Electromagnetic Radiation and the Associated Health Risk to Organs on the Head and Neck Region from the use of Mobile Phones

Mangset, E.W , Dinchi, B.D & Sauri K.A

Department of Physics, University of Jos, Nigeria
Corresponding email: edaci2001@yahoo.com

ABSTRACT

This research work aimed at determining the Specific Absorption Rate (SAR) of cell phones in the 21st century cell phones operating between 900MHz – 2100MHz and to assess the possible health effects to the organs within the head and neck regions exposed to Radio Frequency (RF) radiations from the use of phones. Five phone models comprising of 73 phones were assessed, the electric field (EF), magnetic field (MF) and radiofrequency power densities were determined using a tri-axis meter Electrosmog meter, EMF-390. The SARs values were calculated from the EF and the various dielectric properties of the tissues in the head and neck regions. The results showed that the average SAR values of all the cellular phones studied conformed to the 900MHz recommended limit by International Commission on Non-Ionizing Radiation Protection (ICNIRP) while only 60% conformed to the 1800MHz recommended limit by ICNIRP. The non-conformity implies that the users could suffer adverse health effects ranging from myriad feelings to discomfort to life-threatening diseases. Wireless radiations offer the promise of improved remote sensing, connectivity, communications and data transfer but unfortunately have significant adverse health impacts.

Key words: *Electromagnetic radiation, specific absorption rate (SAR), head, neck, electric and magnetic fields*

INTRODUCTION

The intensive and rapid development of wireless communication devices has inevitably led to public concern about the possible negative consequences of exposure to electromagnetic fields (EMF) on health. Scientific knowledge concerning the bio-effects of EMFs has been accumulating over the previous decades, including the impact of low and high frequency EMFs on the human body and their associated health hazards (NCC, 2012; WHO, 2007;Timur et al, 2019). The ambient EMF in the human environment covers a variety of frequencies ranging from low frequencies (0-50 Hz) up to high level frequency of 5 GHz (wireless LAN). At present, there is a range of Global System for Mobile communications (GSM) band frequencies used for telecommunication applications. In particular, GSM-900, GSM-1800 and GSM-2100 modes are intensively being utilized in Nigeria and most countries, except in America where 850 MHz and 1900 MHz bands are much more popular. The GSM-900 system exploits the frequency of 890-

915 MHz range for sending and 960 MHz for receiving information packs (NCC, 2O12). GSM 1800 utilizes 1785 MHz and 1880 MHz frequencies for receiving and downlink respectively. The mobile phone user is constantly exposed to radiations from the mobile phone even if the person does not actually use the device for voice communication. Additionally, the human body is subjected to perpetual EM exposure from mobile telephony infrastructure particularly from the tower base stations (Levitt and Lai, 2011).

The growth of wireless networking technology such as wireless local area network (WLAN) hotspots, including Wi-Fi networks, can also result in the exposure to excessive radiation (IEEE, 2005). Apart from the direct radiation from individual devices such as mobile phones, humans are also exposed to the EMF from basic radio, electric and telecommunication stations.
The wide deployment of cellular communications technologies makes the cell phone one of the common sources of radio frequency (RF) radiations that cause concerns about the probable health effects due to exposure to RF radiations (Timur et al, 2019). The middle of 20th century was characterized by the growth of radio-broadcasting and the sprouting of thousands of AM/FM radio and TV stations. The situation became even more complicated with the rapid development of new electronic wireless devices designed for communication purposes, and specifically for mobile phones along with associated infrastructure. Because of this rapid growth, global organizations and national health institutions have reacted to this public demand by organizing a number of studies and setting up special commissions. The International Agency for Research on Cancer (IARC), a WHO agency, was assigned to define the link between use of mobile phones and head/neck cancers. As a result, IARC has classified radio-frequency EMF as possibly carcinogenic to humans (Group 2B) (USA,2019). As cell phone is usually held next to the head of the user during conversations, hence, much attention must be paid to investigate the health effects produced due to interaction of head tissue with cell phone radiations. This research therefore intends to assess the possible effect of electromagnetic fields on human health (head and neck region). The findings of the study will be a baseline data for future studies.

