399''	0.1643	142.941	0.1753	0.6135
3	1 OBA ST, ABAKPA	N06°28'8325" E007°30'8179"	0.0495	43.065	0.0528	0.1848
4	35 NIKE RPOAD, OPP SLAUGHTER	N06°28'7417" E007°30'9810"	0.1658	144.246	0.1769	0.6191
5	ENYO FILLING STATION, GARDEN AVENUE	N06°27'0985" E007°29'6308"	0.0765	66.555	0.0816	0.2856
6	GRA, ENUGU, NEAR ALL SAINT, ANG. CHURCH, ABKL RD	N06°27'3936" E007°29'6295"	0.1719	149.553	0.1834	0.6419
7	37 PARK AVENUE	N06°27'7364" E007°27'9080"	0.0101	8.787	0.0107	0.0377
8	5/7 CHIME LANE	N06°27'6095" E007^0 30'4614"	0.1739	151.293	0.1855	0.6494
9	FIRE SERVICE B/S, STAND 3R	N06°27'5267" E007^0 30'5734"	0.1784	155.208	0.1903	0.6662
10	RAILWAY CROSSING FIRE SERVICE	N06°27'5582" E007°30'5138"	0.2098	182.526	0.2238	0.7834
Mean			**0.1249**	**108.671**	**0.1332**	**0.4664**
World Average Value			**0.13**	**59.00**	**0.07**	**0.29x10^{-3}**

Table 4: Radiation Health Indices associated with BIR of different Telecommunication Masts.

				Radiation health indices		
Masts	**Location Name**	**Geographical Location**	**Mean BIR (µSv/h)**	**ADR (nGy/)**	**AEDE (mSv/y)**	**ELCR ×10^{-3}**
11	BUS. ADMIN DEPT, GO UNI.	N06°28'2706" E007°31'6555"	0.0945	82.215	0.1008	0.3528
12	10 TOWN SCHOOL RD, EMENE	N06°29'2988" E007°34'7203"	0.0686	59.682	0.0731	0.2561
13	STUASIA CLOSE, EMENE	N06°28'4218" E007°34'7143"	0.2233	194.271	0.2382	0.8338
14	14 OGUGUA ST., MAINLAND	N06°27'9678" E007°34'0964"	0.1023	89.001	0.1091	0.3820
15	C TO C MAINLAND	N06°27'5286" E007°34'6581"	0.0967	84.129	0.1031	0.3611
16	STATE TRAFFIC, ENUGU	N06°27'8480" E007°31'4234"	0.2306	200.622	0.2460	0.8611
17	STATE TRAFFIC, ENUGU (MTN)	N06°27'8461" E007°31"4283"	0.1771	154.077	0.1889	0.6613
18	3 ONYEBUCHI EZE AVENUE, BY EMENE JUNCTION	N06°27'7953" E007° 31'7831"	0.0753	65.511	0.0803	0.2811
19	9 ONYEBUCHI EZE AVENUE, BY EMENE JUNCTION (MTN)	N06°21'7928" E007° 31'8573"	0.0629	54.723	0.0671	0.2348
20	INFRA FILLING STATION, THINKER'S CORNER	N06°28'0184" E007°31'8115"	0.1819	158.253	0.19408	0.67928
Mean			**0.1313**	114.248	0.1401	0.4903
WorldAverage Value			**0.13**	**59.00**	**0.07**	**0.29x10^{-3}**

3.1.2: Comparison of the Calculated Health Indices with International Permissible Safety Limits or standards.

The comparison and variation of the estimated radiation health indices with the international (ICRP/UNSCEAR) permissible safety limits are statistically presented in figures 1 to 8 below for clearer understanding of tables 3 and 4 above.

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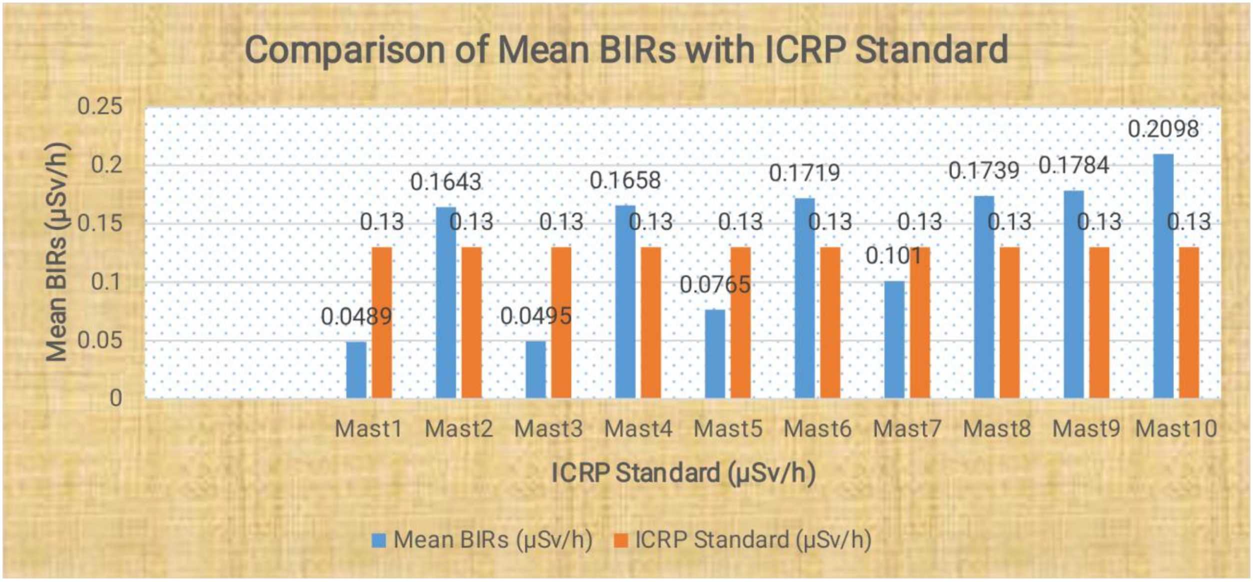

