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Assessment of Radiation Risk from Selected Telecommunication Base Station in Ogwashi-Uku, Delta State, Nigeria

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Abstract

Exposure of humans to electromagnetic radiations emanating from the antenna of telecom masts and its health effects on humans have been a subject matter for many scientists today. In Ogwashi-Uku, there is no documented literature or generally accepted findings on the health effects of exposure to effects of electromagnetic radiations from the antenna of telecom masts which may be a result of studies not exceeding the world's permissible limits. This study, therefore, seeks to evaluate the extent of human exposure to electromagnetic radiation in Ogwashi-Uku. A Trifield EMF Meter Model TF2 was used for the purpose of this study. Measurements were recorded and subsequently used with standard equations to obtain the Specific Energy Absorption Rate (SAR) for different tissues of the head. Results from this study have shown that the mean value for radio frequency radiation is 2.40 mW/m^2 and the average value for SAR to tissues of the head is 0.02 W/kg which is lower than the limit set by ICNIRP indicating that the mobile base stations pose no immediate recommended threat to the people of Ogwashi-Uku and are therefore safe.

Subject Areas

Applied Physics

Keywords

Radiation, Base Stations, Specific Absorption Rate

1. Introduction

The mobile telecommunications market is huge and a major economic driver in many countries, including Nigeria. The development of wireless telecommunications, which allows mobile phone users to access the Internet (among other users) through their mobile phones, has further contributed to the unprecedented growth of the global network for mobile communication applications (GSM). Unfortunately, it is technologically impossible to have a mobile phone without a Base Station (BS). This leads to an increase in inefficiency in the Base Station (BS) or telecommunications equipment [1]. In Nigeria today, telecommunication has proven to be of great benefit to the people, whereas other forms of communication are very limited. Wireless telecommunication technology has increased its use in recent years with an increase in background radiation from its source [2]. Telecommunications construction includes the installation of masts by telecommunications operators. A mast is a vertical structure that supports an antenna at a height that can transmit and receive waves. The issue of the location of telecommunication masts and their impact on health is important because researchers have proven that the location of masts in residential areas has affected public health [3]. In addition to legal and administrative problems arising from control, the rise of the telecommunications industry has led to serious health, business, and environmental problems. This problem is exacerbated in developing countries such as Nigeria, where technical and scientific capacity is limited to manage and reduce the potential health hazards associated with UV emissions or radiation from telecommunications masts [4]. Due to its proximity to residential and other public places, the risk associated with radiation from the main transmission station is high. Communication masts are harmful to the environment, including background radiation, and have negative effects on plants and animals [5]. These masts use electromagnetic radiation to transmit signals [6]. The radiation emitted by the antenna is not ionizing because its energy is too low to directly ionize and break chemical bonds in biological systems. But long-term exposure to this radiation can be harmful. There are health effects associated with high radio frequency energy. Some of the biological effects are heat exposure, non-thermal exposure can affect the structure of cell membranes, and people who live in places where telecommunications poles are built can experience disorders such as cancer, lung disease, sleep disorders and even physical defects in children. In Ogwashi-Uku, there is no documented literature on the measurement of radiation from telecommunication masts and the health effects on its citizens. This gave rise to the need to carry out this research and thus ascertain if the people are safe.

2. Materials and Methods

2.1. Study Area

The study was carried out in Ogwashi-Uku (**Figure 1**), the headquarters of Aniocha south local government areas of Delta state. Ogwashi-Uku is located at 6˚10'59.06 N and 6˚31'27.72 E.

