DETERMINATION OF ELECTROMAGNETIC RADIATION LEVELS FROM CELL PHONES AND GSM MASTS IN ILE-IFE, SOUTHWEST NIGERIA

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ABSTRACT

In this study, all levels of microwave radiation around the 32 Global System for Mobile (GSM) masts/towers in operation at different locations in Ile-Ife city as at July 2012 were assessed. Using an electrosmogmeter, the instantaneous electric field $\bar{E}$, average maximum of electric field $\bar{E}_{max,av}$, instantaneous power density ($\bar{\delta}$), and average maximum power density $\bar{\delta}_{max,av}$, of microwave radiation were measured around these masts. Three hundred and three (303) sampling points were chosen, with a minimum of eight measuring points (with their Global Positional System - GPS coordinates recorded) around each of the masts. Contour maps of the magnitude of these variables at Ile-Ife were thereafter produced using ARCGIS 10.1 software. Furthermore, the same four radiation parameters were measured in some popular brands of cell phones under various operating and signal receptivity conditions. The results showed that in Ile-Ife, $\bar{E}_{max,av}$ ranged from 57 - 480 mV/m, $\bar{E}$ ranged from 85 - 566 mV/m, $\bar{\delta}_{max,av}$ ranged from 25 - 448 $\mu W/m^2$, and $\bar{\delta}$ ranged from 527 - 2,106 $\mu W/m^2$. The lowest value was at Adegoke area with $\bar{E}_{max,av}$ ranging from 9 - 281 mV/m, $\bar{E}$ ranging from 85 - 285mV/m, $\bar{\delta}_{max,av}$ ranging from 0.1 - 217 $\mu W/m^2$, and $\bar{\delta}$ ranging from 0.2 - 225 $\mu W/m^2$. At the OAU Teaching Hospital, $\bar{E}_{max,av}$ ranged from 145 - 708 mV/m, $\bar{E}$ from 173 - 798 mV/m, $\bar{\delta}_{max,av}$ from 65 - 1,361 $\mu W/m^2$ and $\bar{\delta}$ from 96 - 1,811 $\mu W/m^2$. For the cell phones, $\bar{E}_{max,av}$ ranged from 0.9 - 199 mV/m, $\bar{E}$ ranged from 5,700 - 20,000 mV/m, $\bar{\delta}_{max,av}$ ranged from 0.1 - 81 $\mu W/m^2$ and $\bar{\delta}$ ranged from 86 - 989 $\mu W/m^2$. Phone brand, signal strength, and phone activity (standby, connecting, receiving, calling, or texting) significantly affected the radiation outputs from the cell phones. Though radiation output values obtained in this survey were in compliance with guideline values set by the ICNIRP, which is the standard adopted by the Federal Ministry of Environment for Nigeria, they exceed, at several locations, the precautionary limits of 1,000 $\mu W/m^2$ suggested in the more realistic and widely acclaimed Bioinitiative Report.

Keywords: Microwave Radiation, GSM Masts, Health Impacts

INTRODUCTION

Microwave radiation has become an indispensable technological tool in modern day life. Notably, the current astounding developments in Information Communication and Telecommunication are built squarely on microwave radiation. However, it is now clearly evident that considerable adverse health effects could be associated with microwave radiation. In other to effectively study and protect against these adverse effects, it is absolutely necessary that the human exposure to the radiation be well characterized. This will enable individuals to better assess and manage the risks associated with the technology, as well as enable epidemiologists in identifying and correlating exposure patterns with adverse health effects. Other stakeholders would also find the information useful for a variety of purposes. For example, Urban Planners would find it useful for optimal appropriation of space. Radiation levels at certain strategic zones could also be monitored and restricted by recommendation of appropriate measures to accompany the deployment of GSM masts and towers. Cell phones on their own also both emit and receive microwave radiations as part of their operations, typically in the 900 MHz frequency band while the Towers operate in the 1800 MHz band. Safeguards must therefore be holistically devised for the industry by considering both cell phones and the base stations together.