Figure 1: Comparison of Mean BIR with ICRP Standard of Masts 1-10

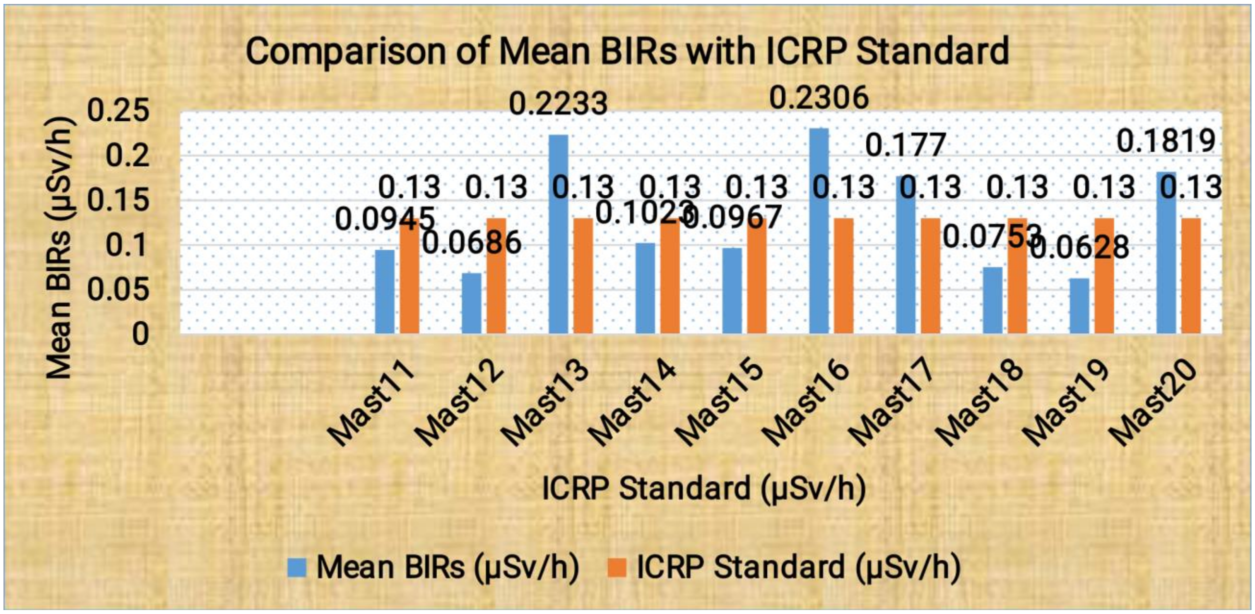

Figure 2: Comparison of Mean BIR with ICRP Standard

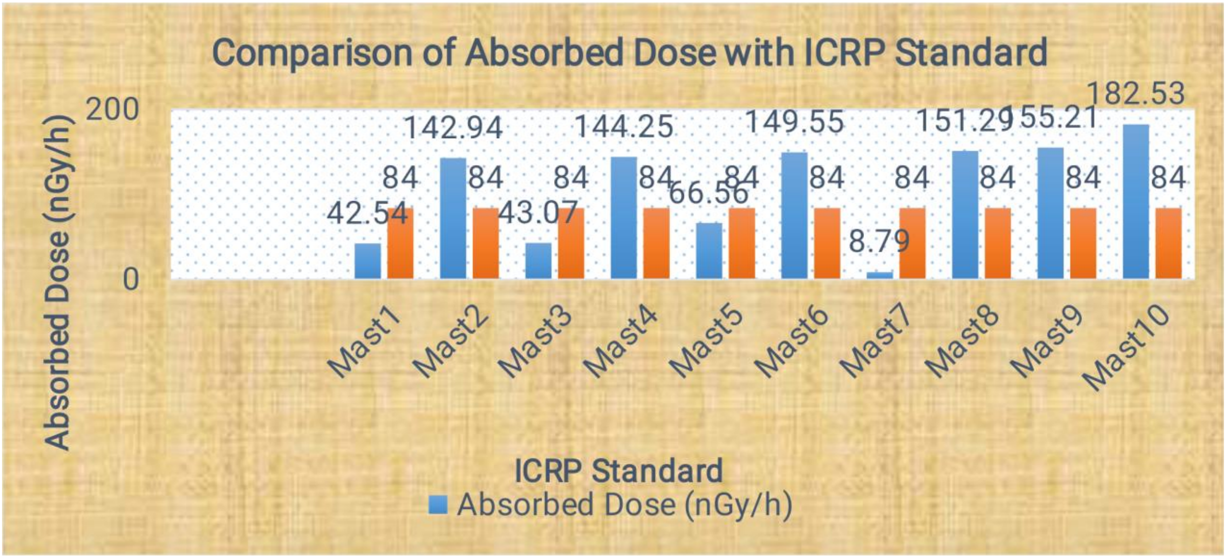