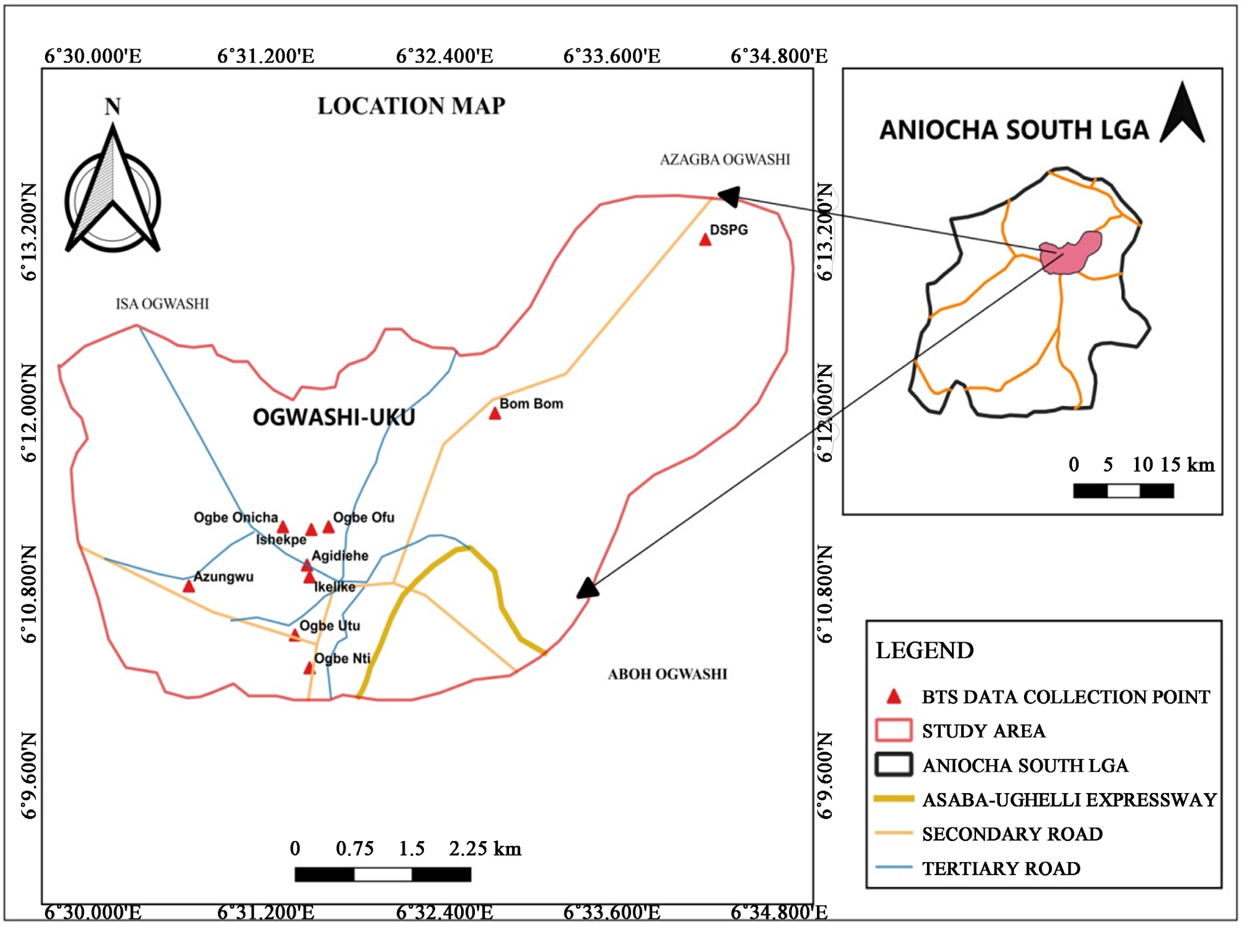

Figure 1. Map showing the MBS locations.

2.2. Materials

The materials used during this investigation are:

The Trifield EMF Meter (Figure 2), a measuring tape, a 1.5 m stand, a geographical positioning system and a note pad.

