ASSESSMENT OF EXPOSURE TO ELECTROMAGNETIC RADIATION FROM GSM ANTENNAS WITHIN AND AROUND TWO HEALTH FACILITIES AT THE OBAFEMI AWOLOWO UNIVERSITY, ILE-IFE, NIGERIA

Akeju, M.[1], Aboyeji, O. S.[2], Salau, H.[1] and Ojo, J.[1, 3]

[1]Nutrition and Health-Related Environmental Research Laboratory, Department of Physics and Engineering Physics, Obafemi Awolowo University, Ile-Ife, Nigeria

[2]African Regional Institute for Geospatial Information Science and Technology (ARIGIST), Obafemi Awolowo University Campus, Ile-Ife, Nigeria

[3]Department of Physical Sciences, Redeemer's University, Ede, Nigeria

Correspondence: jojo@oauife.edu.ng

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ABSTRACT

This study assessed the levels of exposure to electromagnetic (EM) radiation from GSM antennas at the Health Centre/Students' Hostel and the Obafemi Awolowo University Teaching Hospital Complex (OAUTHC) in Ile-Ife in the years 2014 and 2016. Each of these healthcare facilities had a prominent GSM mast in its precinct, in addition to numerous wi-fi antennas at various other locations. Instantaneous electric field E (mV/m), average maximum electric field, $E_{max, av}$ (mV/m), instantaneous power density δ ($\mu W/m^2$), and average maximum power density $\delta_{max, av}$ ($\mu W/m^2$) of microwave radiation were measured around the prominent GSM base stations, within the outdoor environment of the health facilities, and also within Wards and other indoor locations of interest. Measurements were carried out using a portable Electrosmogmeter while geographic locations of the base stations and data points were captured with a hand-held Global Positioning System (GPS) unit. The values for radiation levels were discussed in terms of both the ICNIRP 1998 standard adopted by the Federal Ministry of Environment, and also in terms of attention values suggested by other international expert bodies, based on the precautionary principle in environmental management. The average power density of 806 $\mu W/m^2$ (peak value of 1,386 $\mu W/m^2$) recorded at the neonatal ward of the Teaching Hospital. While the Health Centre enjoyed relatively safe microwave radiation levels, a microwave average maximum power density of 20,003 W/m^2 and peak value of 25,180 W/m^2 were recorded at the adjoining Students' Hostel.

Keywords: Microwave Radiation, Human Health, Mobile Telephones, GIS

INTRODUCTION

Electromagnetic (EM) radiation is a common phenomenon across all developed and most developing countries in the world today, due to technology advancement in the area of mobile telecommunication (Levitt and Lai 2010). Electromagnetic radiation consists of a wide spectrum of radiation frequency such as radio frequency, microwaves, infra-red, ultraviolet ray, x- and gamma rays; but the spectrum used in mobile telecommunication are microwaves and radio frequency which are categorized as non-ionizing radiation (i.e. they have no ample energy to break off electrons from an atom and can only cause excitation) (Calvente *et al*., 2014). The use of frequency radiation that ranged from 100 kHz to 3000 MHz for communication increased significantly from the year 2001 till date with applications in radio, television, mobile communication, radar, computer, devices used in medicine and industries, among others. This development has consequently led to an increase in the level of exposure to electromagnetic radiation in our communities (Shachar *et al*., 2004).

One of the major sources of EM radiation actively used by the public is the mobile phone, a small compact assembly of transmitter and receiver in a single body, radiating electromagnetic waves by unipolar or bipolar antenna (Baltrenas and Buckus 2013). The operations of mobile phones depend critically on telecommunication base stations which help to relay signals from the phones from one location to another. The number of installed base stations required to effectively serve a region depends on the number of subscribers and the density of the traffic they generate (Seyfi, 2015). Sometimes, as is recently the case at the Obafemi Awolowo University Health Centre, more antennas are installed on the same tower/mast as the need to service more phone users arise.