Several studies have implicated GSM towers and cell phones in several adverse health effects. Although the World Health Organization and other governmental agencies (local, national or regional), arguably under pressure from entities

with strong commercial interests in GSM technology, often insist that the evidences for several of these adverse effects have not been convincingly demonstrated beyond reasonable doubts, yet the fact that many of the results were obtained in well-conducted, flawless scientific investigations is not in doubt (Karger, 2005; Levitt and Lai, 2010; Yakymenko *et al.,* 2011; Eskander *et al.,* 2012; Sivani and Sudarsanam, 2012; Gandhi *et al*., 2014; Gulati *et al*., 2015; Meo *et al*., 2015; Yakymenko *et al*., 2015; Black *et al*., 2016; etc.). The non-confirmation of such results in other settings can therefore not invalidate them; especially as it is virtually impossible to perfectly replicate epidemiological research with the several possible confounding variables, known and unknown, that are usually involved. Moreover, it has been pointed out (Genius 2008, Sage and Carpenter, 2009) that even if, for the sake of argument, risks from microwave radiation to individuals are taken as very low, the sheer number of people involved and the increasing exposure patterns, still translate to a veritable looming public health nightmare.

The precautionary principle recommends that we do not wait to get all the evidences in beyond any iota of doubts, before reasonable actions to ameliorate the situation are initiated. Given the long latency period usually involved in the development of such adverse health effects as cancers, by the time all the evidence comes in, an irreversible catastrophe might as well have been on the way. Kumar (2010) listed several compelling anecdotal evidences of deleterious health impacts of radiofrequency radiation associated with GSM technology, which can simply not be waved aside as not meeting rigorous scientific method of inquiry. These include the situation in Berkeley House, Staple Hill, Bristol, UK, where several people living on the top floor of the five story building developed cancer after an Orange mobile mast was erected on the roof. Another is the report from Warwickshire, also in the UK, where 31 cancer cases were recorded on a single street and seven out of 30 staff at a special school developed brain tumors, apparently under the influence of a nearby 30 m high GSM mast. Yet another compelling fact is the situation in the Province of Malagahoy in Malaga where 43 cancer cases were recorded among the 350 residents living near a mobile telephone relay antenna.

It is instructive to note that, after years of controverting the evidence, (INTERPHONE, 2010) it is now generally accepted, even by the official Agency of the WHO on Cancer, the International Agency on Research on Cancer IARC, (WHO, 2014) and also the US National Toxicology Programme (NTP, 2016) that malignant glioma, a form of brain tumor, is associated with use of cell phones. There is a significantly increased risk of malignant glioma in individuals that have used a mobile phone for 10 or more years, with the risk being elevated only on the side of the head on which the phone is used regularly (ipsilateral use). Studies also show (e.g. Khurana *et al.,* 2009) that the risk is greater in individuals who began to use mobile phone at younger ages. Khurana *et al.* (2009) reported that after even just 1 or more years of use, there was a 5.2-fold elevated risk in children who began to use mobile phones before the age of 20 years, whereas for all ages the odds ratio was 1.4. However the evidence for association of adverse health effects with mobile masts is still largely deemed as yet inconclusive (Hyland 2005, Karger, 2005; Cogliano, 2006; Valberg et al., 2997; Khurana *et al*., 2010; IARC, 2011). While the World Health Organization in Factsheet 193 (WHO, 2011) considers existing scientific evidence not sufficiently "convincing;" other organizations, such as Mast Victims, espouse opposite views (MVO, 2016).

Several studies have focused on determining the microwave radiation exposure levels associated with GSM towers in various cities all over the world (e.g. Anglesio *et al*., 2001; Lonn *et al*., 2004; Neitzke *et al*., 2007; Viel *et al*., 2009; Bugi *et al*., 2010; Bolte and Eikelboom, 2012; Beekhuizen *et al*., 2013; Urbinello *et al*., 2014a and b). In Nigeria, there have been reports on the cities of Ibadan (Ayinmode and Farai, 2013), Lagos (Fawole and Adekanye, 2016), among probably many others. In this work, we have provided a GIS-based mapping of the levels of microwave radiation in Ile Ife metropolis. Furthermore, we establish the levels of radiation from some popular brands of cell phones, as well as some factors presumed to be capable of influencing these levels. These will enable realistic assessments of exposure of people to microwave radiation, and consequently

contribute to overall risk assessment of adverse health impacts associated with electromagnetic radiation in the GSM telecommunication industry.

MATERIALS AND METHODS.

Radiation from GSM Masts and Towers

The study area is Ile-Ife metropolis in Osun State of Nigeria. Two hundred data points were selected at various distances in the vicinity of the 32 GSM masts in operation in July 2012. The selected points were strongly influenced by physical access. Afterwards, another set of 103 points were purposely selected to enhance the krigging process needed for interpolation and obtaining contour mapping for the entire city. Hence, a total of three hundred and three data points were sampled. The GPS coordinates of each data point, together with those of the masts, were recorded, thus permitting us to compute distances and elevations as required. The data points are shown in Figure 1.