2.3. Selection and Operation of the Detector

The external view of this compact Electromagnetic Fields (EMFs) meter is shown in Figure 2. The device is basically the Trifield EMF Meter Model TF2 which is preferable to the Electrosmog meter due to its accuracy, cost and ability to capture all EMF and radiation electric field strength with unit of measurement as volt per meter (Vm^{-1}), magnetic field strength with measuring unit as amperes per meter (Am^{-1}) and monitoring high-frequency radiation in the range of 20 MHz to 6 GHz covering most of the wireless communication frequency spectrum. The device has been calibrated to detect and measure EMFs.

The Trifield EMF meter device was switched off and the batteries removed to avoid continuous measurement. Measurements of outdoor EMFs levels were made for ten mobile base stations in strategic positions of the study area. The coordinates of the measured location were obtained using a Global Positioning

Figure 2. Trifield EMF Meter Model TF2.

System (GPS), elevation of the different mobile base stations above sea level, age of each base station, and the proximity to the nearest building were all recorded. The meter was placed at 1.5 m above the ground with its Liquid Crystal Display (LCD) screen facing up to allow easy reading for a minimum time of 5 seconds. All measurements were recorded and evaluated against the exposure guidelines of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) [7]. The ICNIRP specifies a maximum exposure limit for occupational scenario and the general public at frequency range of 100 kHz to 10 MHz and 100 kHz to 10 MHz respectively. The details of this research are given in Table 1. In the study location, the measured mobile base stations were selected randomly with consideration of the major mobile telecommunication operators which are GLO, AIRTEL, MTN, and ETISALAT within the coverage areas in the study location. Thereafter the Peak and Average power density were calculated.

2.4. Fundamental Principles of the Calculation

The major result of Maxwell's equation was the prediction of the existence of Electromagnetic Waves (EMWs) where he proved that an electromagnetic disturbance that originated from a single charged body would travel out as an electromagnetic wave with velocity of light in free space [8]. The wave propagation phenomenon occurs as a result of the relationship which exists between a time-varying magnetic field induced electric field and vice versa.

Maxwell's equations for this time-varying phenomenon are:

$$\nabla \times E = -\mu \frac{\partial H}{\partial t} \tag{1a}$$

$$\nabla \cdot E = \frac{\rho}{\varepsilon} \tag{1b}$$

$$\nabla \times H = J + \varepsilon \frac{\partial E}{\partial t} \tag{1c}$$

$$\nabla \cdot H = 0 \tag{1d}$$

where E and H are electric and magnetic field strengths, $J (= \sigma E)$ is the current density, ρ is charge density, σ is conductivity, ε is permittivity and μ is permeability, respectively.

The electric and magnetic field strengths are vector quantities expressed in Volt per meter (Vm^{-1}) and Ampere per meter (Am^{-1}), respectively. Both fields are mathematically interdependent [9] which implies that either the magnitude of the electric field or magnetic field has to be measured. As knowing the magnitude of the electric field for instance, one can easily determine the value for the magnetic field and vice versa. The pointing vector is used to relate the electric and magnetic field vector thereby giving the power density, S.

$$S = E \times H \tag{2}$$

The magnitude of the average power density or average power flow per unit area

$$S = \frac{E^2}{\eta} = \eta H^2 \tag{3}$$

where η for free space is the characteristics wave impedance and is given as

$$\eta = \sqrt{\frac{\mu_0}{\varepsilon_0}} = 120\pi = 377H^2 \tag{4}$$

$$S = \frac{E^2}{120\pi} = 377H^2 \tag{5}$$

Tissues that depend on the coupling mechanisms and the frequency occur as a result of the tissue exposure to time-varying EMFs which results in internal energy absorption of the tissues [10].

The time derivative of the incremental internal energy, $\mathrm{d}W$ absorbed by an incremental mass, $\mathrm{d}m$ of tissue contained in a volume element, $\mathrm{d}V$ of a given density ρ is defined as the specific absorption rate of an EMF [11], that is:

$$\mathrm{SAR} = \frac{\mathrm{d}}{\mathrm{d}t}\left(\frac{\mathrm{d}P}{\mathrm{d}m}\right) = \frac{\mathrm{d}}{\mathrm{d}t}\left(\frac{\mathrm{d}P}{\rho \mathrm{d}V}\right) \tag{6}$$

where $\mathrm{d}m = \rho \mathrm{d}V$ (ρ in kgm^{-3}).