The explosive penetration and pervasiveness of this mobile communication as part of our modern life has stimulated concerns on possible adverse health effects to the general public, that might be associated with both acute over-exposure or chronic low-exposure to electromagnetic radiation from mobile telecommunication equipment and their base stations. In the early 1980s, base stations were presumed safe even in populated areas because broadcast transmitters having higher power than base stations were assumed safe as long as they were below the allowed limits. However, numerous studies, have implicated GSM telecommunication base stations in a number of adverse health impacts, including glioma, a form of brain tumour (Wolf and Wolf, 2004; Khurana *et al.*, 2010; Kumar, 2010; Levitt and Lai, 2010; Seyfi, 2015). Other researchers have also come up with findings associating (whether causal or not) microwave radiation from GSM technology with adverse health effects such as childhood leukaemia clusters, adult leukaemia, lymphoma clusters, mental illness, sleep disorders, decreased concentration, anxiety, elevated blood pressure, headaches, memory and learning impairment in children, increased white cell counts, malignant melanoma, nonlinear immune system changes in women, decreased lung function in children (Taki and Watanabe, 2001; Navarro *et al.*, 2003; Abdel-Rassoul *et al.,* 2006; Hutter *et al.*, 2006; Panagopoulos *et al.*, 2006; Kostoff and Lau, 2013; Calvente *et al.*, 2014).

However, mobile telephony, and its companion communication base stations, has simply become indispensable to modern society with numerous benefits accruing from it. What needs to be done is holistically assess the risks and benefits, and adopt common-sense measures to protect the public while enjoying the benefits associated with GSM technology. In this regard, it is evident that the major health impacts of microwave radiation will be amplified in vulnerable populations. Probably the most vulnerable population groups are to be found at health facilities. Here we have concentrated populations of people with immune system weakened by some pathological conditions, those facing mental challenges in psychiatric wards, those with several body defensive mechanisms already being severely taxed (e.g. pregnant women) or still being developed (e.g. newborns, including neonates), etc. Some of these subjects spend extended periods, restricted to the wards. It could be disastrous and counter-productive to the medical attention they are receiving, if such spaces to which they are restricted happen to be hotspots for EM radiation.

There are two major healthcare facilities within the expansive campus of the Obafemi Awolowo University, Ile-Ife. The Health Centre is a private facility supporting the students, staff, and dependants of staff of the University; while the Teaching Hospital Complex (OAUTHC) is part of the College of Health Sciences and is one of the major hospitals not only in the city of Ile-Ife, but in the entire SW region of Nigeria. A previous study had shown that as at 2012, the location with the highest microwave radiation level in the entire city of Ile-Ife happened to be situated within one of the wards at the OAUTHC (Olorunfemi *et al.*, 2016). This has further stimulated us to conduct this more detailed study at the two major health facilities operated by the Obafemi Awolowo University. In this study, we have evaluated intensities of microwave radiation within and in the neighbourhood of these health facilities. Measurements reported here were carried out in the year 2014 and repeated in 2016.

METHODOLOGY

The study area is located within longitudes 4° 28´ to 4° 34´ East and latitudes 7° 24´ to 7° 33´ North in Ife Central Local Government Area of Osun State, Nigeria. The two sites studied (Health Centre/Students' Hostel and OAUTH Complex) are located within the land area of the Obafemi Awolowo University. These locations are shown in Figure 1.

