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Evaluation of Exposure of Radio Frequency Field (RF) Radiation from Mobile Communication Base Stations in Port Harcourt, Rivers State, Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author UNF designed the study, wrote the protocol and wrote the first draft of the manuscript. Authors OAG, CPO and EEO performed the statistical analysis and managed the analyses of the study. Author EEO managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The work evaluates the exposure of radio frequency field (RF) radiation from Mobile Communication Base Stations in Port Harcourt, Rivers State, Nigeria. The instruments used in this study include: RF field strength meter, a portable meter and a GPS. Some locations within Port Harcourt City were selected which include: Rumuokoro, Mile 3, Garrison and Mile 1. The readings were taken from 5 m to 400 m from the telecommunication base stations at about 1.5 m above the ground. The total average amount of radiation measured from different locations were 22.475 μW/cm^2 for Rumuokoro, 26.906 μW/cm^2 for Mile 3, 34.286 μW/cm^2 for Mile 1 and 22.876 μW/cm^2 for Garrison with their corresponding values of coefficient of correlation as -0.52, -0.46, -0.788, and -0.831 respectively. Since this study revealed that the RF exposure hazard index in the Port Hancourt City was below the permitted RF exposure limit to the general public recommended by ICRNIP and WHO, it is highly likely there is no significant impact on human health.

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1. INTRODUCTION

An electromagnetic field (EMF) radiofrequency (RF) radiation is what virtually all device operating on wireless technology make use of today in the world. Mobile communication base station technology makes use of radiofrequency radiation at different frequency band and power level, depending on its application [1]. Mobile communication base stations are located in various part of Port Harcourt city in Nigeria, (residential area, school, market place and office premises). In such environment, millions of people may be exposed to variable levels of electromagnetic fields (radiofrequencies), that is be emitted from the Mobile communication base stations with respect to the distance, the presence of passive structures to either amplify the wave or to shield them, the number of transmission calls within the transmitters and their position with relationship to the orientation of the antenna [2]. Since the introduction of mobile communication base stations in Nigeria the health implication of electromagnetic field (EMF) radiofrequency (RF) radiation from the mobile communication base stations has been of great concern to the Nigerian citizens. Some interested groups believed that radiation from mobile communication base station (GSM) Masts are dangerous to health, others do not believed that RF radiation have effect on human health when exposures to RF field [3]. They also believed that exposure to radiation from base station for long period could cause different diseases like cancer, destroys reproductive organs, congenital anomalies, epilepsy and persistent headache. It is generally agreed that further research is needed to determine the effects and their possible relevance, if any, to human health [4].

However, in spite of the continuous research that has be carried out by many researchers in order to determine a safety limit for RF radiation exposure, biological effects as relate to human exposure standards throughout Nigeria need to be harmonized. The recommended level have being revised many times recently and not all scientific bodies have being able to reach an agreement on this issue.

In Nigeria the International Commission on Non-ionizing radiation protection standards (ICNRP) for maximum limits of exposure is adopted by the Nigeria Communications Commission (NCC) as the standard limit of exposure [5,6]. Human exposure is quantified by the distribution of the time derivative of the absorbed electromagnetic energy per unit mass, *i.e.*, specific absorption rate (SAR). The standards give the accepted maximum values for this quantity, in the form of basic restrictions, which are the starting point in the computation of the reference levels given in the standards [7]. There are few regulatory bodies providing recommendations or precautionary limit to prevent any possible health effect that may be associated with GSM radiation exposure. The Nigerian Communication Commission (NCC) adopted the International Commission on Non Ionization Radiation Protection (ICNIRP) guideline which is 4.5 μW/m^2 for GSM 900 and 9.00 μW/m^2 for GSM 1800, and this guideline is based on the thermal effects of radiofrequency (RF) radiation exposure [5].

The Australian Radiation protection and Nuclear safety Agency (ARPANSA), has listed the type of health hazards due to the high frequency as follows: Electro-stimulation of excitable tissue (3 kHz - 100 kHz), Adverse effects arising from localized or whole body heating (100 kHz – 6 GHz), Excess heating of skin or cornea for frequencies in the range (6 GHz – 300 GHz), Nuisance auditory effects (300 MHz – 6 GH$_Z$) and Adverse effects associated with extremely high pulsed fields (3 kHz – 300 GHz).