SAR is the amount of energy a unit mass of tissue usually 1 g or 10 g of tissue can absorb at a time when exposed to radiofrequency from an electromagnetic field [12] [13]. The S.I unit of SAR is Watt per kilogram (Wkg^{-1}).

The SAR can be related to the electric field at a point by using Equation (7) (IEEE, 2005):

$$\mathrm{SAR} = \frac{\sigma E^2}{\rho} \tag{7}$$

where σ is conductivity of the tissue (Sm^{-1}), ρ is mass density of the tissue (kgm^{-3}) and E is rms electric field strength in tissue (Vm^{-1}). The conductivity varies for different tissues and different field frequencies [10]. The SAR values depend on the following factors: 1) the incident field parameters 2) the characteristics of the exposed body 3) ground effects and reflector effects of other objects in the field near the exposed body [14].

3. Results and Discussion

3.1. Results

The results of the radiofrequency concentration measurement for 10 mobile base station in Ogwashi-Uku headquarters of Aniocha south local government area of Delta state were obtained using the Trifield EMF meter which was placed at 1.5 m above the ground with its Liquid Crystal Display (LCD) screen facing up to allow easy reading for a minimum time of 5 seconds. Table 1 shows the Specific Energy Absorption Rate (SAR) to different tissues of the head which includes skin, fat, bone, dura, brain, and Cerebrospinal Fluid (CSF) were calculated using relevant equations as presented in equations above.

3.2. Discussion

The results of radio frequency Power Density (PD), magnetic field and electric

Table 1. Measured magnetic, electric fields and power density in the study locations.

S/N	Location	H (Am^{-1})	E (Vm^{-1})	Coordinates	PD (mW/m^2)	Elevation (m)	MBS Proximity (m)	Age of MBS
1.	DSPG	2.0	1.560	6.5710 6.2191	3.425	200	20	16
2.	Bom Bom	0.5	4.820	6.5466 6.2000	2.194	206	17.2	8
3.	Ogbe-Onicha	0.7	0.833	6.5220 6.1875	0.540	195	10	8
4.	Ogbe-Ofu	1.0	10.562	6.5273 6.1875	6.515	198	16.4	13
5.	Ikelike	0.2	3.320	6.5251 6.1820	0.663	197	7	5
6.	Ogbe-Nti	1.9	0.500	6.5251 6.1720	0.440	202	26	2
7.	Ogbe-Utu	0.3	4.452	6.5234 6.1756	1.721	201	15	11
8.	Agidiahe	0.3	2.043	6.5248 6.1833	0.456	197	10	6
9.	Azungwu	1.4	6.311	6.5111 6.1810	6.310	196	18	9
10.	Ishekpe	1.0	1.830	6.5253 6.1872	1.715	199	8	7

field measured for 10 mobile base stations in Ogwashi-Uku are presented in Table 2. The values obtained ranges from 0.440 to 6.515 mWm^{-2} at a height of 1.5 m from ground level. The highest power density concentration were obtained in Ogbe-Ofu station with the value of 6.515 mWm^{-2} followed by Azungwu station with value of 6.310 mWm^{-2} while the lowest value of 0.440 mWm^{-2} were obtained in Ogbe-Nti station followed by 0.456 mWm^{-2} obtained in Agidiehe station. This high value obtained in Ogbe-Ofu station may be due to the presence of additional high-powered mobile Base Transceiver Station (BTS) clusters at a distance from the spot. For most of the masts, the PD falls and rises at distance between them which do not follow the inverse square rule due to the scattering of the electromagnetic wave.

Figure 3 show the relationship between power density and age of the different mobile base stations, observed here is a slight decreasing linear trend indicative

Table 2. Average power (mW) for the study locations.