Microwave radiation parameters at each selected points were measured with a portable Electrosmogmeter. The Electrosmogmeter has a non-directional (isotropic) electric probe with three channels measurement sensor and capacitated with frequency ranges from 10 MHz to 8 GHz. The parameters measured for each data point were instantaneous electric field $\bar{E}$ (mV/m), average maximum of electric field $\bar{E}_{max,av}$ (mV/m); instantaneous power density $\bar{\delta}(\mu W/m^2)$, and average maximum power density, $\bar{\delta}_{max,av}$ $(\mu W/m^2)$.

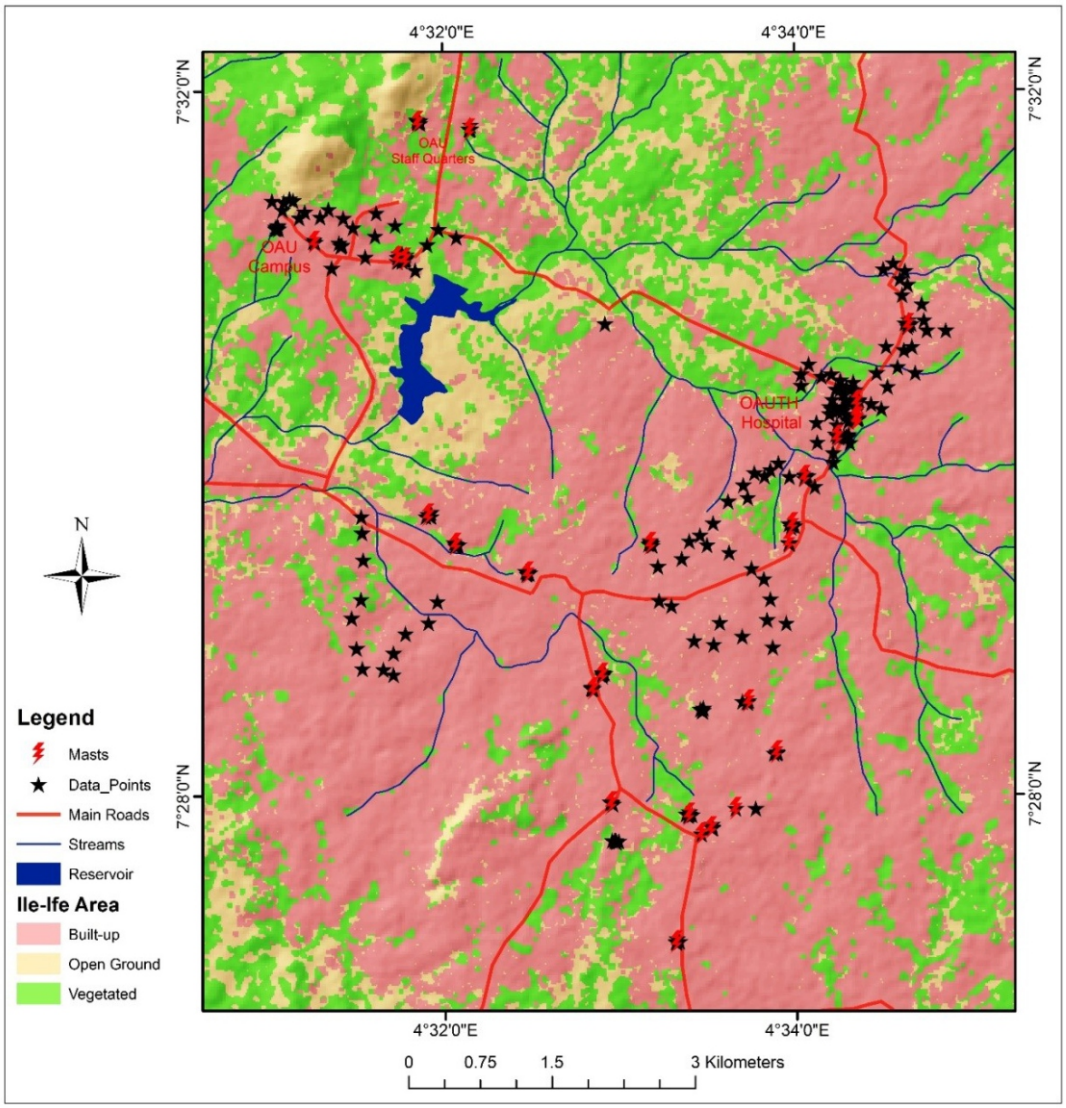

Figure 1: Location of GSM Masts and Sampling Points in Ile-Ife Township

Radiation from GSM cell phones

To study the determinants of microwave radiation emitted by cell phones, 5 cell phones were incorporated into the study. These comprised of a Nokia 5130C, a Nokia 1202, two Nokia N1280 (1 month, and 12 months in use respectively), and a Techno. As for the study on Masts/towers, four parameters characterizing microwave radiation strength from the phones were measured. These were the instantaneous electric field $\bar{E}$, average maximum of electric field $\bar{E}_{max,av}$, instantaneous power density ($\bar{\delta}$), and average maximum power density $\bar{\delta}_{max,av}$. The influence of Brand, Age, battery level, signal reception level, and phone activity (standby, connecting, receiving, calling or texting), were systematically investigated. To correct for fluctuations in radiation intensities from the source in the course of the measurements, the background "no activity" reading is first noted and subtracted from the subsequent level under the condition under investigation. All the measurements were taken with the electrosmogmeter nearly touching the surface of the phone's antenna.

RESULTS AND DISCUSSION

GSM Masts and Towers

Contour plots indicating regions of equal values for the four parameters characterizing microwave radiation levels at Ile-Ife are shown in Figures 2 and 3 (for Electric Field and Power Density, respectively).