Figure 3: Comparison of Absorbed Dose with ICRP Standard

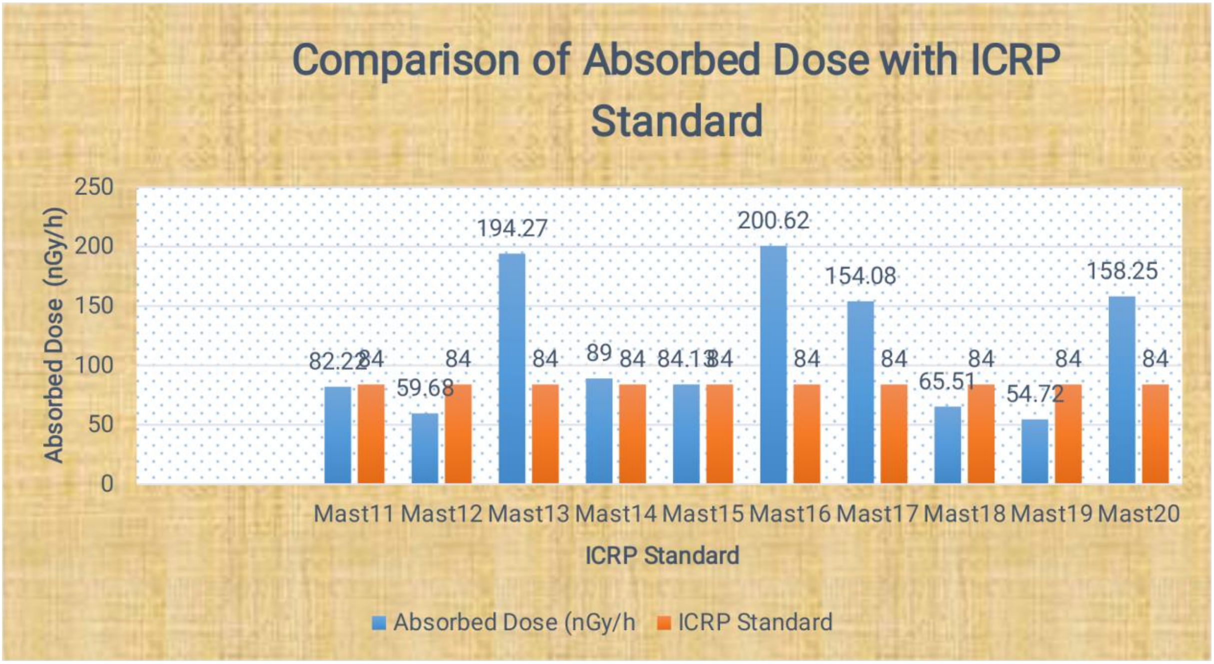

Figure 4: Comparison of Absorbed Dose with ICRP Standard

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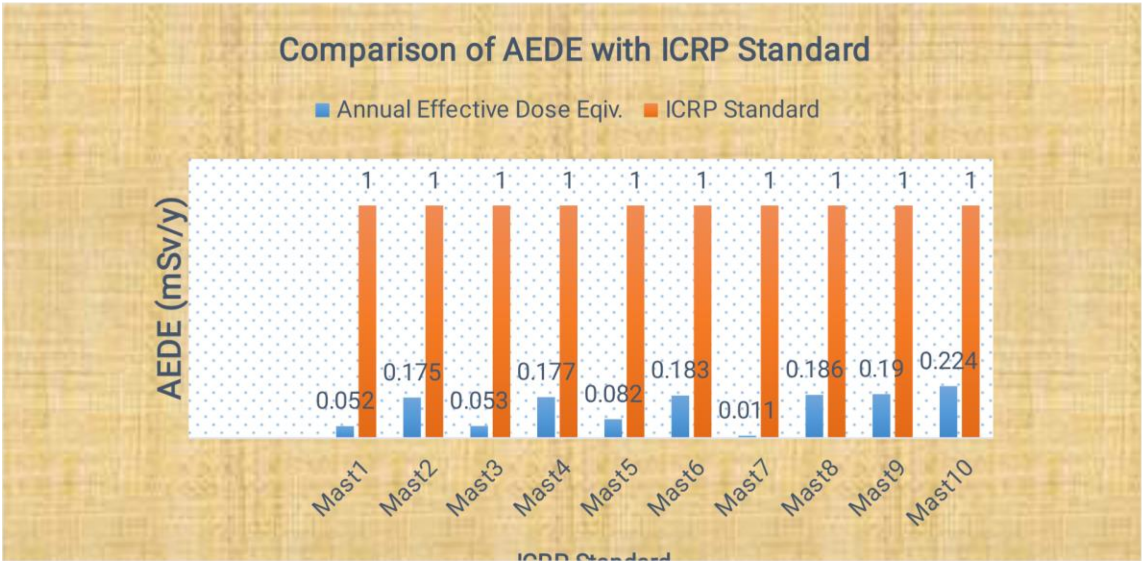