Locations	PD (mWm^{-2})	Adult Men (1.9 m^2)	Adult Women (1.6 m^2)	Children 12 - 13 yrs (1.33 m^2)	Children 10 yrs (1.14 m^2)	Children 9 yrs (1.07 m^2)
DSPG	3.425	6.508	5.480	4.555	3.905	3.665
BOM BOM	2.194	4.169	3.510	2.920	2.501	2.348
Ogbe-Onicha	0.540	1.026	0.864	0.718	0.616	0.085
Ogbe-Ofu	6.515	12.379	10.424	8.665	7.430	6.971
Ikelike	0.663	1.260	1.061	0.882	0.756	0.710
Ogbe-Nti	0.440	0.840	0.704	0.590	0.502	0.471
Ogbe-Utu	1.721	0.910	1.076	1.294	1.510	1.610
Agidiehe	0.456	0.240	0.285	0.343	0.400	0.430
Azungwu	6.310	3.321	3.944	4.744	5.541	5.897
Ishekpe	1.715	0.903	1.072	1.290	1.504	1.603

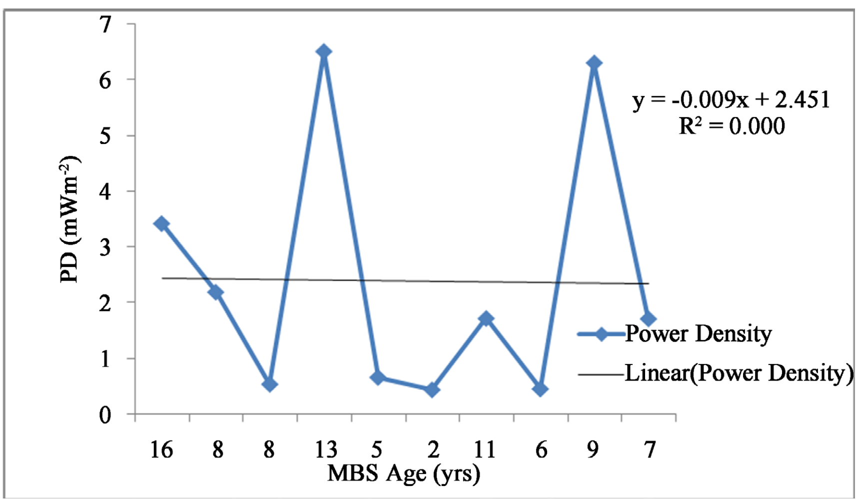

Figure 3. Graph showing the relationship between PD and MBS age (yrs).

of the fact that radio frequency PD is not proportional to the age of the MBS in the study locations with zero regression.

Figure 4 is a column chart which shows the level of PD according to the measured location. MBS in Ogbe-Ofu gave the highest measured value for all measured locations while Ogbe-Nti gave the lowest measured value.

The average power received by humans raging from children between the ages of 9 to 13 years and adult men and women were calculated and presented in Table 2 for all measured locations. Children and adults in Ogbe-Ofu received more when compared to other measured locations in the study as evident in Figure 5.

Conductivity, permittivity and density of layers of the human head can be found in Table 3. Poynting vector S and SAR in six tissue layers of the human head was evaluated at 1800 MHz, which is the standard for the mobile communication