The results showed that in Ile-Ife, $\bar{E}_{max,av}$, ranged from 57 - 480 mV/m, the $\bar{E}$ ranged from 85 - 566 mV/m, the $\bar{\delta}_{max,av}$ ranged from 25 - 448 W/m^2 and $\bar{\delta}$ ranged from 527 - 2,106 W/m^2. The lowest value was recorded at Adegoke area with $\bar{E}_{max,av}$ ranging from 9 - 281 mV/m, $\bar{E}$ ranging from 85 - 285mV/m, $\bar{\delta}_{max,av}$ ranging from 0.1 - 217 W/m^2 and $\bar{\delta}$ ranging from 0.2 - 225 W/m^2. At the OAU Teaching Hospital, $\bar{E}_{max,av}$ ranged from 145-708 mV/m, $\bar{E}$ from 173 - 798 mV/m, $\bar{\delta}_{max,av}$ from 65 - 1,361 W/m^2 and $\bar{\delta}$ from 96 - 1,811 W/m^2

Microwave radiation level depends on the configuration of the antenna on the masts (the types, number, orientation, tilt, operating power, etc.), the height of the mast, the topography of the region, distance to point of measurement, and intervening medium (houses, vegetation, etc.). The operating power of the mast depends on the level of use at the particular point in time.

Current regulation for operations of mast/towers in Nigeria is however still based on the 1998 recommendations of the International Commission for Non-Ionizing Radiation Protection (ICNIRP), a non-governmental body. According to Regulation 8 (2) of the National Environmental (Standards for Telecommunications and Broadcast Facilities) Regulations, 2011 pages B361-370. "Permissible radiation level for occupational staff on site and for the general public shall conform to all extant standards, regulations and the permissible limits approved for telecommunications/broadcasting facilities by the World Health Organisation (WHO) and the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and any amendments thereof."

In the 400 - 2000 MHz range, ICNIRP's Guideline values for Public exposure are given by Power Density: f/200 W/m2 and E-field: $1.375\sqrt{f}$V/m. For GSM towers (with transmitting frequency in GSM1800 of 1872 MHz), these translate to Power Density - 9.36 W/m^2, and Electric Field - 59.5 V/m. For Cell phones (transmitting frequency in GSM900 of 945 MHz), the values are Power Density - 4.73 W/m^2; Electric Field - 42.3 V/m.

