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Baseline Study of Radiofrequency Emission from Telecommunication Base Station in Umuahia Urban, Nigeria

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Abstract
There has been a proliferation of Base Transceiver Stations (BTS) in recent years especially in urban areas due to an expansion of Mobile telephone networks. This has been accompanied by an increase in the level of community concern about possible health effects of radiation emissions from BTSs in Umuahia urban. Based on this, a baseline study of radiations from BTS in Umuahia urban was conducted to provide information on the levels of radiation to which members of the public may be exposed. Measurements of non-ionizing RF power density were made with a hand held TES-92 Electrosmog meter held at 1.5 m above the ground level. A maximum of 300 m radial distance from the foot of each BTS was considered, and measurements were made at 25m intervals from 60 BTSs. The minimum mean power density from individual BTS in the study area was 65.66μW/m^2, with the significance level of 0.5% contribution; while the maximum was 553.98μW/m^2 with 4.0% contribution. The maximum and minimum power densities of the combined BTS surveyed were 32888μW/m^2, 2070.97μW/m^2 between 0.0 m and 300 m radial distance respectively. This signifies that mean power density of a BTS decreases with increase in radial distance and that radiation intensity varies significantly from one BTS to another even at the same distance away. Results also showed significant variations in power density in the interaction of one BTS with another and one radial distance with another; with a coefficient variation of 6.5% and 12.3% respectively for BTS and radial distance. The RF power density exposure hazard index was below the permitted RF exposure limits of 4.5W/m^2 and 9.0W/m^2 ICNIRP recommended standard. In view of the potential hazards of long-term exposures, mobile network providers should adopt at least 150m setbacks for BTS installation in residential and densely populated areas and those BTS with high power densities radiation emissions should be relocated.

Key words: Base Station, Power Density, Radiations, Umuahia Urban.

1.0 Introduction

Rapid developments in various fields of science and technology in recent years have intensified the human interference into the natural environment and associated physical, biological and ecological systems. The intensity of man-made electromagnetic radiation has become so ubiquitous and it is now increasingly being recognized as a form of unseen and insidious pollution that might perniciously be affecting life forms in multiple ways (Balmori, 2009). The electromagnetic fields (EMF) as a pollution called electro-smog is unique in many ways. Unlike most other known pollutants, the electromagnetic radiations are not readily perceivable to human sense organs and hence, not easily detectable. However, their impacts are likely to be insidious and chronic in nature. It is possible that other living beings are likely to perceive these fields and get disturbed or sometimes fatally misguided (Carpenter, 2010).

Radiofrequency emissions and associated phenomena can be discussed in terms of energy, power, radiation or field. According to Bello (2010), electromagnetic radiation can best be described as waves of electric and magnetic energy moving together through space. Many things have been said about electromagnetic radiations and its likely dangerous consequences on the lives of the people living around its emission sites as reported by (Santini *et al*, 2002). It is known from a variety of scientific studies including microwave engineering that significant biological effects result from non-thermal effects of extremely periodic pulsed high frequency radiations (Lonn *et al*, 2005).

Base stations and mobile phones form part of the infrastructure required for effective communication system (Henderson *et al*, 2006). A base station is therefore an integral component of mobile communication. In terms of their license, the service providers are obliged to provide an adequate coverage for their clients and to achieve this; they must provide an infrastructure of base stations and masts capable of meeting their legal requirements (Bechet *et al*, 2013). Majority of these towers are installed near residential and office buildings to provide good mobile phone coverage to the users. In cities, millions of people reside within these high radiation zones. Cell phone traffic through a single site is limited by the base station's capacity; there are a finite number of calls or data traffic that a base station can handle at once. This limitation is another factor affecting the spacing of cell mast sites. In suburban areas, masts are commonly spaced 2-3Km apart and in dense urban areas, masts may be as close as 400-800m (Hoskote *et al*, 2008; Mixon *et al*, 2009).

The introduction of GSM phone with the unregulated sitting of communication base stations had increased the exposure of great percentage of the population to electromagnetic radiation and the concomitants environmental and health hazards in developing countries, and this has continued to generate strong concerns (Deatanyah *et al* (2012). This notwithstanding, GSM has become a vital and an indispensable tool of transmitting or exchanging of information for a modern man. Not only that, it is a significant infrastructure that promotes the growth and development in every facets of man's activities such as agriculture, education, industry, banking, transportation etc. Unfortunately, presently it is not technologically feasible to have mobile telephone without base stations. To communicate with each other, mobile phones and base stations must exchange signals (Kim *et al*, 2010). The basic fact is that there are practical limitations to the geographical area that a base station can effectively serve and a limit to the number of calls it can accommodate at a point in time (Viel *et al*, 2009).