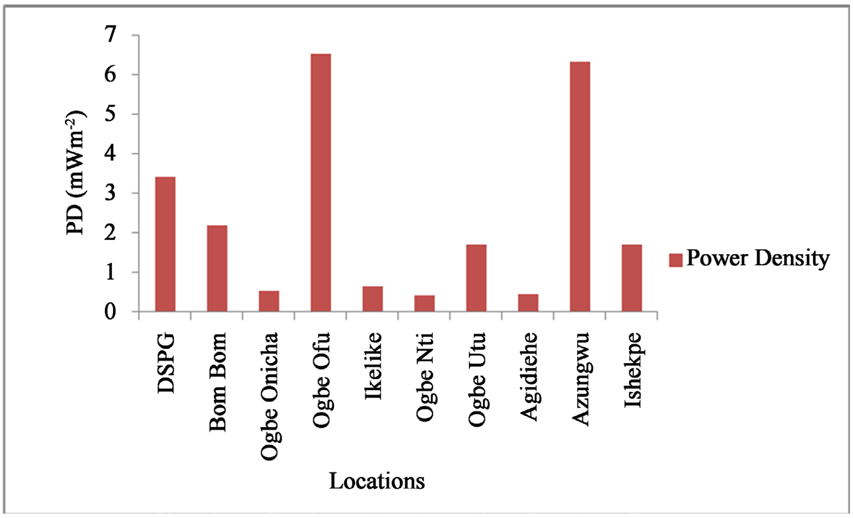

Figure 4. Column chart showing PD level according to locations.

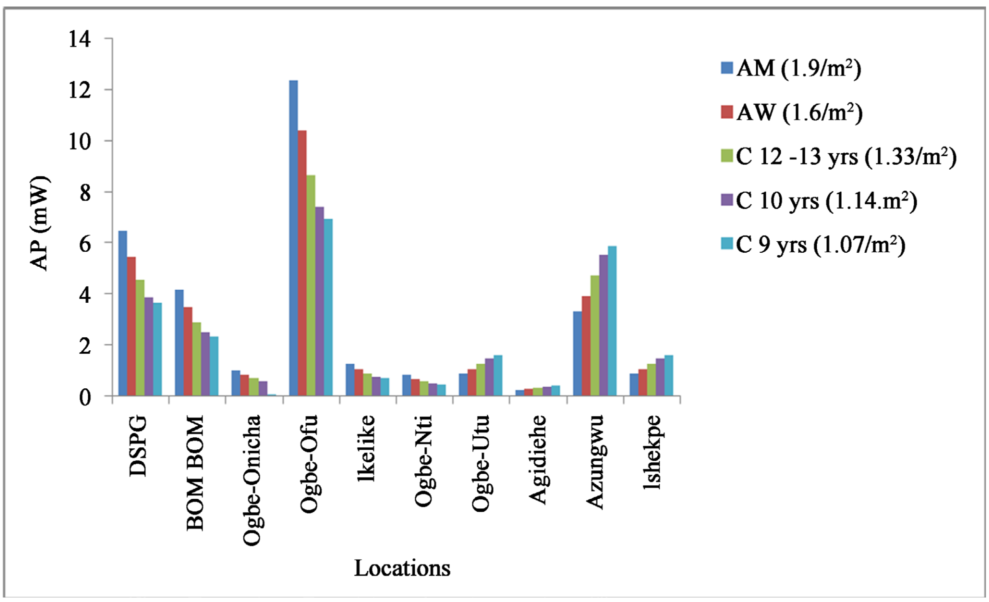

Figure 5. Column chart showing the Average Power (AP) received by humans in the study locations.

systems. The calculated values are presented in Table 4.

The results however reveals that the calculated SAR to the head skin ranged from 0.000 - 0.120 W/kg, that to the fat ranged from 0.000 - 0.009 W/kg, to the bone (skull) ranged from 0.000 - 0.017 W/kg, that to the dura mater range from 0.000 - 0.140 W/kg, that to the CSF range from 0.000 - 0.310 W/kg and that to the brain range from 0.000 - 0.125 W/kg. These variations in the value of SAR to the different tissue layer are attributed to the electric field strength of the mobile base stations and the dielectric properties (conductivity and permittivity) of the head tissues. Every human body part has a different dielectric property dependent on the exposure to frequency [15]. Increase in head conductivity is proportional to an increase in the SAR values which contradicts with permittivity, where increases in permittivity are inversely proportional to SAR values [15]. The cerebrospinal fluid with conductivity higher than the rest tissues has SAR values higher than the tissues layer.