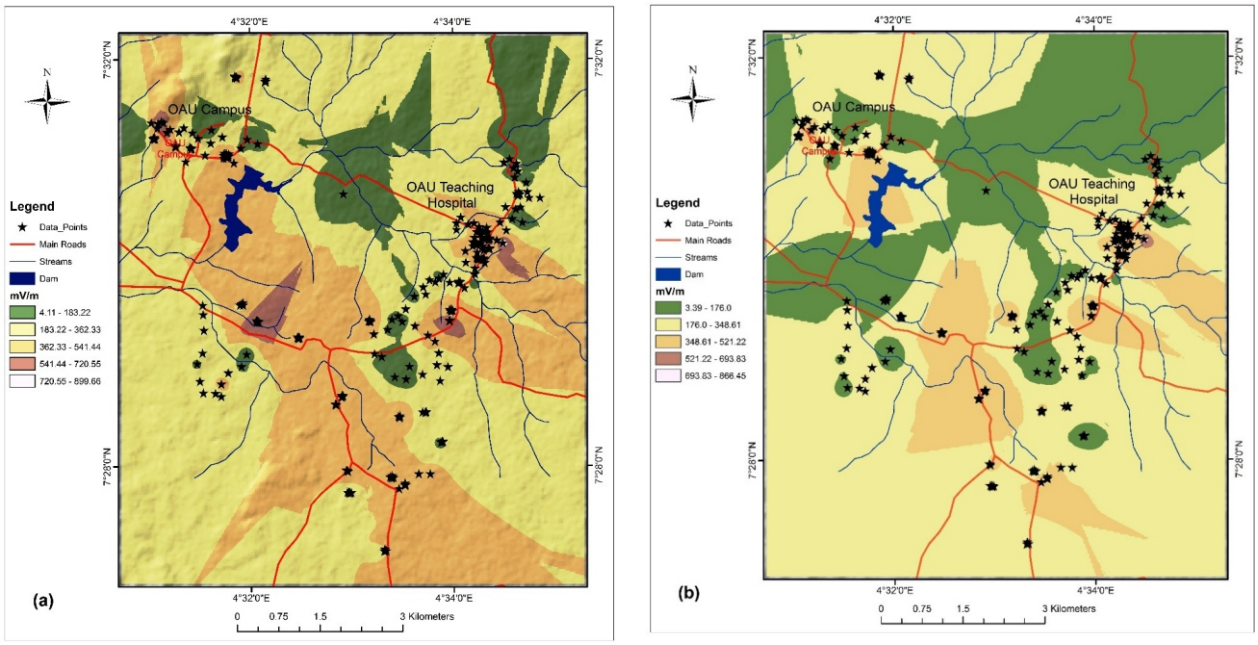

Figure 2 Distribution of Maximum Instantaneous Electric Field and Maximum Average Electric Field from radiofrequency Microwave radiation in Ile-Ife

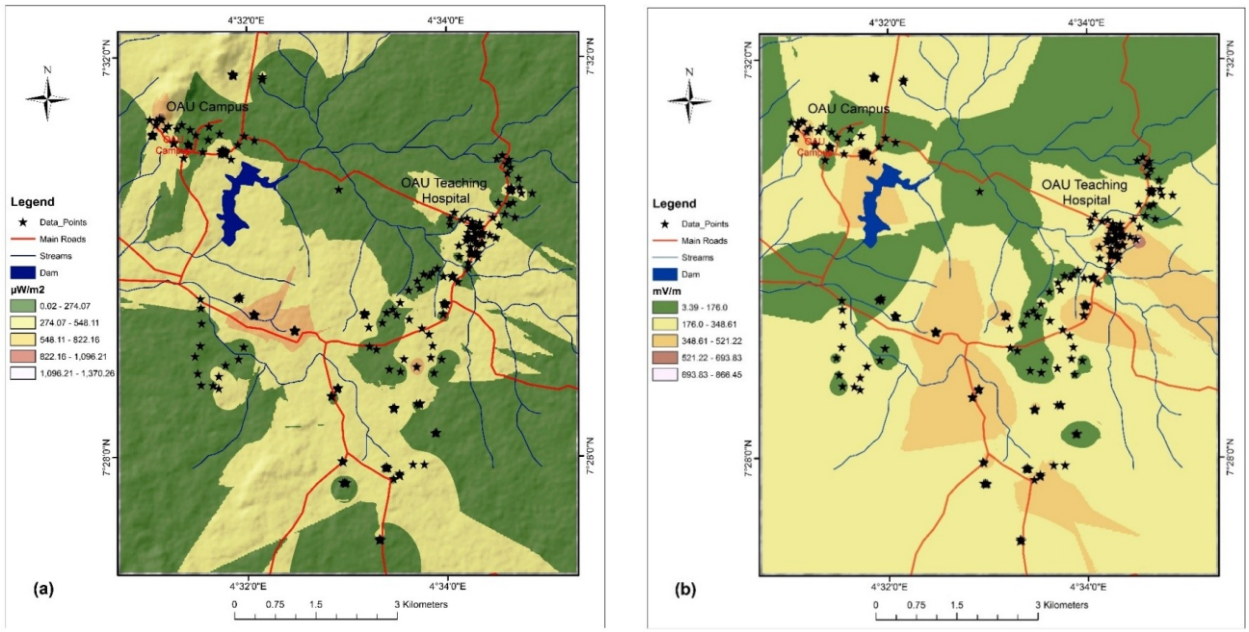

Figure 3: Distribution of Maximum Instantaneous Power Density and Maximum Average Power Density from radiofrequency Microwave radiation in Ile-Ife