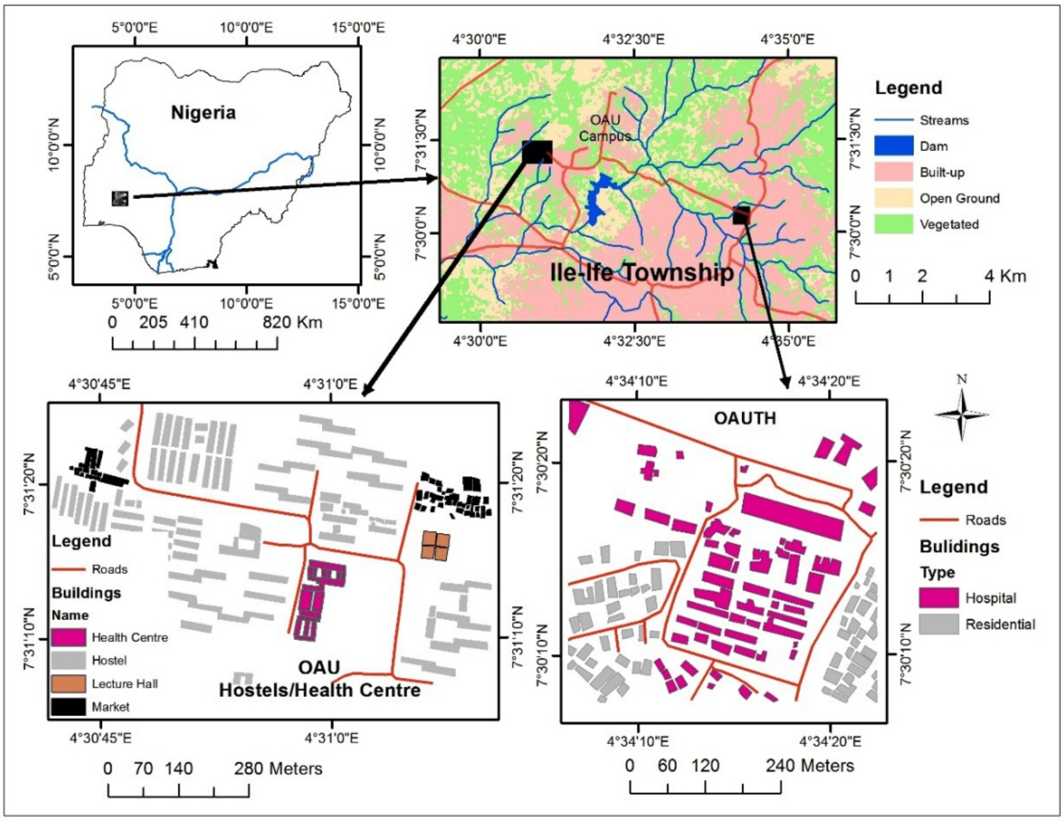

Figure 1: The Study Areap

Microwave radiation around the base stations was measured with a portable Electrosmogmeter. The Electrosmogmeter has non-directional (isotropic) electric probe with three channels measurement sensor and capacitated with frequency ranges from 10MHz to 8GHz. Eighty (80) data points around selected base stations at the Health Centre/Students Hostels and at the Obafemi Awolowo University Teaching Hospital were used for the study (Figure 2). At each station, electromagnetic radiation of a minimum of eight data points were taken at near and far regions to masts. Data was collected on instantaneous electric field $\bar{E}$ (mV/m), average maximum electric field, $\bar{E}_{max,\ av}$ (mV/m), instantaneous power density, $\bar{\delta}$ (μW/m2), and average maximum power density, $\bar{\delta}_{max,\ av}$ (μW/m2). Geographic location of the base stations and data points were captured with a hand-held Global Positioning System (GPS) unit.