The average SAR to a human head when compared to ICNIRP reference levels

Table 3. Conductivity, permittivity and density of layers of the human head.

Tissue	Density ρ (Kg/m^3)	Conductivity σ (S/m)		Permittivity	
		900 MHz	1800 MHz	900 MHz	1800 MHz
Skin	1100	0.87	1.18	41.4	38.9
Fat	920	0.051	0.078	5.46	5.34
Bone (Skull)	1850	0.14	0.28	12.45	11.8
Dura	1050	0.96	1.32	44.4	42.9
CSF	1060	2.41	2.92	68.7	67.2
Brain	1030	0.77	1.15	45.8	43.5

Table 4. Electric field, Poynting vector and SAR values to tissues of human head of MBS in Ogwashi-Uku.

Locations	E (V/m)	S (W/m^2)	SAR to Tissues of the Head Layers (W/kg)						Average SAR to Human Head (W/kg)
			Skin	Fat	Skull Bone	Dura	CSF	Brain	
DSPG	1.560	0.006	0.003	0.000	0.000	0.003	0.010	0.003	0.003
Bom Bom	4.820	0.062	0.025	0.002	0.004	0.030	0.064	0.026	0.030
Ogbe-Onicha	0.833	0.002	0.001	0.000	0.000	0.001	0.000	0.001	0.001
Ogbe-Ofu	10.562	0.000	0.120	0.009	0.017	0.140	0.310	0.125	0.120
Ikelike	3.320	0.030	0.012	0.000	0.002	0.014	0.030	0.012	0.012
Ogbe-Nti	0.500	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000
Ogbe-Utu	4.452	0.053	0.021	0.002	0.003	0.025	0.055	0.020	0.021
Agidiehe	2.043	0.011	0.004	0.000	0.000	0.010	0.011	0.005	0.005
Azungwu	6.311	0.106	0.043	0.003	0.010	0.050	0.013	0.044	0.004
Ishekpe	1.830	0.009	0.004	0.000	0.000	0.004	0.010	0.004	0.004

and recommended limits for general public exposure at frequency of 1800 MHz as shown in **Table 5** is quite low except for Ogbe-Ofu with values at 0.120 W/kg same goes for electric and magnetic fields.

Figure 6 shows power density concentration in the study area with Ogbe-Ofu and Azungwu having the highest level and Ogbe-Nti and Agidiehe having the lowest level recorded.

4. Conclusion

With an increasing population, development and continuous demands for mobile phone usage as a means for communication, sending and receiving information. This increase in usage has led to high demand for more mobile base stations to be

Table 5. ICNIRP reference levels and recommended limits for general public exposure to time-varying E, H fields, power density and SAR at different frequency.

Frequency (MHz)	E-field (Vm^{-1})	H-field (Am^{-1})	PD (Wm^{-2})	SAR Body Average (W/kg)
900	41.25	0.111	4.5	0.08
1800	58.34	0.157	9.0	0.08