Figure 5: Comparison of AEDE with ICRP Standard

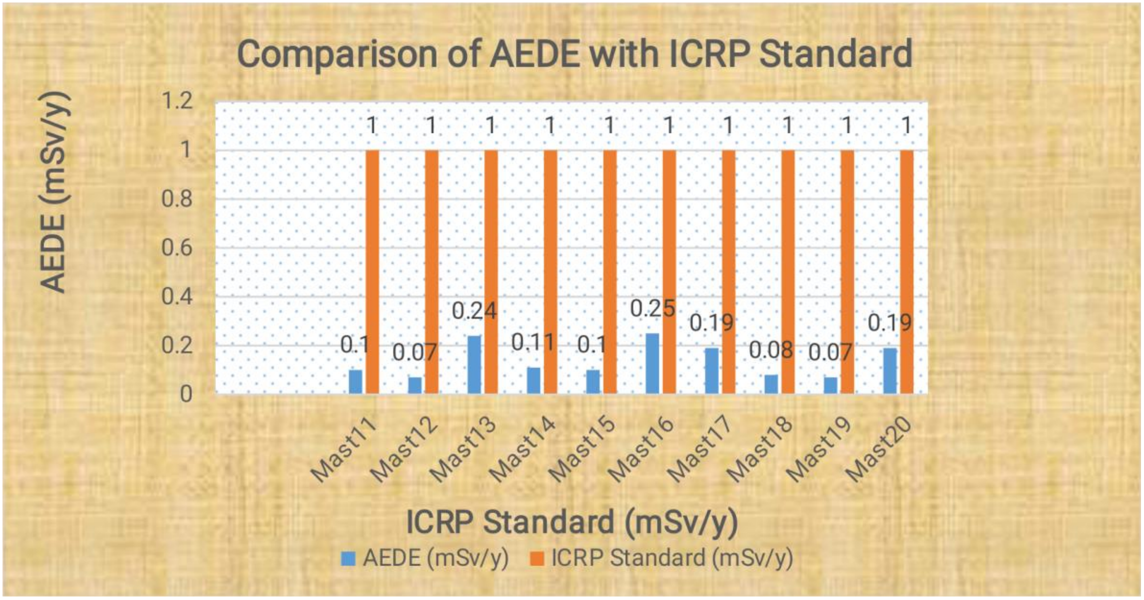

Figure 6: Comparison of AEDE with ICRP Standard

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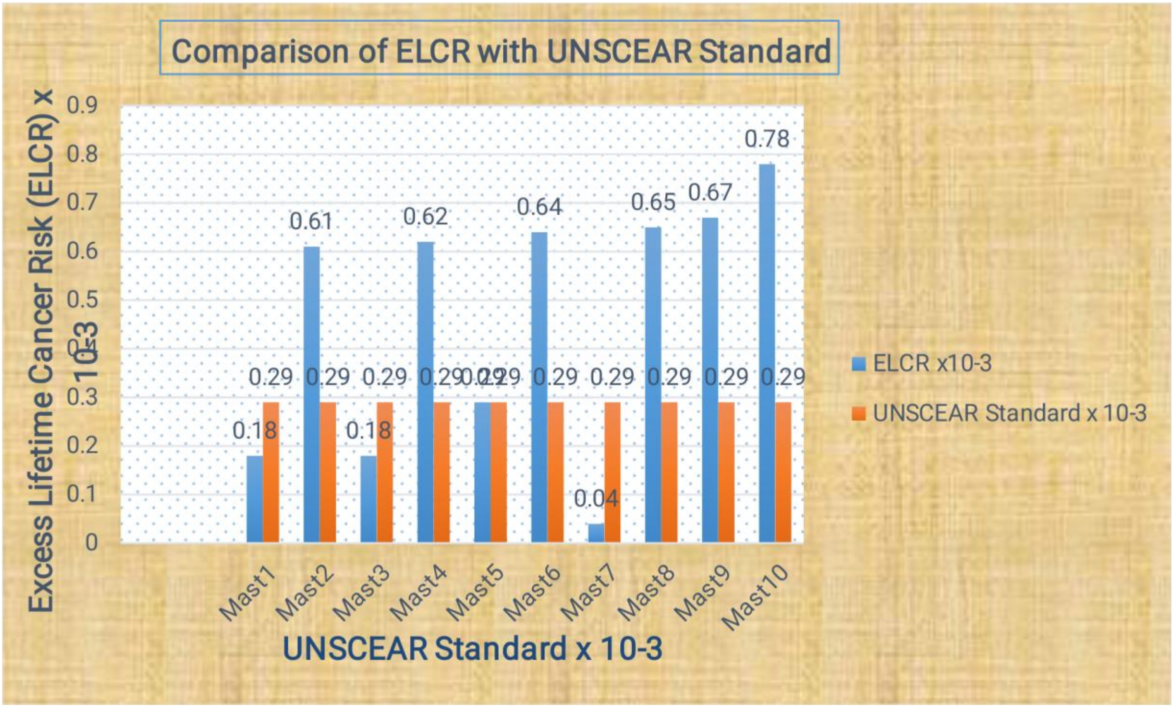