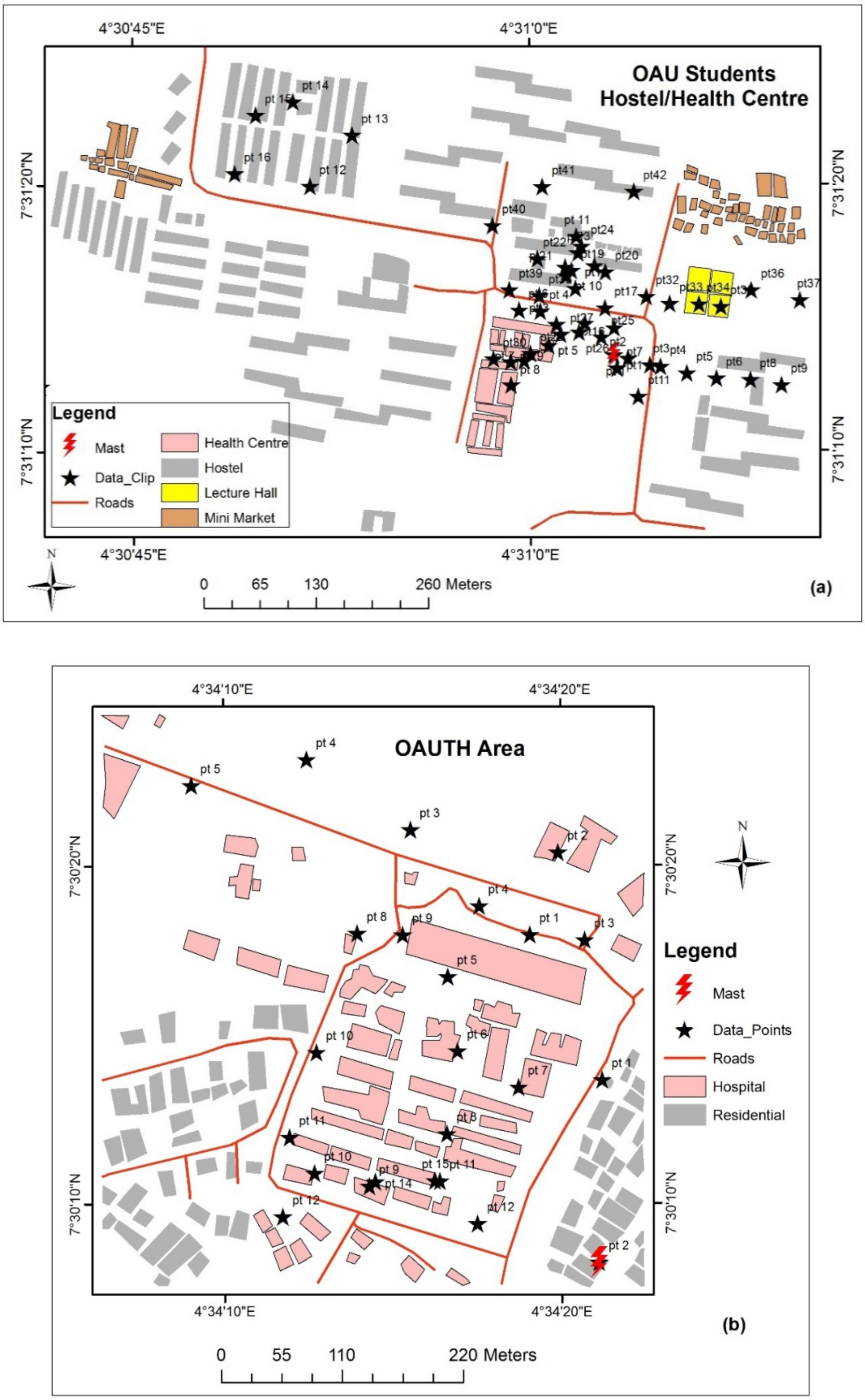

Figure 2: Study Sites and Points of Data Collection (a) OAU Students' Hostel/Health Centre (b) OAUTHC Area