This paper aims at evaluating the exposure level of radio frequency field (RF) radiation from mobile communication base stations in Port Harcourt, Rivers State, Nigeria.

1.1 Physics of EMF Transmission

EMF is hidden lines of force that envelop any electrical appliance. An electromagnetic wave is made up of a combination of electric and magnetic field perpendicular to each other as shown in Fig. 1. Electromagnetic waves are described by the electromagnetic theory postulated by James Maxwell which is based on four concepts:

1. Electric fields E move from positive charges to negative charges and coulombs law can be applied in determining the E and the force on a given charge.

$$E = \frac{q}{4\pi\varepsilon_o r^2} \quad (1)$$

$$F = qE \quad (2)$$

2. Magnetic fields are continuous lines of force consisting of closed loops.

$$B = \frac{\varphi}{A \, Sin \, \theta} \quad (3)$$

$$B = \frac{q}{qv \sin \theta} \quad (4)$$

A changing magnetic field induces an Electromagnetic force and therefore an electric field (Faraday's Law).

$$E = -N \frac{\Delta\varphi}{\Delta T} \quad (5)$$

$$\Delta\varphi = B\Delta A \quad (6)$$

$\Delta\varphi$ = changing flux

3. Moving charges or electric current induce a magnetic field B

$$B = \frac{\mu_o NI}{L} \quad (7)$$

Where E= Electric field, B = magnetic field, T = time, ε_o = electric Permittivity, μ_o = Magnetic Permeability in free space, N = no of turns, L= length and i = Electric current

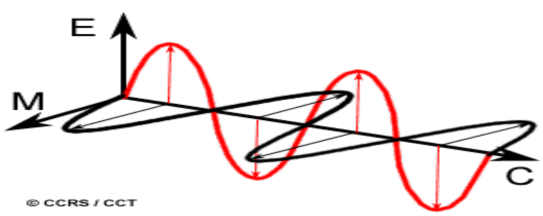

Fig. 1. Electromagnetic wave

Maxwell's equation:

1) Gauss' law for electricity

$$\oint E.dA = \frac{q}{K_{el}} \quad (8)$$

2) Gauss' law for magnetism

$$\oint B.dA = 0 \quad (9)$$

3) Faraday's law of induction

$$\oint E.ds = \frac{-d\varphi_s}{dt} \quad (10)$$

4) Ampere – Maxwell's law

$$\oint B.ds = \mu_{oi} + {}^{1}/_{C^2} \, {}^{\partial}/_{\partial t} \int E.dA \quad (11)$$

EMF can be transmitted by the use of antennae. An antenna is an electrical device which converts electrical power into radiowaves and vice versa [8]. An antennae has the ability to detect EMF by intercepting the power of EMF waves in order to produce a tiny voltage at its terminal which can be amplified. Antennae are utilized in all equipment that use the radio technology to operate such as telecommunication masts, mobile phones, radio and television broadcasting, satellite communications, automatic door openers, baby monitors e.t.c. In mobile phone technology, the antennae in the mobile phone and the one in the mast are always in constant communication. It is the antennae that help to transmit information back and forth between the telecommunication mast and the mobile phone.

An antenna consists of an arrangement of metallic conductors electrically connected to a receiver. Omni directional antennae are designed to receive radio waves from all direction while directional antennae receive radio waves from only a specified direction.

1.2 Study Area

The study area is Port Harcourt which is the capital of Rivers State, Nigeria. The city is located in the oil rich Niger Delta region, southern part of Nigeria. Port Harcourt is situated between Latitudes 43°north and 4°45'north and Longitudes 7°00'east and 7°15'east in the geographical map [9]. The City occupies about four hundred and seventy square kilometers 470.00 sq km of land. According to the 2006 census, the population of the area is 1,000,908 persons [9]. The locations covered are Rumuokoro, Mile 3, Mile 1 and Garrison cluster. The map of the study area is shown in Fig. 2.