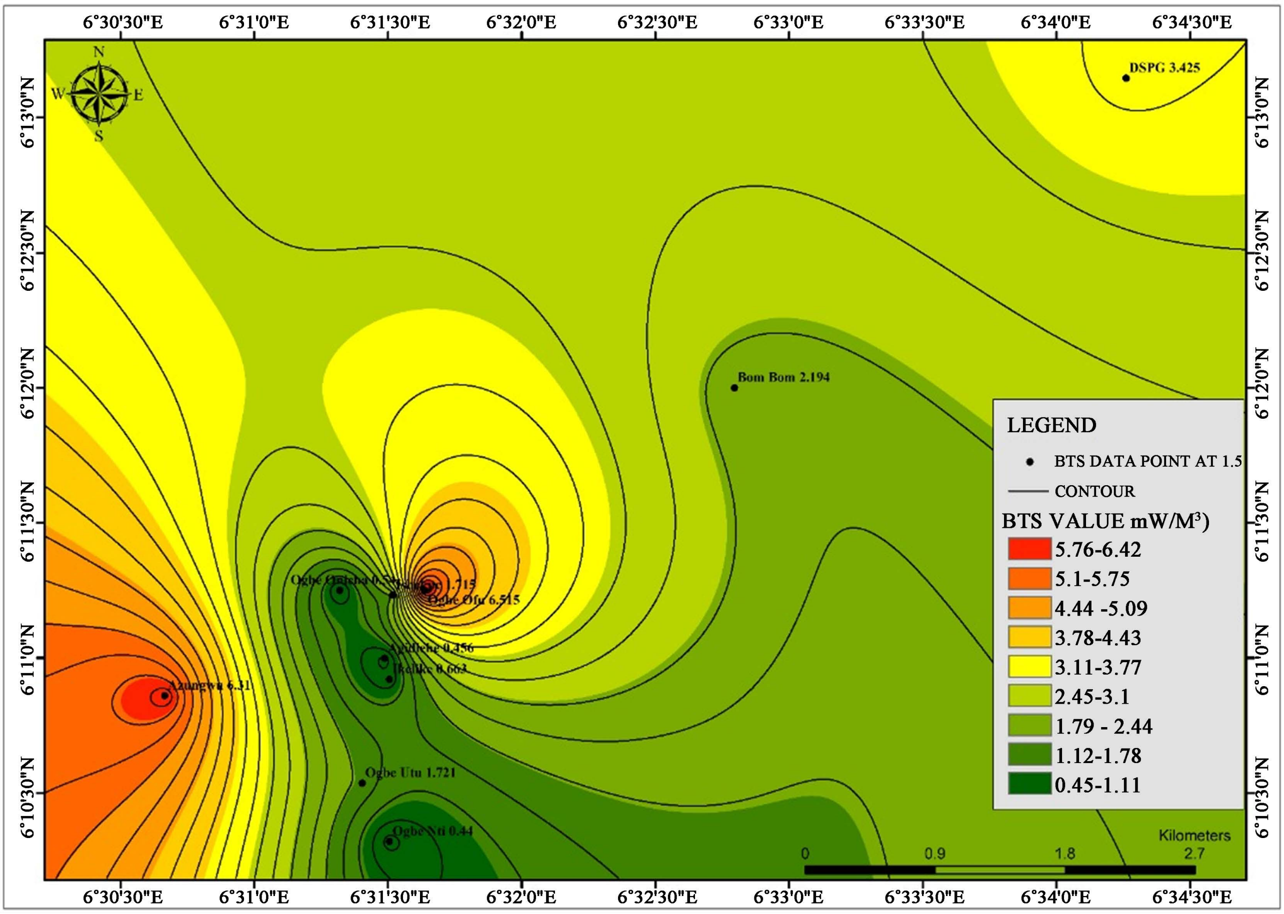

Figure 6. A radiometric map showing level of power density concentration in the study area.

erected in Ogwashi-Uku. This significant increase has led to concern among radiation and health experts about any possible health effect from exposure to radio frequency radiation from these base stations as there is no evidence from the literature of the association between exposure to radio frequency radiation to any health effect in the study location and compliance of telecommunication network operators to ICNIRP recommended limits. This explains why the measurement of radio frequency radiation and the amount of the SAR to various tissue layers of the human head is of great importance. This study has been able to measure the radio frequency dosimetry quantities of mobile base stations in Ogwashi-Uku. The mean value for radio frequency radiation is 2.40 mWm^{-2} and the average value for SAR to tissue layers of the human head is 0.02 Wkg^{-1} which is lower than the recommended limit of 0.08 Wkg^{-1} set by ICNIRP indicating that the erected mobile base stations pose no immediate threat to the people of Ogwashi-Uku and they are therefore safe.

Conflicts of Interest

The authors declare no conflicts of interest.

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