All the values recorded at Ile-Ife were well below these ICNIRP 98 values. However these values have been severely criticized in that they are set to protect only against high-intensity, short-term, tissue-heating thresholds, ignoring completely the well-established adverse effects associated with low-intensity, chronic exposures. The values therefore do not protect against cancer, for instance, and they are insensitive to vulnerable groups such as children and pregnant women. One of the several protests raised by scientists all across the world against the continued adoption of ICNIRP's guideline values by the WHO is the International EMF Scientist Appeal, ("http://emfscientist.org/index.php/emf-scientist-appeal).

According to the Appeal: "WHO's International

Agency for Research on Cancer classified Radiofrequency radiation as a Group 2B "Possible Carcinogen" in 2011, and Extremely Low Frequency fields in 2001. Nonetheless, WHO continues to ignore its own agency's recommendations and favors guidelines recommended by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). These guidelines, developed by a self-selected group of industry insiders, have long been criticized as non-protective." ICNIRP itself recognizes the need for "other entities" to further modify its guidelines based on "precautionary principles" and other factors which ICNIRP has not taken into considerations. For instance, in the Factsheet on extremely low frequency (ELF) radiation, ICNIRP admits that certain epidemiological results which it has not made use of "have triggered concern within the population in many countries." It then went on to state that," It is ICNIRP's view, that this concern is best addressed within the national risk management framework" of such countries (ICNIRP, 2009).

There is virtually no developed country in the world whose national regulations for protection against GSM microwave radiation are based on ICNIRP's values. Apart from national "precautionary," or "attention" or similar values, most nations encourage local entities, including cities, to formulate guidelines to limit exposure to radiofrequency EM radiation as they deem appropriate. The EU Parliament recommends a value of 100 W/m^2, while the Building Biology of Germany associates "Severe Concern" with values in the range 10 – 1000 W/m^2. As seen in Table 1, the recommended value adopted in New South Wales, Australia is nearly a millionth the ICNIRP's value. The precautionary value recommended by the widely acclaimed Bioinitiative Project (Sage and Carpenter, 2012) of 1,000 W/m^2 is $9{,}000^{th}$ the value currently adopted for protecting the Nigerian public against radiofrequency EM radiation. This situation should be urgently redressed.

Since installation and upgrading of GSM towers/masts is an ongoing exercise, the contour mapping of the microwave radiation is not static. The picture provided in this study should therefore be periodically reviewed; and the relevant authorities might wish to delimit some zones for peculiar use, where minimal towers installation would be permitted, or at least a specified configuration to ensure exposure is minimised, is enforced. In another report (Akeju *et al.*, 2016), we reported that due to recent reconfigurations on GSM masts at the Obafemi Awolowo University, Ile-Ife, average maximum power densities in excess of 10,000 W/m^2 are now being delivered at one of the students' hostels. This probably reflects the situation in several other campuses in the country where delivery of superfast and reliable microwave signals at student hostels has remained the priority for service providers. The costs should however be carefully counted, and sensible options adopted to assure sustainable development in this important sector of our society.

Table 1: International Radiation Density Limits for GSM1800

Power Density (W/m^2)	International Exposure limits adopted by various countries
10	FCC (USA) OET-65, Public Exposure Guidelines at 1800 MHz
9.2	ICNIRP Recommendation 1998 – *Adopted in Nigeria*
3	Canada (Safety Code 6, 1997)
2	Australia
1.2	Belgium (ex Wallonia)
0.5	New Zealand
0.24	Exposure limit in CSSR, Belgium, Luxembourg
0.1	Exposure limit in Poland, China, Italy , Paris
0.095	Exposure limit in Italy in areas with duration > 4hours
0.095	Exposure limit in Switzerland
0.09	ECOLOG 1998 (Germany*) Precaution recommendation only*
0.025	Exposure limit in Italy in sensitive areas
0.02	Exposure limit in Russia (since 1970), Bulgaria, Hungary
0.001	USA. Recommendation of Bioinitiative Project. "Precautionary limit" in Austria, Salzburg City only.
0.0009	*BUND 1997 (Germany) Precaution recommendation only*
0.00001	New South Wales, Australia