Nigeria is one of the fastest growing GSM Industries in the world and is gradually becoming a global village due to great advancement in telecommunications. A major breakthrough is the wireless telephone system especially GSM. According to Genc *et a*l (2010), the market for mobile telecommunication is very big and it is a major economic driver in many Countries including Nigeria (Bechet *et al*, 2012).During the last 16 years, Nigeria has seen exponential growth of mobile telephoning. With this growth, a number of private and government players are coming in to this lucrative and growing sector. Nigeria is one of the top largest and one of the fastest growing telecommunication markets in the world, with 27 mobile wireless telecommunication service providers. More than 35, 000 Base Transceiver Stations (BTS) spread across the Country, with above 148 million active lines (handsets) connected and over 92 million internet users and more than 26 million smart phone users (Yahaya ,2015) . However, necessary regulatory policies and their implementation mechanism have not kept pace with the growth of mobile telephoning. Therefore, the general objective of the survey was to determine whether the Radiofrequency power density radiations from base stations in Umuahia Urban comply with recommended thresholds and standards concerning health risks.

2.0 Study Area

Umuahia, the Abia State capital, has witnessed remarkable expansion, growth and developmental activities such as the construction of buildings and infrastructure as well as many other anthropogenic activities since 1991. This has therefore resulted in a sustained increase in urban land usage, modification and alterations of Umuahia and its environs over time. Umuahia is located along the rail road that lies between Port Harcourt to Umuahia's south and Enugu to its north. It has an area of 245 km² and a population of 220,660 at the 2006 census (Nnadozie, 2014). It lies between latitudes 5º 33′ 20′′ N and longitude 7º 28′ 52′′E. Located within the equatorial belt of Nigeria, the area is dominated by a tropical rainforest vegetation and climate which is characterized by two distinct weather seasons: rainy and dry seasons. The area is characterized by a long dry season (November-March) and a longer rainy season (April-October). The mean annual rainfall is between 2,500mm to 3,100mm (Onyeka *et al,* 2008). The monthly mean temperature ranges from 25^0C to 32^0C, while mean relative humidity ranges from 60-90%. Highest and lowest monthly mean relative humidity is observed during rainy and dry seasons respectively. Our area of interest in this study was Umuahia North, which specifically was categorized into seven distinct political boundaries: Afara Area, Amuzukwu Area, Umuahia Urban 1 Area, Umuahia Urban 3 Area, Ossah Area, Ugwunchara Area and World Bank Area.

3.0 Materials and Methods

In this research work, the method of broadband analysis was employed in the measurements. TES-92 Electrosmog meter was used in the RF survey. The meter is a hand held

Broad band device for monitoring high frequency radiation in the range of 50 MHz to 3.5 GHz. The meter measures the value of the electric field E and converts it into the magnetic field H and then power density S using equation (1) according to (ICNIRP, 1998). Power density S (i.e. the power per unit area) is expressed in Watts per Meter squared (W/m²). Measurements of RF radiation (Power density) were made by pointing the meter to the source of the RF radiation. A maximum of 300m radial distance from the foot of the base station was considered and measurements were taken at 25m interval from each base station. The proximity of residential /commercial buildings to base stations and the manner in which structures were erected around the base stations was noted during the field work. A total of 60 base stations geo-referenced in the study area were considered. The meter was set to the triaxial measurement mode and also to the maximum instantaneous measurement mode, to measure the maximum instantaneous power density at each point. Each measurement was made by holding the meter away from the body, at arm's length and at about 1.5m above the ground level pointing towards the mast as suggested by Ismail *et al* (2010). The values of the measured power densities taken were recorded after the meter was stable (about 3 minutes). We ensured that the measured values were not influenced by unwanted sources and disturbances. Such precautions taken were to avoid the movement of the meter during measurements. We also ensured (where possible) that movement of cars and phone calls were reduced before taking measurements.