2. MATERIALS AND METHODS

The instruments and materials used in this research work are radiofrequency field strength meter (ALRF05 Model, Toms Gadgets), GPS 76 (Garmin Model), measuring tape and stop watch. The radiofrequency field strength meter (ALRF05 Model, Toms Gadgets) is a broadband device for monitoring high frequency radiation in range

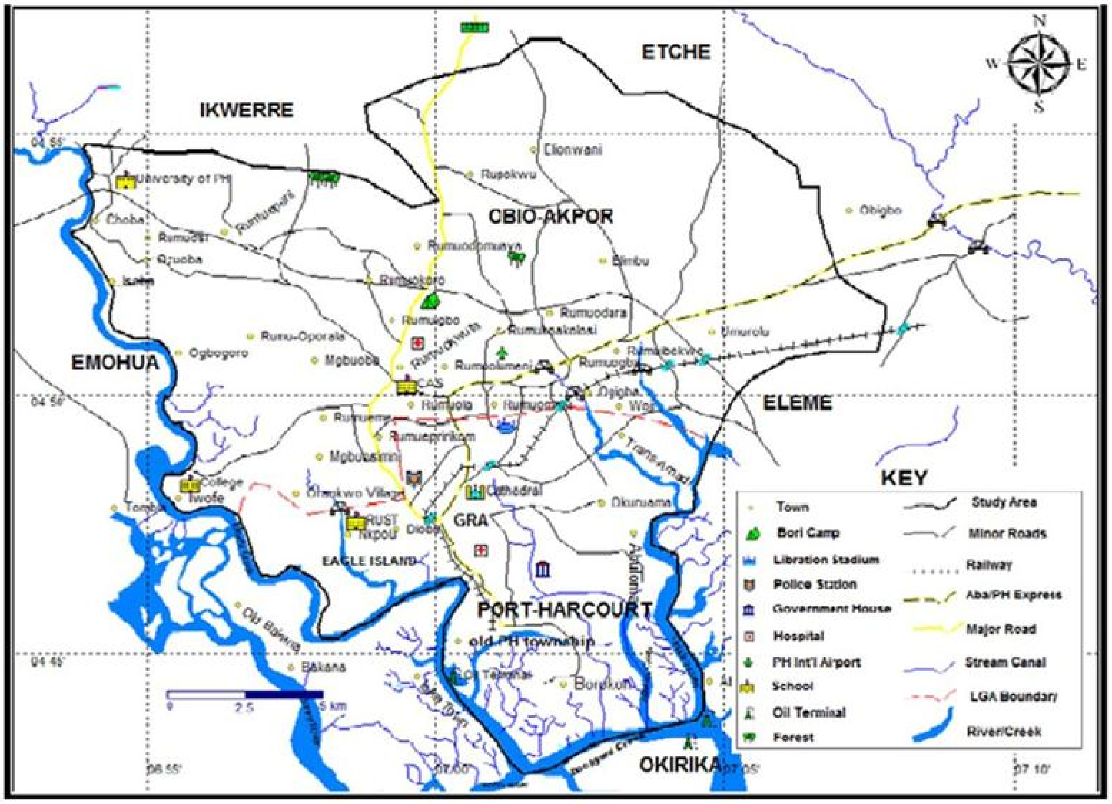

Fig. 2. Map of Port Harcourt City showing study area

of 50MHz to 3.6GHz. In this study, an *in situ* measurement approach was employed to measure the power density of electromagnetic radiation at strategic distances (5 m -400 m) away from the clusters of telecommunication base stations at the four cardinal (north, south, east and west) directions at regular time daily. The radiofrequency field strength meter was place at the height of one meter above the ground during monitoring. The GPS 76 (Garmin Model) was used to measure the geographical positions of the measured locations. The data (power density) were collected from the major three (3) GSM operator's telecommunication base stations, which were located in Port-Harcourt City of River State, Nigeria.