Inverse distance weighted interpolation (IDW) procedure was used to model the spatial distribution of microwave radiation. IDW interpolator is a weighted average of neighbouring values. It weights the points closer to the prediction location greater than those farther away (Burrough, 1986; Baltrenas and Buckus, 2013). Weighting is assigned to sample points through the use of a weighting coefficient that controls how the weighting influence will drop off as the distance from new point increases. The greater the weighting coefficient, the less the effect points will have if they are far from the unknown point during the interpolation process. As the coefficient increases, the value of the unknown point approaches the value of the nearest observational point. The general formula of IDW interpolation for 2-D problems (Shashi and Hui, 2008) is

$$w(x,y) = \sum_{i=1}^{N} \lambda_i w_i \qquad \lambda_i = \frac{(\frac{1}{d_i})^p}{\sum_{k=1}^{N}(\frac{1}{d_k})^p}$$

where *w(x,y)* is the predicted value at location *(x,y)*, N is the number of nearest known points surround λ_I are the weights assigned to each known point value w_i at location (x_i,y_i), d_i are the 2-D Euclidean distance between each (x_i,y_i) and *(x,y)*, and p is the exponent, which influences the weighting of w_i on *w*.

The modelling of the spatial pattern of microwave radiation from GSM base stations around the study area was performed in ArcGIS 10.2 software environment.

At the OAUTHC, measurements were taken at the Male and Female Wards (medical and surgical), neo-natal Ward, Children's Ward, Children Emergency Ward, Intensive-Care Unit and one of the Consulting Rooms, as well as at other relevant public space. At the Health Centre, measurements were taken at the Consulting rooms, Pharmacy Shop, Nursing room, Waiting rooms, Treatment rooms, Male and female Wards as well as at a number of public spaces of interest. Due approval was secured before the indoor measurements were taken.

RESULTS AND DISCUSSION

Indoors Microwave Radiation Levels

The results of the 4 microwave radiation parameters at the various indoor locations at the two health facilities are shown in Tables 1 and 2. Only results for the year 2016 are shown. At the Health Centre, maximum average microwave power levels ranged from 40.8 W/m^2 at RMB2 to 280.3 W/m^2 at the Pharmacy. At the OAUTHC, the levels ranged from 0.1 W/m^2 at the old Children Ward to 925.3 W/m^2 at the Male Ward. However, the 806.1 W/m^2 measured at the Neonatal Ward is probably more significant, considering the vulnerability of the occupants of that location.

Table 1: Intensity of Indoor Microwave Radiation at OAU Health Centre (2016)

Location	Maximum Power Density (μW/m^2)	Maximum Average Power Density (μW/m^2)	Maximum Electric Field (mV/m)	Maximum Average Electric Field (mV/m)
Consulting Room 2	82.7	45.2	14.9	3.00
Nurses room	100.0	67.1	15.0	3.01
Pharmacy	460.3	280.3	16.5	3.40
Consulting Room 1	391.1	247.3	16.3	3.32
Consulting Room 6	271.3	206.4	16.0	3.28
Waiting Room 1	111.6	94.6	16.2	4.77
Waiting Room 2	192.6	158.2	15.0	3.01
Treatment &Injection Rm	126.2	148.8	15.5	3.01
RMB 22	75.6	43.2	14.8	2.91
RMB 20	63.4	40.8	14.6	2.96

Table 2: Intensity of Indoor Microwave Radiation at OAU Teaching Hospital (2016)

Location	Maximum Power Density ($\mu W/m^2$)	Maximum Average Power Density ($\mu W/m^2$)	Maximum Electric Field (mV/m)	Maximum Average Electric Field (mV/m)
Male Ward	6105.0	925.3	30.1	12.3
Female Ward	161.6	129.0	16.4	3.0
Neo-natal Ward	1386.0	806.1	22.3	8.01
Intensive-Care Unit Ward	805.3	576.9	20.1	6.12
Plastic Female Surgery Ward	904.3	634.1	21.7	5.98
Plastic Male Surgery Ward	863.4	544.6	18.6	5.81
Consulting Room	739.4	0.1	18.4	5.72
Children's Ward (Old)	521.9	0.1	16.8	3.1
Children Emergency Ward	429.7	0.7	16.6	3.04

Outdoors Microwave Radiation Levels

Plots of electric field and power density of microwave radiation, outdoors, at the two study sites are shown in Figures 3 and 4. Results for both years 2014 and 2016 are displayed together for comparison. It can be seen that whereas the change in radiation levels between 2014 and 2016 is quite low at the OAUTHC, there has been a massive change in levels at the Health Centre.