MATERIALS AND METHOD
Seventy three (73) 21st century mobile phones of different models whose operational frequencies are between 900MHz- 2100MHz found in plateau State, Nigeria were studied using a GQ EMF-390 meter with serial number 330A4B37333395 manufactured by GQ Electronics LLC Seattle USA, the tri-axis meter is portable with dimension,5.25"x 2" x 1" , and capable of measuring Magnetic Field in milligauss or micro Tesla (mG or µT), Electric Field in Volt per meter (V/m) and Radio Frequency in milliwatts per meter square (mW/m^2) simultaneously.

DATA COLLECTION
The Electric-field (E), Magnetic-field (H) and RF of seventy three mobile phones commonly used in Plateau State Nigeria were determined and their SARs value calculated. The E, H and RF were determined using be GQ EMF-390 meter. The measurement was done in isolation to avoid direct interference from other RF sources. For each measurement, the background RF field measurement was taken and this was subsequently subtracted. The Electric-field (E) and Magnetic-field (H) strengths are vector quantities expressed in Volt per meter (V/m) and Ampere per meter (A/m), respectively. Both fields are mathematically interdependent (Isabonaet al, 2016), implying that either the magnitude of the E or H has to be measured. If the Electric-field is known, the Magnetic-field can be determined and vice versa. The power density (S) was also

calculated.   The power density, S of an electromagnetic wave is related to the E and H vectors by the equation 1 below:

$$S = EH \text{ -- 1}$$

Almost all technology around releases some level of radiation, and the best way to measure it is through Specific Absorption Rate (SAR) (Kula B et al, 2000). The SAR gives an indication of how much electromagnetic radiation emanates from a mobile phone and is measured in watts per kilogram (W/kg). The SAR of the studied mobile phones were   determined by the related electric field at a point as shown in equation 2 below (IEEE, 2005). Using equation 2. The respective SAR values were calculated and recorded accordingly.

$$SAR = \frac{\sigma(E)^2}{\rho} \text{ ------------------------------------ 2}$$

Where; E is the root mean square (RMS) value of the internal electric field (V/m), ρ is the mass density of the tissue (Kg/m^3) and σ is the conductivity (S/m) of the tissue.
To precisely quantify the rate of RF radiation absorption to different tissues of the head from the phones at defined frequencies between 900MHz and   1800MHz, the specific absorption rates (SAR) were calculated using the measured E-field strength, dielectric property (relative permittivity, ε and electrical conductivity, σ) and density, ρ of the head tissues. The dielectric properties and density of the head and neck tissues of interest were extracted from (Faruque et al, 2011;Sabbahet al, 2011).

RESULTS AND DISCUSSION
The results of this study are presented in table1, table 2 and table 3 below:

Table 1: Phone network, electric field intensity magnetic field intensity, and power density of 73 mobile phones.

S/N	PHONE MODELS	NETWORK	ELECTRIC FIELD INTENSITY (V/m)	MAGNETIC FIELD INTENSITY (mA/m)	POWER DENSITY (mW/m^2)
1	Tecno pop-1	3G	14.33	37.98	544.30
2	Tecno K7	H+	12.05	31.90	384.40
3	Tecno F1	3G	17.64	46.76	825.00
4	TecnoCammon 15	4G	10.29	27.27	280.70
5	Tecno spark 4	4G	11.37	30.15	342.90
6	Tecno WF1	3G	18.19	48.23	877.40
7	Tecno CG8J	4G	15.53	41.15	639.10
8	Tecno L8 lite	4G	8.35	22.18	185.20
9	Tecno KC8	4G	9.24	24.48	226.20
10	Tecno spark 16	4G	16.45	43.66	718.20
11	Tecnocamon 12	4G	18.61	49.38	918.90