2.1 Method of Data Analysis

The data obtained were analyzed using correlation analysis to determine the coefficient of correlation between the exposure to GSM RF to human health and the period of exposure. Graphical representations were used to analyze the total amount of radiation obtained at each GSM masts. The equation below was used to determine the coefficient of correlation [3].

$$r = \frac{\sum XY - \frac{(\sum X)(\sum Y)}{n}}{\sqrt{\left(\sum X^2 - \frac{(\sum X)^2}{n}\right)\left(\left(\sum Y^2 - \frac{(\sum Y)^2}{n}\right)\right)}} \quad (12)$$

Where r = Cofficient of correlation, X = Average amount of radiation measured, Y= Period of exposure to GSM RF radiation and n = The number of terms

3. RESULTS AND DISCUSSION

The analysis of the results were done by determining the coefficient of correlation and graphical analysis in other to establish the fact that whether exposure to GSM base station has effect or no effect on human health for a long period of time. Table 1 showed the analysis of radiation level from the cluster at different Locations in River State, and the coefficient of correlation of each location computed are presented in Tables 2 - 5 which is calculated from Equation (1).

Table 1. Analysis of radiation level from the cluster at different locations in River State

Distance (Y)	Rumuokoro X_1 (μW/cm^2)	Mile 3 X_2 (μW/cm^2)	Mile 1 X_3 (μW/cm^2)	Garrison X_4 (μW/cm^2)	Average X (μW/cm^2)
5	2.978	3.372	4.427	2.255	3.258
10	4.295	3.290	5.728	2.928	4.060
20	2.849	1.592	2.573	4.145	2.790
30	2.359	1.566	3.985	2.986	2.724
40	1.501	1.584	3.649	2.396	2.283
50	0.591	1.894	2.779	2.349	1.903
60	0.610	1.554	3.688	1.917	1.942
70	0.838	1.113	2.419	1.391	1.440
80	0.797	1.827	1.634	0.896	1.289
90	0.751	1.640	1.167	0.498	1.014
100	1.120	2.342	0.719	0.423	1.151
150	1.165	1.633	0.517	0.339	0.914
200	1.410	2.084	0.550	0.206	1.063
300	0.670	0.893	0.322	0.099	0.496
400	0.541	0.522	0.129	0.048	0.310
Total	22.475	26.906	34.286	22.876	26.636

Table 2. Statistical analysis of radiation from the cluster at Rumuokoro

X	Y	XY	X^2	Y^2
2.978	5	14.890	8.868	25
4.295	10	42.950	18.447	100
2.849	20	56.980	8.117	400
2.359	30	70.770	5.565	900
1.501	40	60.040	2.253	1600
0.591	50	29.550	0.349	2500
0.610	60	36.600	0.372	3600
0.838	70	58.660	0.702	4900
0.797	80	63.760	0.635	6400
0.751	90	67.590	0.564	8100
1.120	100	112.000	1.254	10000
1.165	150	174.750	1.357	22500
1.410	200	282.000	1.988	40000
0.670	300	201.000	0.449	90000
0.541	400	216.400	0.293	160000
ΣX=22.475	ΣY=1605	ΣXY=1487.94	ΣX^2=51.214	ΣY^2=351025
r = - 0.52				

Y= Time, X= Average Amount of Radiation

The radiation level of field measurements of the directional mobile telecommunication base stations at the height of 1.5 m above the ground during monitoring showed that the average RF EMF power density rapidly declined with increasing distance from the base stations (Fig. 3). At distances of 10 m, the RF EMF power density has the highest value of 4.060μW/cm^2. At 50 m distance it decrease reaches 1.903μW/cm^2, at 100 m it is 1.151μW/cm^2, at 200 m it is 1.063μW/cm^2, at 300m it is 0.496μW/cm^2, and at 400 m it is 0.310μW/cm^2. At a distance of more than 400 m, the electromagnetic power density fluctuates very marginally and is distributed in the interval between 0.02 and 0.15μW/cm^2. The total average RF EMF power density of the studied area is 26.636μW/cm^2. These measured values are quite small compared to international standard limits of International Commission on Non-ionizing Radiation Protection (ICNIRP) which is 9mW/m^2 for the public and 22.5mW/m^2 for those professionals involved in telecommunication industry. Obviously, the created exposure limit of the mobile antenna depends on the antenna's ERP and its height above the earth's surface. Fig. 4 showed the total amount of radiation measured at different locations in River State. The highest total power density was recorded in Mile 1, mile 3, Rumuokoro and Garrison respectively.