4.0 Results and Discussion

Results

The maximum power density values occurred at a radial distance of 0m away from the foot of the base stations. Power densities varied significantly from one base station to another and from one radial distance to another, depending on prevailing factors at the base transceiver station.

Table 1: Measured Power Density (μW/M²) of Surveyed BTSs at 25m Distance Interval

	Radial Distance (M)												
BTS	**0**	**25**	**50**	**75**	**100**	**125**	**150**	**175**	**200**	**225**	**250**	**275**	**300**
1	607	401	298	228	221	196	147	107	101	89	84	70	50
2	787	587	510	360	306	216	191	144	137	120	80	56	42
3	575	543	447	395	289	231	201	139	115	94	67	89	48
4	818	724	654	545	407	366	292	231	180	123	82	51	34
5	516	399	315	224	193	173	117	79	78	47	50	40	27
6	567	461	387	304	254	169	137	106	92	64	48	38	23
7	406	323	260	209	194	192	189	148	114	76	56	38	23
8	544	445	557	466	386	394	327	327	240	170	122	116	98
9	466	437	394	351	327	294	261	221	180	155	116	107	72
10	815	780	682	582	503	395	305	254	172	107	93	67	42
11	**1232**	1028	947	827	751	633	523	380	295	196	194	116	80
12	909	818	724	654	545	445	372	291	231	149	119	51	34
13	323	308	409	254	194	169	149	137	114	92	48	38	23
14	417	391	331	306	289	231	216	141	132	116	96	79	53
15	494	396	346	215	190	157	111	154	132	121	114	87	56
16	410	309	180	137	114	110	93	77	46	34	28.3	19.3	13.7
17	686	554	531	430	410	333	260	213	182	127	122	100	64
18	255	201	164	109	88.3	87	83	65	48	37	24	19.3	11
19	570	523	356	334	290	198	137	115	105.3	89	66	33	14
20	727	644	479	394	288	197	146	124	109	90	66	39	23
21	374	309	221	218	207	178	150	129	103	88	70.3	38	18
22	922	866	750	595	508	232	259	146	121	113	103	93.3	78
23	806	607	504	449	308	247	193	175	145	108	95.3	68.3	26
24	533	447	363	214	259	209	184	141	109	64	30	18	11
25	319	275	208	181	155	105	83	79	55	38.3	26.3	15	11.3
26	275	258	335	247	209	176	135	124	115	108	92.7	55.3	35
27	459	383	313	284	254	229	207	178	137	85	73.7	55.3	35
28	827	827	788	602	256	228	204	148	131	109	69	48	19
29	248	207	150	134	116	105	78.3	55	39.7	25	11.3	11	7.3
30	626	563	433	355	261	226	196	118	94.3	80	46	39.3	23.7

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31	753	697	631	531	466	411	330	260	217	185	142	97	76.7
32	536	510	424	456	383	302	242	194	125	108	75.3	45.3	26.7
33	380	323	266	208	215	182	208	189	147	100.3	74.3	52.3	29.7
34	331	323	266	212	182	160	126	107	77	66	45.3	26.3	15
35	268	233	211	204	158	125	90.3	62.7	40.3	26	17.3	13.7	10.7
36	753	710	614	680	519	437	310	264	142	88	76	35.7	23.7
37	616	548	516	470	311	294	353	270	214	166	134	116	103
38	339	308	256	134	120	105	88	62	33	22.3	15.3	11	7.3
39	260	208	166	139	109	87.3	78.3	76.7	60.7	49.3	33.3	19	12.3
40	504	448	413	356	253	210	176	138	112	92	73	41	23
41	869	774	699	569	443	410	343	278	198	131	108	91.7	54
42	783	699	607	515	399	315	224	162	117	79.3	60.3	53.7	34.3
43	472	431	372	316	233	215	178	122	104	77	72.7	58	31
44	269	224	187	141	114	86.7	78.3	80	66.7	47.7	30	21.3	12.7
45	388	316	304	265	211	186	137	111	90.7	80	77.7	44.7	23
46	192	166	132	106	96	85.7	70.3	53	27	16	11	8.3	**5.7**
47	869	774	657	576	456	414	343	333	280	198	129	91.3	58
48	681	570	540	444	391	288	232	160	138	93.7	68.3	51.7	43.3
49	512	287	365	307	296	279	215	188	154	117	99	80	46
50	356	287	232	176	147	121	106	95.7	76.3	42.7	26.3	14	8.67
51	459	423	411	343	236	202	173	144	107	87.7	60.3	30	15.3
52	228	203	183	157	123	104	85	59	38	25.3	17.3	10	9.0
53	926	811	767	644	560	421	333	232	186	151	119	92.3	58
54	649	536	488	429	390	356	301	239	205	151	131	110	78.3
55	545	450	366	309	265	208	186	123	109	93	77.7	46.7	29
56	184	144	115	99	82.3	73.7	53.3	34.7	19.3	16	12	10.3	10
57	405	316	254	202	175	132	117	100.3	80	69.7	54.3	32	22
58	221	203	175	133	106	86	66.7	44	27.3	19.7	13	18.3	16.3
59	919	840	785	516	458	366	310	215	178	122	89	74.7	46
60	708	629	584	509	424	359	303	202	160	120	98.3	79.7	47.3