The results show that at the Health Centre/Students Hostels in 2014, $\bar{E}_{max, av}$ ranged from 2.1 - 5.45 mV/m, the $\bar{E}$ ranged from 14.0 - 20.1 mV/m, the $\bar{\delta}_{max, av}$ ranged from 0.1 -1,862 $\mu W/m^2$ and δ ranged from 0.1 - 2,106 $\mu W/m^2$. By 2016 however, $\bar{E}_{max, av}$ now ranged from 129.4 - 2,472 mV/m, the $\bar{E}$ ranged from 272 - 3,007 mV/m, the $\bar{\delta}_{max, av}$ ranged from 58.6 - 20,003 $\mu W/m^2$ and $\bar{\delta}$ ranged from 76.4 - 25,180 $\mu W/m^2$. Spatial pattern of $\bar{\delta}_{max, av}$ (Figure 5a) indicates that the highest concentration occurs around the two storeys Alumni Hall located on a foothill and directly facing the radiation antenna. Low values occur at the back of the antenna (where the Health Centre is situated) and at far distances away from the base station.

At the OAUTHC complex in 2014, the $\bar{E}_{max, av}$ ranged from 2.7 - 11.9 V/m, the $\bar{E}$ ranged from 15.9 - 16.8 V/m, the $\bar{\delta}_{max, av}$ ranged from 19.6 - 2,058 $\mu W/m^2$ and $\bar{\delta}$ ranged from 101.2 - 3,850 $\mu W/m^2$. In 2016 at the OAUTHC the $\bar{E}_{max, av}$ now ranged from 10.0 - 1,217 mV/m, the $\bar{E}$ ranged from 16 - 1,792 mV/m, the $\bar{\delta}_{max, av}$ ranged from 48.4 - 4,037 $\mu W/m^2$ and $\bar{\delta}$ Distribution of $\bar{\delta}_{max, av}$ on the terrain (Figure 5b) indicates occurrence of highest concentration at the centre of the hospital complex (around the Gynaecology Unit) which faces the radiating antenna, and values progressively decrease away from the mast, with the minimum registered around the School of Nursing area.