Figure 7: Comparison of ELCR with UNSCEAR Standard

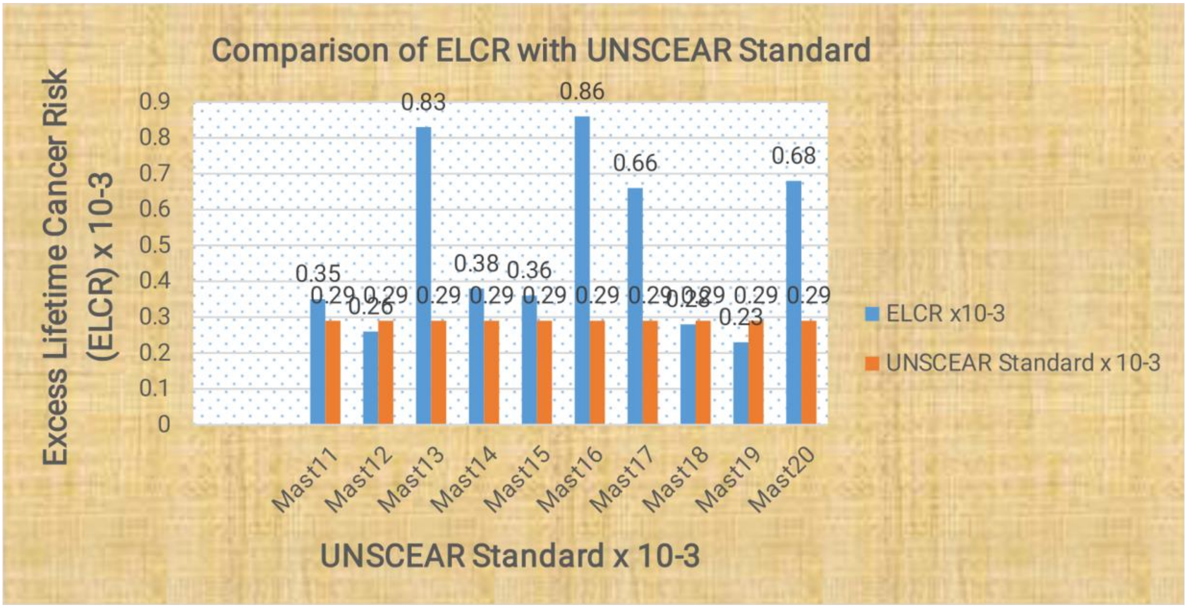

Figure 8: Comparison of ELCR with UNSCEAR Standard

3.2: Discussions

The BIR exposure levels of the first ten Base stations displayed in table 1 above ranged from 0.028µSv/h to 0.432µSv/h with a total mean value ranging from 0.0489 µSv/h to 0.2098 µSv/h. Mast 8 had the highest maximum value (0.432 µSv/h), with its minimum value of 0.108 µSv/h and mean value of 0.1784 µSv/h. Mast 4and mast10 both had the second highest maximum BIR values of 0.288 µSv/h, their minimum BIR values were 0.082 µSv/h and 0.144 µSv/h respectively, while their mean BIR values were 0.1658 µSv/h and 0.2098 µSv/h respectively. Masts 1, 2, 7 and 9 had maximum BIR values of 0.144 µSv/h, minimum BIR values of 0.028 µSv/h and 0.08 µSv/h for 1 and 2 respectively and 0.1 µSv/h for both mats 7 and 9. Masts 1 and 3 both had the lowest minimum BIR values of 0.024 µSv/h and maximum values of mast 1 already reported while that of mast 3 was 0.094 µSv/h. Masts 5 and 6 ranged from 0.036 - 0.104 µSv/h and 0.072 – 0.112 µSv/h respectively. Their mean values were 0.0765 µSv/h and 0.1719 µSv/h respectively.

In all, the BIR exposure levels of masts 2, 4, 6, 8, 9 and 10 were observed to be very high as all their mean BIR values (0.1643, 0.1658, 0.1719, 0.1719, 0.1739, 0.1784 and 0.2098 respectively) were observed to be much higher than ICRP safety limit of 0.13 µSv/h. The radiation levels of mast10 is dangerous owing to its closeness to an open mechanic workshop where people receive radiations directly from the mast as they work daily within the premises. Contrarily, BIR exposure levels of masts1, 3, 5, and 7 are low as the all their mean values (0.0489, 0.0495, 0.0765 and 0.0101 respectively all in µSv/h were observed to be lower than ICRP safety limit of 0.13 µSv/h, implying that they are in line with ICRP safety limit