Source: Authors Fieldwork, 2017

The radiofrequency power density radiation (S) decreased exponentially as the radial distance from the foot of the base station increased. Power densities varied significantly from one base station to another and from one radial distance to another, depending on prevailing factors at the base transceiver station (Table 1). The highest values of power density were recorded at 0.0 m radial distance from each of the Base Transceiver Stations surveyed, while minimum values were recorded at 300 m radial distance for each Base Transceiver Station. These maximum values recorded at 0.0m radial distance decreased progressively as the radial distance increased with significant variations.

Generally, the highest power density of 1232 μW/m² was recorded at 0.0m in BTS 11 (located in Urban 3), while the least power density of 5.7 μW/m² was recorded at 300m radial distance in BTS 46 (located in World Bank/Agbama area) as shown in Table 1.The interactions of one radial distance with another in the same/or different levels of Base Transceiver Station (BTS) were statistically significant with 12.3% coefficient of variation. However, the mean power density (combined) decreased significantly with increase in radial distance as observed in Table 1. Power density varied from one Base Transceiver Stations to another and one radial distance to another, depending on a variety of prevailing factors at Base Transceiver Station as a result of frequency differences.

However, the interactions of one Base Transceiver Station with another when analyzed statistically using FLDS at 5% level of significance, show significant differences in most cases; while they were not significant differences in few cases with 6.3% coefficient of variation. This might be attributed to the rate at which the particular Base Transceiver Station was being accessed by subscribers (Cicchetti *et al.*, 2004). This might cause the peak power to either increase or decrease. The traffic channel may fluctuate whenever subscribers are accessing the Base

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Transceiver Station. The existence of a large number of scatterers and absorbing objects around the Base Transceiver Station lead to highly non uniform field distribution in the environment. As a consequence, this brought about shadowing and fast fading effects. Houses, trees, cars and other objects seen around the Base Transceiver Station can lead to radiation/signal variations. Building alone can cause a strong shadowing effect that makes the field/radiation distribution to be very heterogeneous (Miclausi *et al.*, 2007; Hamnerius *et al.*, 2008; Stewart, 2000 and Jochen, 2003). According to Igo *et al* (2009), wet trees absorb signals/radiations more than dry trees and could cause radiation variations in the environment.

Table 2: Mean Power Density of each BTS and their Percentage Contribution (%)

BTS	Mean Power Density (μW/m²)	Percentage Contribution (%)
1	199.97	1.4
2	271.97	1.9
3	247.28	1.8
4	346.74	2.5
5	173.69	1.2
6	203.77	1.5
7	171.49	1.2
8	322.46	2.3
9	260.10	1.9
10	369.00	2.6
11	**553.98**	4.0
12	410.97	3
13	173.62	1.2
14	215.25	1.5
15	198.02	1.4
16	120.89	0.9
17	308.59	2.2
18	91.61	0.7
19	217.65	1.6
20	255.80	1.8
21	161.77	1.2
22	368.08	2.6
23	287.05	2.1
24	198.57	1.4
25	119.30	0.9
26	169.21	1.2
27	207.15	1.5
28	327.38	2.3
29	91.35	0.7
30	235.48	1.7
31	368.98	2.6
32	263.64	1.9
33	182.64	1.3
34	148.97	1.1
35	112.31	0.8
36	357.88	2.6
37	316.23	2.3
38	115.43	0.8