Electric Field Intensity Power Density

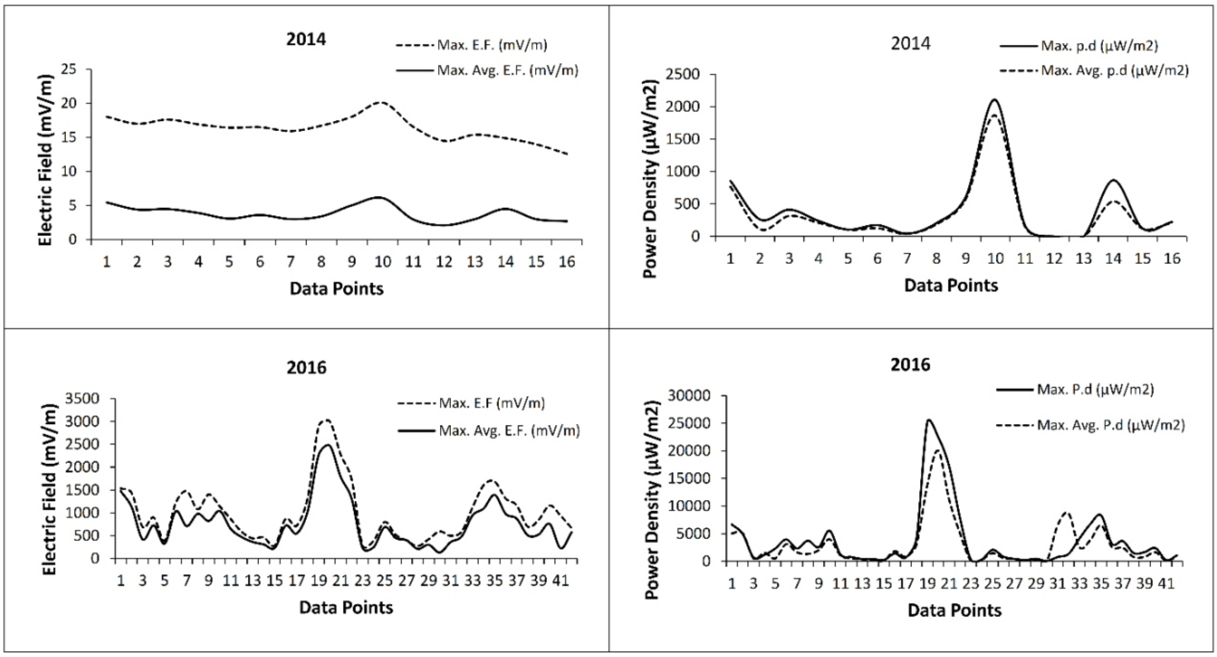

Fig. 3: Plots of Electric Field Intensity and Power Density of Microwave Radiation at Health Centre/ Students Hostel for 2014 and 2016

Electric Field Intensity Power Density

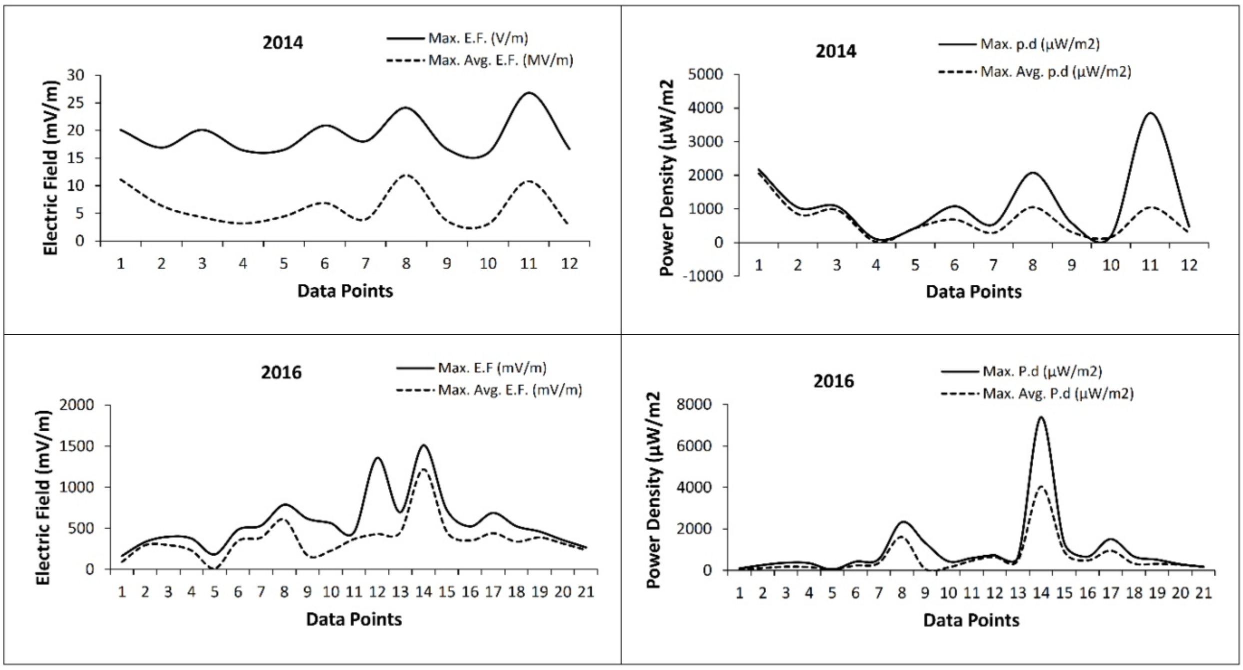

Fig. 4: Plots of Electric Field Intensity and Power Density of Microwave Radiation at OAU Teaching Hospital Complex for 2014 and 2016