Table 3. Statistical analysis of radiation from the cluster at Mile 3

X	Y	XY	X^2	Y^2
3.372	5	16.860	11.370	25
3.290	10	32.900	10.824	100
1.592	20	31.840	2.534	400
1.566	30	46.980	2.452	900
1.584	40	63.360	2.509	1600
1.894	50	94.700	3.587	2500
1.554	60	93.240	2.415	3600
1.113	70	77.910	1.239	4900
1.827	80	146.160	3.338	6400
1.640	90	147.600	2.690	8100
2.342	100	234.200	5.485	10000
1.633	150	244.950	2.667	22500
2.084	200	416.800	4.343	40000
0.893	300	267.900	0.797	90000
ΣX=26.384	ΣY= 1205	ΣXY= 1915.400	$ΣX^2$=56.251	$ΣY^2$=191025
r= -0.46				

Table 4. Statistical analysis of radiation from the cluster at Mile 1

X	Y	XY	X^2	Y^2
4.427	5	22.135	19.598	25
5.728	10	57.280	32.810	100
2.573	20	51.460	6.620	400
3.985	30	119.550	15.880	900
3.649	40	145.960	13.315	1600
2.779	50	138.950	7.723	2500
3.688	60	221.280	13.601	3600
2.419	70	169.330	5.852	4900
1.634	80	130.720	2.670	6400
1.167	90	105.030	1.362	8100
0.719	100	71.900	0.517	10000
0.517	150	77.550	0.267	22500
0.550	200	110.000	0.303	40000
0.322	300	96.600	0.104	90000
ΣX=34.157	ΣY= 1205	ΣXY= 1517.745	$ΣX^2$=120.622	$ΣY^2$=191025
r= -0.788				

Table 5. Statistical analysis of radiation from the cluster at Garrison

X	Y	XY	X^2	Y^2
2.255	5	11.275	5.085	25
2.928	10	29.280	8.573	100
4.145	20	82.900	17.181	400
2.986	30	89.580	8.916	900
2.396	40	95.840	5.741	1600
2.349	50	117.450	5.518	2500
1.917	60	115.020	3.675	3600
1.391	70	97.370	1.935	4900
0.896	80	71.680	0.803	6400
0.498	90	44.820	0.248	8100
0.423	100	42.300	0.179	10000
0.339	150	50.850	0.115	22500
0.206	200	41.200	0.042	40000
ΣX=22.729	ΣY=905	ΣXY=889.565	$ΣX^2$=58.011	$ΣY^2$=10102
r= -0.831				