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39	99.91	0.7
40	218.38	1.6
41	382.13	2.7
42	311.43	2.2
43	206.21	1.5
44	104.49	0.7
45	171.85	1.2
46	74.54	0.5
47	398.33	2.8
48	284.69	2.0
49	226.54	1.6
50	129.90	0.9
51	207.02	1.5
52	95.51	0.7
53	407.79	2.9
54	312.56	2.2
55	215.95	1.5
56	**65.66**	0.5
57	150.71	1.1
58	86.87	0.6
59	378.38	2.7
60	324.87	2.3
Total	**13997.99**	**100**

The mean power densities from the BTSs ranged from 65.66 $\mu W/m^2$ to 553.98 $\mu W/m^2$.. The highest mean power density of 553.98 $\mu W/m^2$ with percentage contribution of radiations of 4% was recorded at BTS 11 (located in Urban 3). BTS 56 (located in Afara area) had the least mean radiation of 65.66$\mu W/m^2$ with a percentage contribution of radiations of approximately 0.5%. Other BTSs with significant percentage radiation contribution of ≥2% were; Base Stations 4, 10, 11, 12, 17, 22, 23, 28, 31, 36, 37, 41, 42, 47, 48, 53, 54, 59 and 60; while others had percentage contribution of <2% as presented in Table 2. These variations in the percentage contributions of radiations may be attributed to the rate at which the base stations were being accessed by the subscribers at the point of measurement, or, other factors such as attenuation, shadowing effects. The power density also might drop due to congestion or over loading. But the very low measured values may have been distorted by ambient noise (Rafiqul, 2006 and Mann *et al.*, 2000).

Results also show significant differences among the means of radiations from the combined Base Transceiver Stations in most cases. The mean power densities radiation levels in Umuahia urban range between 171.49 $\mu W/m^2$ (BTS 7) and 346.74 $\mu W/m^2$ (BTS 4) in Ossah area, 91.61 $\mu W/m^2$ (BTS 18) and 553.98 $\mu W/m^2$ (BTS 11) in Urban 3; 91.35 $\mu W/m^2$ (BTS29) and 327.38 $\mu W/m^2$ (BTS 28) in Urban 1; 112.31 $\mu W/m^2$ (BTS 35) and 368.98 $\mu W/m^2$ (BTS 31) in Ugwunchara area, 99.91 $\mu W/m^2$ (BTS 39) and 316.23 $\mu W/m^2$ (BTS 37) in Amuzukwu area, 74.54 $\mu W/m^2$ (BTS 46) and 398.33 $\mu W/m^2$ (BTS 47) in World Bank/Agbama area; and 65.66 $\mu W/m^2$ (BTS 56) and 407.79 $\mu W/m^2$ (BTS 53) in Afara area (Table 2). It was observed that the level of maximum or worst case scenario of exposure in Urban 3 was higher than other areas. The only factor that might have contributed to the difference in the level of exposure in these areas may be attributed to higher demand for communication from base stations relative to the availability of space in the area.

Limited land space and population density encouraged the cluster of base stations, installation of many base transceiver stations collocations and the presence of so many radiating antennas in the area.