*Adapted from Kumar (2010)

Cell Phone Study

For the cell phones, $\bar{E}_{max}$ ranged from 0.9 - 199 mV/m, $\bar{E}$ from 13 - 20 mV/m, $\bar{E}_{max,av}$ from 0.1 - 81 $\mu W/m^2$ and $\bar{\delta}$ from 86 - 989 $\mu W/m^2$. Phone brand and signal strength significantly affected the radiation outputs from the cell phones. At sites with good signal strength, maximum power density ranged from 86 mW/m^2 for Techno phone, to 920 mW/m^2, for Nokia N1280. With poor signal strengths, Techno phone still had lower power density, but the relative increase was more than the relative increase from the Nokia phones. The age of the Nokia phones did not affect their power outputs. The influence of level of battery voltage could not be consistently determined, presumably due to fluctuations in the emissions from the base station source over the period required to discharge the battery considerably. However, averaging the power outputs at the two levels of "Full" and "Discharged" confirmed lower radiation outputs when the battery is full.

The biological impact of EM radiation from cell phones depends on the amount and rate of energy absorbed by a given mass of a region of the body. This is in addition, of course, to the radio sensitivity of that region (e.g. brain, eye, gonads, more sensitive than hands and feet). The Specific Absorption Rate, SAR, limit derived from ICNIRP exposure limits (for head region) for mobile devices is 2.0 watts / kilogram (W/kg) averaged for 6 minutes over ten grams of body tissue. In the U.S. the SAR limit adopted for general public is 1.6 watts / kilogram averaged over one gram of body. Impact of EM radiation will then depend heavily on not just the SAR from the cell phone itself, but also on habits and pattern of usage by individual subjects. For instance, glioma is associated with the side (ipsilateral) of the brain frequently engaged in phone usage. The risk associated with phone use could be drastically reduced by such practices as: fractionating the dose over both sides of the head during extended calls; use of the speaker mode, which allows the phone to be positioned several centimetres away from the head; waiting for the phone to connect, thereby switching to lower power level, before speaking etc.

Other factors identified in the literature (Vrijheid *et al.*, 2009) as affecting cell phone radiation intensity include: Phone case (good phone case reduces radiation level while the bad case amplifies the exposure intensity); Brand of Phone: Multipurpose phones (some phone are used for calling, chatting, as modem, for television, and radio); antenna strength; Signal Reception condition: Function of Weather (precipitation, thunderclouds and temperature inversion); source emissions from nearby masts, distance from the masts and intervening media, voltage of battery etc.

This study was able to confirm the influence of the above well-known factors on the radiation output from cell phones. It also confirmed that while imported used *"Tokunbo"* phones may constitute a significant contributor to e-waste in Nigeria, they do not constitute any worse microwave radiation hazard than brand new ones, as there is no significant difference in their radiation outputs. The same result had been earlier confirmed for microwave ovens (Odekunle, 2014). As a matter of fact, if there would be any impact of age on microwave generating devices, it would most likely be in the deterioration of the klystron or other system responsible for generating microwave radiation. Hence while the performance of the device may depreciate with age, hazards associated with the radiation also can only decrease as less radiation is generated. That is assuming the safety devices were not compromised with age!

These results are graphically illustrated in Figure 5 comparing radiation outputs with (i) age of phone, (ii) battery voltage status, (iii) signal reception, and (iv) operation mode of phone.