Similarly, the background ionization radiation (BIR) levels of the last ten base stations displayed in table 2 (masts11 – 20) ranged from 0.990 – 0.036 µSv/h with a total mean ranging from 0.0628 to 0.2306 µSv/h. Mast11 ranged from 0.288 µSv/h to 0,048 µSv/h with mean value of 0.0945 µSv/h, masts 12 and 19 both having the lowest BIR levels, had maximum BIR of 0.144 µSv/h and minimum BIR of 0.043 µSv/h and 0.041 µSv/h respectively and mean BIR values of 0.0686 µSv/h and 0.0638 respectively. Mast13 had the highest BIR level which ranged from 0.090 µSv/h – 0.990 µSv/h, with mean BIR value of 0.2233 µSv/h, followed by mast16 having the highest mean BIR value of 0.2306 µSv/h and BIR ranging from 0.144 µSv/h to 0.336 µSv/h. Masts14, 15, 17, 18 and 20 had their BIR level range from 0.048 – 0.129 µSv/h, 0.060 – 0.195 µSv/h, 0.096 – 0.224 µSv/h, 0.036 - 0.099 µSv/h and 0.155 – 0.288 µSv/h, with their mean BIR values as 0.1023 µSv/h, 0.0967 µSv/h, 0.1770 µSv/h, 0.0753 µSv/h and 0.1819 µSv/h respectively.

The BIR exposure levels of masts 13, 16, 17 and 20 were observed to be very high as all their mean BIR values (0.2233 µSv/h, 0.2306 µSv/h, 0.1771 µSv/h and 0.1819 µSv/h respectively) were observed to be much higher than ICRP safety limit of 0.13 µSv/h. On the contrary, the BIR exposure levels of masts11, 12, 14, 15 and 18 were low as the all their mean values (0.0945, 0.0686, 0.1023, 0.0967, 0.0753 and 0.0629 respectively all in µSv/h were observed to be lower than ICRP safety limit of 0.13 µSv/h, thus, signifying that they were in line with ICRP safety standard.

The variations in BIR can be majorly attributed to the RF radiation from the base stations. The high values of BIR can further be traced to the different geological and geophysical characterization of the environments, (Ugbede, 2018; Nwachukwu *et al.*, 2021)

The radiation health indices associated with the mean BIR levels from the twenty studied base stations (masts 1-10 and masts 11-20) were displayed in table 3 and 4 respectively above

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The radiation health indices (which include the mean absorbed dose (ADR), annual effective dose equivalent (AEDE) and excess cancer lifetime rate (ELCR) associated with the mean BIR levels from masts 1 -10 are and 11 – 20 were displayed in tables 3 and 4 respectively

In table 3, the estimated absorbed dose rates (ADRs) from the mean BIR of Mast 1-10, representing telecom base station located at 30 Atani St., Abakpa, 32 Nkpor St., Abakpa, 1 Oba St., Abakpa, 35 Nike Rd., opposite Slaughter, Abakpa, Enyo Filling Station, Garden Avenue, GRA, Enugu, near All Saint, Ang. Church, Abakaliki Road, 37 Park Avenue, 5/7 Chime Lane, Fire Service B/S, Stand 3R and Railway Crossing Fire service respectively as depicted in table 3 were 42.543, 142.941, 43.065, 144.246, 66.555, 149.553, 8.787, 151.293, 155.208, 182.526 nGy/hr respectively with mean value of 108.672 nGy/hr. It was observed that the mean ADR arising from the 10 base stations and the specific ADRs from the BIR levels of masts 2, 4, 6, 8, 9 and 10 (which include 142.941, 144.246, 149.553, 151.293, 155.208 and 182.526 nGy/hr respectively) were far above both world average value (WAV) of 59 nGy/h and the ICRP recommended safe limit of 84.0 nGy/hr h (Benson & Ugbede, 2018; Agbalagba, 2017; Monica, Visnu, Soniya & Jojo, 2016; Kwan-Hoong 2003**;** Bandara, 2016; UNSCEAR, 2018; Ononugbo & Mgbemere, 2016)**.**

The radiation levels of mast 2 located at 33 Nkpor Street, Abakpa is dangerous considering its location in the compound where both children and adults live, especially children who spend reasonable time playing around the base station. Also, the radiation levels of mast 10 is dangerous given its closeness to an open mechanic workshop where people receive radiations directly from the mast as they work daily within the premises. ADR value of mast 5 located at Enyo Filling Station, Garden Avenue, was 66.555 nGy/hr. This value was higher than the world average value and lower the ICRP recommended safe limit. Mast 7 located at 37 Park Avenue had the least ADR value of 8.787 nGy/hr, followed by mast 1 and 3 located at 30 Atani St., Abakpa and 1 Oba St., Abakpa with their estimated absorbed dose rates of 42.543 and 43.065 nGy/hr respectively were lower than both the world average value and ICRP permissible limit. The least value of the mean BIR and the associated health indices of mast7 was as a result of the far distance between the base station and the point where readings were taken, as there was no access to the base station

In as much as the mean absorbed dose rate of BIR exposure from the studied masts and the specific ADR values from the BIR levels of masts 2, 4, 6, 8, 9 and 10 were higher than the ICRP safety limit, they do not pose any instant radiological threat to human health, evidenced by their associated annual effective dose equivalent values which were lower than the ICRP permissible limits.