Fig. 5: Spatial Distribution of Maximum Average Power Density of Microwave Radiation at Students Hostel/Health Centre (a) and OAUTH Complex (b)

At a given location, values of radiation level depend on distance from the source (presumably the mast), as well as the topography, elevation, and nature and density of intervening vegetation cover between the source and the location of interest. For indoor measurements, thickness and nature of the materials for indoor walls and partitions, as well as the presence of other minor sources of microwave radiation (such as wi-fi from laptops or phones) within the room will all affect the level of radiation measured. There is also the possibility of the radiation intensity from the main source, the GSM mast, changing in the course of the measurements depending on the traffic from users.

Going by the ICNIRP guidelines for levels of microwave radiation deemed capable of producing adverse health effects in humans (about 9,400 W/m^2 for radiation between 400 – 2000 MHz range), all locations at the two healthcare facilities could be considered relatively safe. However, the ICNIRP guidelines values assume that adverse health effects from microwave radiation arise only via thermal effect (Vecchia, 2012). Several authorities vigorously challenge this assumption, and they have persuasively shown that non-thermal effects are important and should be considered in setting guidelines on exposure to microwave radiation. Most developed countries concur with these other authorities and accordingly base their regulations on far more conservative values, consistent with the Precautionary Principle. Countries like England, USA, Belgium, Switzerland, Portugal, Netherland and Germany base their guidelines on the more conservative values recommended by the European Commission (Kumar, 2010).

For instance, in making recommendation for microwave radiation levels within residential buildings (sleeping areas), the respected Germany-based Institute for Building Biology rates microwave radiation levels of between 0.1 – 10 W/m^2 as of "Slight Concern"; those between 10 – 1000 W/m^2 as of "Severe Concern", and finally, those above 1,000 W/m^2 as of "Extreme Concern" (Building Biology, 2008). From this perspective, the microwave radiation levels at several locations both at the Health Centre and the OAUTHC are of "Severe Concern."

Furthermore, the measurements at the outdoor facilities around the Health Centre, show that while the Health Centre enjoys relatively safe microwave radiation levels, one of the students' hostels, on the other hand, was so positioned to receive alarmingly high levels. The microwave average maximum power density of 20,003 W/m^2 (peak value of 25,180 W/m^2) measured at this students' hostel (especially at the Porter's Lodge) is extremely high, and surpasses even the overly liberal ICNIRP specification upon which the current regulations from the Nigeria's Federal Ministry of Environment are based. In the fierce competition to provide very high GSM reception at student hostels, the Mobile Telecommunication service providers have become insensitive to the possible deleterious health impacts (Ariyoosu, 2014). Given the ubiquity of GSM masts all over the country, the data obtained in this work is an eye-opener as to what could be happening at similar establishments elsewhere. We believe there is the need for the installation of some form of EM radiation shielding at critical locations, not only within healthcare facilities where particularly-vulnerable subjects might be subjected to extended stays (such as the Intensive Care Units, Psychiatric, and the Neonatal Wards), but also at similar non-medical facilities, including Day care facilities for babies.

CONCLUSION

Indoor and outdoor microwave radiation levels have been measured at two health facilities within the Obafemi Awolowo University, Ile-Ife. Both average and peak (maximum of instantaneous) values were noted. The differences in the measurements made in 2014 and those made in 2016 reflect the upgrades to the GSM masts within that period, as well as the loading (number of subscribers connecting) at the particular time of our measurements. The radiation power density at most of the locations investigated was below the maximum limit of 9,400,000 μW/m^2 stipulated by the Federal Ministry of Environment, based on values suggested by the non-governmental agency, the International Commission on Non-ionizing Radiation Protection (ICNIRP), and recommended by the World Health Organization. It is noted however that these values are overly liberal, being based on thermal effects only.

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