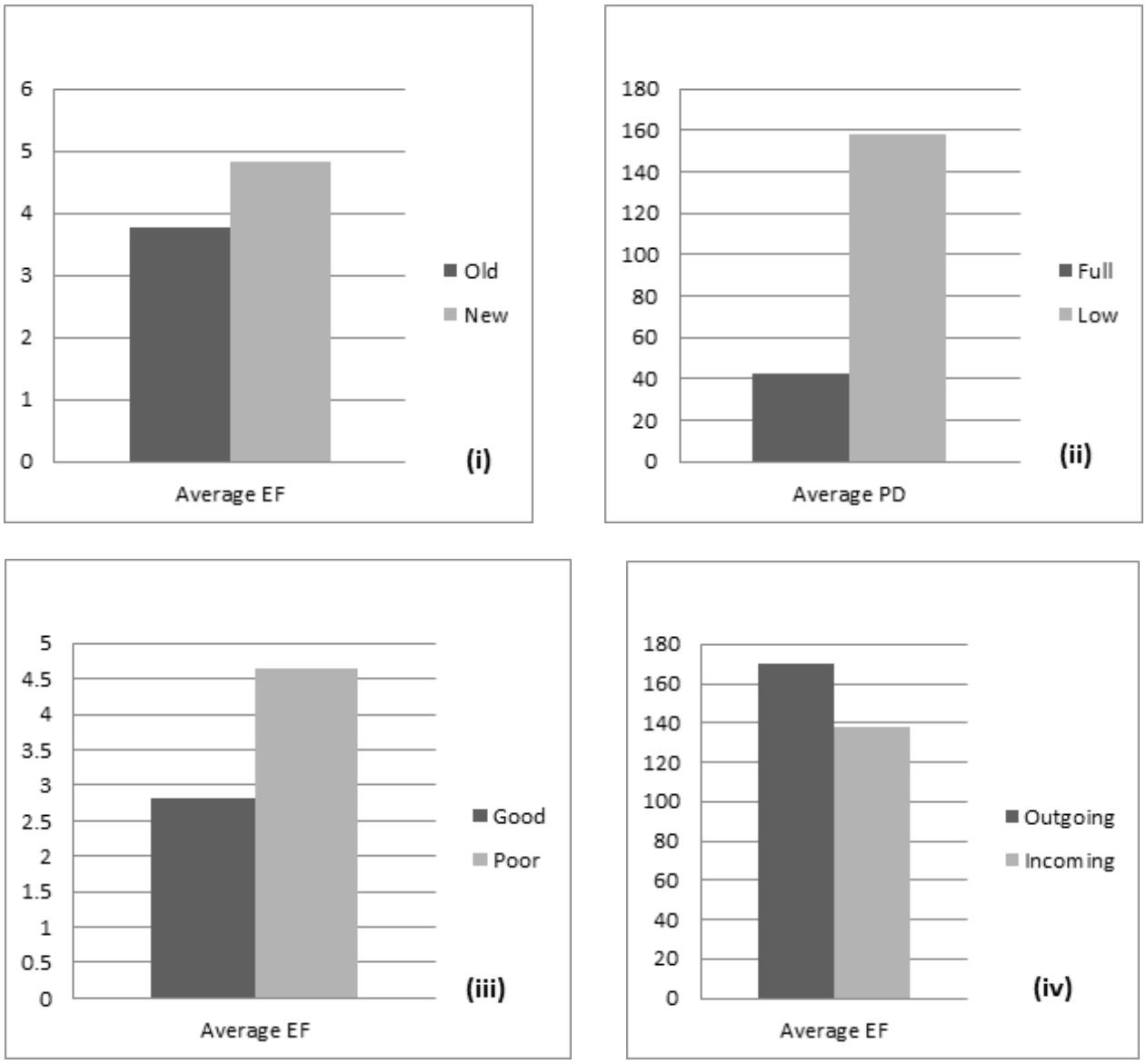

Figure 5: Typical values depicting influence (i) Age of Phone, (ii) Battery Voltage Status, (iii) Signal Reception, and (iv) Operation Mode of Phone on Average Electric Field (EF)/Power Density (PD) from GSM Phones

CONCLUSION

This study has provided typical values for EM microwave radiation associated with GSM technology in Ile-Ife. The spatial distribution shown could be of value to individuals, epidemiologists, or town planners. However, it should be noted that more stringent safety requirements on base stations, if not carefully and creatively implemented, would eventually result in poorer telecommunication services on one hand, and consequent higher emissions at the receptor (cell phone) end. At the end of the day, recognizing the hazards might as well be the most important factor in our safe exploitation of EM microwave radiation for telecommunication. There are a number of technological options, including customizing the actual geometry for the deployment of the masts/towers (mast height, configuration, direction, tilt, etc. of antenna), creative use of land resources, including possible designation of Wi-Fi free regions such as day care centres, (where alternative technologies can be deployed, even if at higher costs), use of creative building designs and special customized building materials, etc. (see Hakgudener, 2015; Seyfi, 2015). Radiofrequency shielding systems and devices can also be installed in special cases where a blanket restriction on EM radiation is not advisable.

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