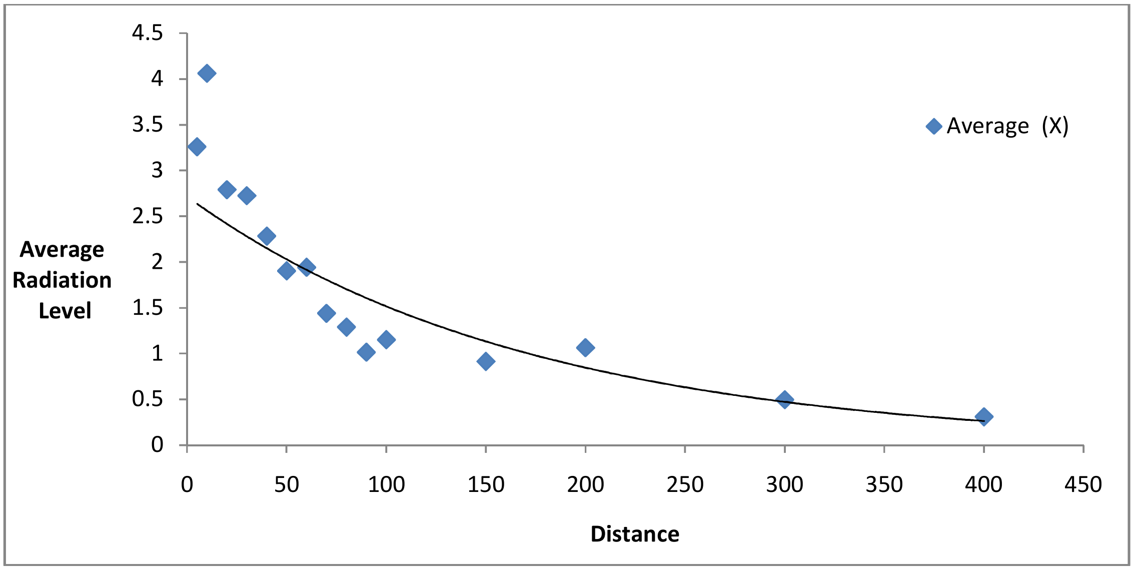

Fig. 3. Average radiation level with distance in River State

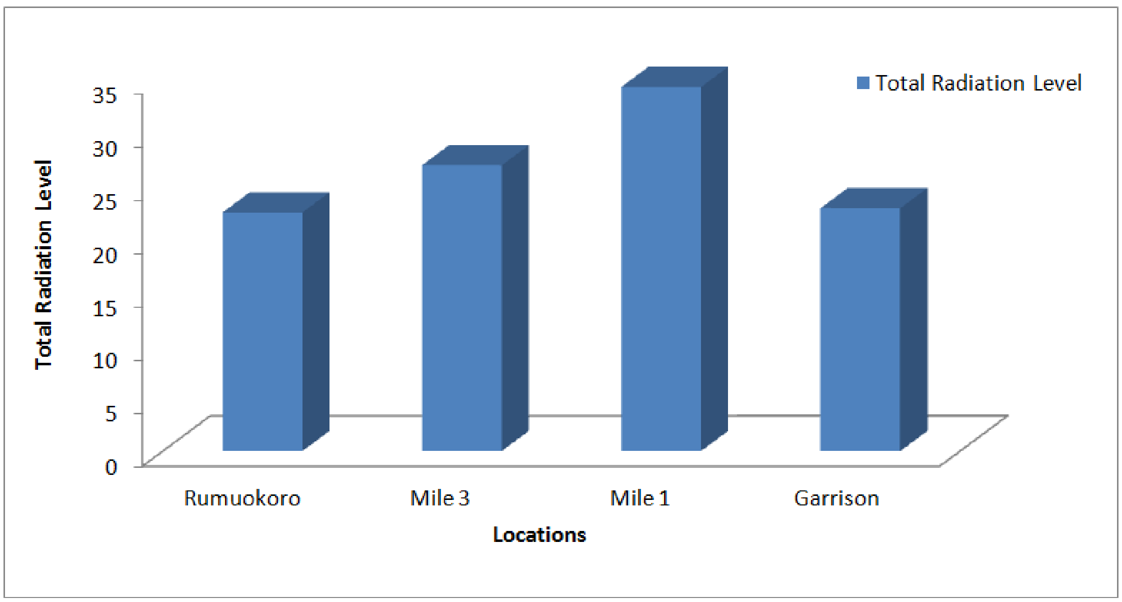

Fig. 4. Total amount of radiation measured at different locations in River State

The analysis of the results in Tables 2–5 showed that there is an insignificant and negative correlation between exposure of RF radiation, human health and long period of time, with coefficient of correlation of -0.52, -0.46, -0.788, and -0.831. This is in line with the results obtained by Shalangwa [3], using the same method of analysis. The negative values show that the relationship between the values of the power density and human health is insignificant. This means that there is no effect on human health because the low power emission has no sufficient ionization energy to destroy any part of cell in human body.

4. CONCLUSION

The average RF EMF power density declined with increasing distance from the base stations and radiation intensity varies from one mobile telecommunication base station to another. The highest total power density in Port Harcourt City was recorded in Mile 1, Mile 3, Rumuokoro and Garrison respectively.

Therefore the study has revealed that the RF exposure hazard index in the Port Hancourt City was below the permitted RF exposure limit to the general public has recommended by ICRNIP and WHO. However, as much as possible, mobile network providers should site mobile base stations at least 200 m away from residential areas and other sources of electromagnetic radiation. The coefficient of correlation values are of negative correlations which are insignificant to exposure of human health.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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