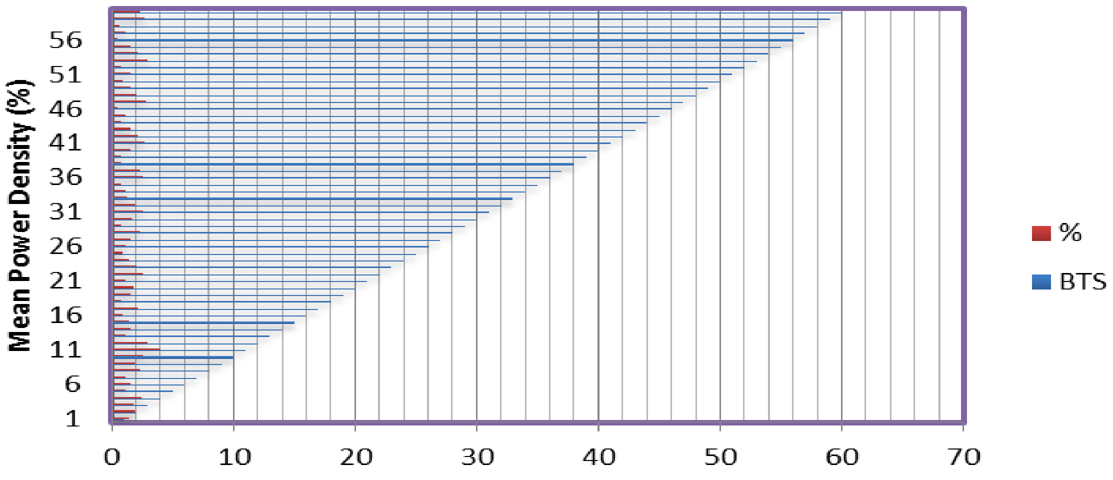

Fig1: Showing BTS

Table 3: Combined Mean Power Density of all the surveyed BTS

BTS	Distance (M)	Mean Power Density (µW/m²)
1 – 60	0	**32888**
	25	27842
	50	25022
	75	20749
	100	17093.6
	125	14142.4
	150	11802.5
	175	9345.1
	200	7382.6
	225	5555
	250	4272.6
	275	3171.1
	300	**2070.97**

The mean power density (combined) of all the surveyed base stations from base station 1 to base station 60 was recorded as 32888 µW/m², 27842 µW/m², 25022 µW/m², 20749 µW/m², 17093.6 µW/m², 14142.4 µW/m², 11802.5 µW/m², 9345.1 µW/m², 7382.6 µW/m², 5555 µW/m², 4272.6 µW/m², 3171.1 µW/m², and 2070.97 µW/m² respectively for 0.0m, 25m, 50m, 75m, 100m, 125m, 150m, 175m, 200m, 225m, 250m, 275m, and 300m. This showed that the highest value of 32888 µW/m² was obtained at 0.0m radial distance which decreased significantly with an increase in radial distance (Table 3). Ayinmode *et al* (2014) in the evaluation of radiation power densities in three major Cities in Nigeria; Abuja, Lagos and Ibadan, reported radiation power densities to range from 139.63µW/m² to 296.82µW/m² in Lagos; 1263µW/m² to 5411.26µW/ m² in Abuja and 116.82µW/m² to 162.49µW/m² in Ibadan. Abuja was significantly higher than the one obtained in this study; Ibadan was lower while Lagos was comparable to the one

obtained from this study. Generally, the combined results from the three Cities ranged from 162.49µW/ m² to 5411.26µW/ m²; which were significantly higher than the results of this study. These fluctuations could be attributed to some factors such as; topography (elevation) of the land area around a referenced Base Transceiver Station, interference from radiation and /or noise from moving objects such as vehicles, motorcycles etc, obstruction constituted by immobile structures placed or erected within the line of sight of measurements and wave interference from other Base Transceiver Stations clustered around a reference Base Transceiver Station. However, Victor *et al* (2013) in assessing the radiofrequency radiation exposure levels from selected Mobile Base Stations in Lokoja Nigeria; reported radiation power densities that ranged from 2.3μW/ m² to 1927μW/ m² which were significantly comparable and conform to the results obtained in this study. The minimum average power density from individual Base Transceiver Station surveyed in Umuahia Urban was 65.66 μW/m², while the maximum was 553.98 μW/m². The maximum mean power density of the combined BTS was 32888 μW/m² (0.0m) radial distance, while the minimum power density was 2070.97 μW/m² (300m) radial distance. Therefore, the RF power density exposure hazard index in Umuahia Urban was significantly within the permitted 4.5W/M² and 9 W/M² RF exposure limit to the general public as recommended by

International Commission on Non-Ionizing Radiation Protection (ICNIRP, 2011).

Conclusion and Recommendations

The minimum average power density from individual BTS surveyed in the area was 65.66 μW/m², while the maximum was 553.97 μW/m². Therefore, the RF exposure hazard index in Umuahia Urban was significantly below the permitted RF exposure limit of 4.5 W/m² 9 W/m² to the general public as recommended by ICRNIP. Although the level of exposure in Umuahia Urban are far less than the recommended reference levels, precautions should be taken on how close a BTS is installed to residential buildings and on the rapid increase in the number of BTS in the area. Based on the findings of this research, indicating the levels of electromagnetic radiations to which members of the public are being exposed to in Umuahia urban, and on the growing telecommunication industry and number of base stations being installed which may lead to possible changes in exposure level, an independent audit of all base stations throughout the country be carried out to ensure that exposure guidelines are not exceeded and high safety precautions should be taken in designing and installing new base stations.

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