In table 4, the calculated absorbed dose rates (ADRs) from the mean BIR of Masts 11-20, representing base station located at Business Administration Department, Godfrey Okoye University, Enugu, 10 Town School Rd, Emene, STUASIA Close, Emene, 14 Ogugua St., Mainland, C TO C Mainland, State Traffic 1, State Traffic 2, 3 Onyebuchi Eze Avenue, by Emene Junction, 9 Onyebuchi Eze Avenue, by Emene Junction and Infra Filling Station, Thinker's Corner were 82.21, 59.68, 194.27, 89.00, 84.13, 200.62, 154.07, 65.51, 54.72 and 158.25 nGy/h respectively with their mean value of 114.25 nGy/h. It was observed that the calculated value (54.72 nGy/h) of ADR from the BIR levels of only mast9 base station (9 Onyebuchi Eze Avenue, by Emene Junction) fell below the world average limit of 59 nGy/h, implying that it was in good agreement with the global permissible limit. Values of 59.68nGy/h, 65.51nGy/h and 82.2nGy/h from BIR level of mast 12, 18 and 11 (10 Town School Rd, Emene, 3 Onyebuchi Eze Avenue, by Emene Junction and Business Administration Department, Godfrey Okoye University, Enugu, respectively were observed to be above world average value (WAV) of 59nGy/h and lower than the ICRP safe limit of 84nGy/h while that of 84.13nGy/h for mast 15 approximately corresponds to the ICRP safe limit. Furthermore, the calculated mean ADRs value from the BIR levels of masts 11 – 20 and the specific values of 194.27, 89.00, 200.62, 154.07 and 158.25nGy/h calculated from BIR levels of masts 3, 4, 6, 7 and 10 were all observed to be far above ICRP limit of 84nGy/h.

In as much as the mean absorbed dose rate of BIR exposure from the studied masts and the specific ADR from the BIR levels of masts 2, 4, 6, 8, 9 and 10 were observed to be higher than the ICRP safe limit, they do not cause any instant radiological threat, supported by their associated annual effective dose calculated values which were lower than the ICRP permissible limits

The mean AEDE value as well as the values associated with masts 2, 4, 5, 6, 8, 9 and 10 were all higher than the UNSCEAR recommended limit of 0.07 mSv/yr (Benson & Ugbede, 2018); (Agbalagba, 2017); (Al Mugren, 2015), but lower than the ICRP recommended permissible limits of 1.00 mSv/yr for the general public and 20.00 mSv/yr for occupational workers respectively within a year recommended by (ICRP, 2007; Benson & Ugbede, 2018**;** ICRP, 2007; UNSCEAR, 2008; Ugbede & Echeweozo, 2017). The estimated values of AEDE arising from BIR levels of masts 1 and 3 were slightly lower than the world average value (WAV), while that of mast 7 having the lowest AEDE value was much lower than the WAV. These indicates that the studied masts are in good agreement with permissible safe limit and do not result to any instant radiological health effect on the general public.

The annual effective dose equivalent AEDE associated with masts 11 – 20 were 0.100, 0.073, 0.238, 0.109, 0.103, 0.246, 0.188, 0.080, 0.067 and 0.194mSv/h with the mean value of 0.140mSv/h (table 4). The minimum value of the AEDEs from the BIR levels of these masts was 0.067mSv/y for mast 19 located at 9 Onyebuchi Eze Avenue, by Emene Junction, followed by 0.073mSv/y value of mast 12 located at 10 Town School Rd, Emene), both approximately corresponded to the world average value of 0.07mSv/y. Other AEDE calculated values associated with masts 11, 13, 14, 15, 16.17, 18, and 20 as well as their mean value stated above were far above world average value (WAV) and lower than the ICRP permissible safe limit.

In table 3, the estimated ELCR value from BIR levels from masts 1, 3 and 7 were 0.182 $\times 10^{-3}$, 0.185 $\times 10^{-3}$ and 0.038 $\times 10^{-3}$ respectively. Mast 7 having the lowest value, followed by that of masts 1 and 3 respectively. These excess lifetime cancer risk for these stations' users were all lower than the 0.29 $\times$ 10^{-3} world recommended value, and therefore, suggests that the base stations' workers will not likely develop radiation-related illnesses over a longer time, the ELCR value for mast 5 was approximately 0.29 $\times$ 10^{-3} which corresponds to the recommended world average value (WAV), while the cancer risk values for masts 2, 4, 6, 8, 9 and 10 (which include.0.61$\times$ 10^{-3}, 0.62$\times$ 10^{-3} , 0.64$\times$ 10^{-3} , 0.65$\times$ 10^{-3} , 0.67$\times$ 10^{-3} and 0. 78$\times$ 10^{-3} as well as the mean value of the studied masts were much higher than the average value of 0.29$\times 10^{-3}$ (Audu, Avwiri & Ononugbo, 2019; Nwachukwu *et al.*, 2021; UNSCEAR, 2008 and 2018; Avwiri *et al*., 2016). The implication of this is that workers who visit the base stations on daily basis and members of the public who either live or work few meters away from the stations and end up spending long hours within the stations are likely to develop cancer at ages of 65 to 70 years or above of their lifetime (Nwachukwu *et al.,* 2021).

Moreover, considering the cancer risk values (ELCR) associated with masts 11 – 20 (0.35x10^{-3}, 0.26x10^{-3}, 0.83x10^{-3}, 0.38x10^{-3}, 0.36 x10^{-3}, 0.86 x10^{-3}, 0.66 x10^{-3}, 0.28 x10^{-3}, 0.23 x10^{-3} and 0.68 x10^{-3} respectively), depicted in table 4, it was observed that the first three lowest cancer risk values were 0.23 x10^{-3}, 0.26x10^{-3} and 0.28 x10^{-3} for masts 19, 12 and 18 respectively, all were lower than the world average value of 0.29 x10^{-3} as recommended by UNSCEAR (Audu *et al.,* 2019; Nwachukwu *et al.,* 2021; UNSCEAR, 2008 and 2018; Avwiri *et al.,* 2016), thus, implying no excess life cancer risk for workers who visit the base stations on daily basis and members of the public who either live or work few meters away from the stations and end up spending many hours within the stations. On the other hand, the cancer risk values associated with masts 11, 13, 14, 15, 16, 17 and 20 (0.35x10^{-3}, 0.83x10^{-3}, 0.38x10^{-3}, 0.36 x10^{-3}, 0.86 x10^{-3}, 0.66 x10^{-3}, and 0.68 x10^{-3} respectively), were observed to be much higher than the world average value of 0.29 x10^{-3} as recommended by UNSCEAR. This indicates that workers who visit the base stations on daily basis and members of the public who either live or work few meters away from the stations and end up spending many hours within the stations are likely to develop cancer at ages of 65 to 70 years or above of their lifetime (Nwachukwu *et al.*,, 2021)**.**

It is therefore, recommended that the radiation levels of the masts and the surroundings be checked against additional rise. The high ELCR values from the above studied base stations were due to the high absorbed dose and AEDE resulting from high BIR exposures (table 3 and 4) which were attributed to enhanced concentration of natural radionuclides in the environment due to human activities. Thus, critical observations reveal that the estimated values of all the health indices arising from the BIRs of masts 11 – 20 were much higher that estimated from BIR of masts 1 – 10 (tables 3 and 4)

Note:

For clearer understanding of the entire work, the variation of the mean BIRs levels and their associated health indices with the international safety limits were presented in the bar charts displayed in figures 1-8 above.

4: Conclusion.

The background ionizing radiation (BIRs) measurements of twenty different base stations (masts 1-10 and masts 11-20) were studied in this work, and among them, the mean BIRs of ten base stations were found to be higher than the ICRP recommended safe limit of 0.13 μSvh^{-1} (0.013mR/h) while the BIRs of the remaining ten base stations were observed to be lower than the ICRP recommended safe limit. Close observations reveals that the radiation exposure level from mast 11-20 were quite higher those emitted by masts 1- 10 as reflected in both their respective mean values and their associated health indices values (tables 3 and 4). The high BIRs values can be traced primarily to RF radiation released from the masts. It also be attributed to the geological formations, the enhanced concentration of radionuclides and geographical settings of the area. The estimated values of the average dose rate (ADR in nGy/h) of ten base stations among the 20 were observed to be above the ICRP permissible limit of 84nGy/h, one value corresponds to the ICRP permissible limit of 84nGy/h, four were lower than ICRP permissible limit but above the world (UNSCEAR) average value and four values fell below both the word average value and the ICRP permissible limit, and thus are in agreement with both world average (UNSCEAR) value and ICRP standard. In as much as the mean absorbed dose rate of BIR exposure of the ten masts were higher than the ICRP safety limit, it does not result to any instant radiological risk. This is evidenced by the estimated values of the annual effective dose (AEDE) of the masts which were all lower than the ICRP permissible limits of 1 $mSvy^{-1}$. The associated excess lifetime cancer risk (ELCR) values from the BIRs from thirteen base stations were all observed to be far above the UNSCEAR recommended average value of 0.29×10^{-3}, implying that people who live or work close to the base stations and who spend long time there, have high potential of developing cancer from the ages of 65 years and above, one corresponds to the UNSCEAR recommended average value. For the remaining six base stations whose associated ELCR values fell below world average standard of $0.29\times10^{-3,}$ people who live or work close to them and spend long time there, do not have the potential of developing cancer throughout their life time.

Though, the studied base stations do not create immediate hazard both to human health and the environment; the result showed they undoubtedly do on the long run.

Therefore, it is recommended that consistent radiological checks be maintained, and the data taken as a radiological reference point for telecommunication masts in Enugu State.

This should be stretched to the unchecked base stations particularly those found within public facilities and inhabited areas like some of the ones studied in this work. The NESREA 10-meter setback of base stations from residential buildings should be sternly adhered to, as observations revealed that it is not often the case.

It is however required that periodic BIR check and assessment be carried out at the base stations against additional rise

This study has been well considered or characterized and the results will serve as a reference data to public health agencies and the government in planning and monitoring of radiation protection programs and for future research purposes.

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