12	Tecno spark K7	4G	17.71	46.95	831.40
13	Tecno pourvoir	H+	18.83	49.94	940.40
14	Tecno pop 2F	4G	14.55	38.58	561.30
15	Tecno pop 2	3G	18.33	51.30	940.40
16	Tecno pop 2+	4G	15.65	41.52	649.80
17	Tecno spark 5 Air	4G	16.39	43.48	712.70
18	TecnoCamon C X air	H+	12.81	33.99	435.40
19	Tecno 350	H+	12.20	32.37	395.00
20	TecnoCamon C 8	3G	14.72	39.03	574.50
21	Tecno K9	3G	10.73	28.47	305.50
22	Tecno CAMON G621	3G	14.00	37.12	519.70
23	Tecno Pop 4	3G	15.77	41.85	659.90
24	Tecno Spark 5 Pro	4G	15.83	42.01	665.00
25	Tecno Pop 3	3G	17.57	46.60	818.70
26	TecnoCamon 11	4G	15.71	41.68	654.80
27	Techno A31	3G	18.26	48.42	884.20
28	Tecno J8	4G	16.97	45.01	763.80
29	TecnoCamon 11Pro	4G	15.47	41.05	635.00
30	Infinix not 3	3G	8.42	22.34	188.10
31	Infinix S-lite	4G	12.66	33.06	425.40
32	Infinix X-hot	3G	10.61	28.13	298.50
33	Infinix not-4 pro	4G	11.86	31.46	373.20
34	Infinix smart 5	4G	12.91	34.24	442.10
35	Infinix note 5	4G	13.94	37.00	515.80
36	Infinix hot 8	H+	16.02	42.48	680.50
37	Infinix smart 2	4G	16.08	42.64	685.80
38	Infinix .not 8 I	4G	13.42	40.87	548.50
39	Infinix hot 6	H+	16.58	43.99	729.40
40	Infinix hot 7	4G	8.07	21.41	172.80
41	Infinix hot 4	3G	12.05	31.94	384.90
42	Infinix hot S4	4G	18.33	48.61	891.00
43	Infinix note 8I	4G	12.47	33.08	412.50
44	Infinix hot 8 Lite	4G	12.14	32.10	390.90
45	Infinix hot 6 Lite	3G	17.91	47.51	850.90
46	Infinix hot 5	3G	16.33	43.31	707.20
47	Infinix Smart 5	3G	14.00	37.12	519.70
48	Infinix hot 7	3G	15.77	41.85	659.90
49	Nokia 5.3	4G	14.38	38.14	548.50
50	Nokia 2.0	3G	16.02	42.48	680.50
51	Nokia TA-1053	4G	18.54	49.19	911.90
52	Nokia 5.0	3G	17.37	46.06	800.00
53	Itel P 33+	3G	13.37	40.40	540.10
54	Itel A56	H+	18.60	49.40	918.90
55	Itel A16 plus	H+	18.40	48.80	897.90
56	Itel A56	3G	17.10	45.40	775.70

57	Itel 1507	3G	15.71	41.68	654.80
58	Itel P 33	H|+	14.55	38.58	561.30
59	Itel A 33	4G	10.73	28.47	305.50
60	Samsung S7 edge	4G	9.03	23.92	216.00
61	Samsung A50	4G	10.05	26.77	268.00
62	Samsung J6 plus	4G	15.83	42.01	665.00
63	Samsung A31	4G	10.65	28.24	300.80
64	Samsung A30	4G	4.60	12.20	56.13
65	Samsung A10	4G	6.33	20.22	128.00
66	Samsung A51	4G	17.57	46.59	818.70
67	Samsung A205F	4G	13.47	35.72	481.20
68	Samsung GG	4G	18.83	49.94	940.40
69	Samsung A32	4G	16.58	43.99	729.40
70	Samsung C9 Pro	4G	17.84	47.32	844.30
71	Samsung	4G	11.24	29.81	335.10
72	Samsung S 9 Plus	4G	10.53	27.92	294.00
73	Samsung T231	H+	14.44	38.28	552.80

Table 2: SAR values to various tissues of the head and neck region of different phones at 900MHz

S/N	PHONE MODELS	SARs TO TISSUES OF THE HEAD AND NECK REGION (W/kg)							
		skin	Fat	Bone (skull)	Dura	CSF	Brain	Eye ball	Localized SAR (head and neck)
1	Tecno pop-1	0.162412	0.011383	0.015548	0.187748	0.480477	0.149169	0.414805	1.421533
2	Tecno K7	0.114842	0.008049	0.010988	0.132757	0.339746	0.105477	0.293309	1.005168
3	Tecno F1	0.246107	0.017250	0.023548	0.284498	0.728076	0.226038	0.628563	2.154080
4	Tecno Cammon 15	0.083745	0.005870	0.008013	0.096808	0.247748	0.076916	0.213886	0.732985
5	Tecno spark 4	0.102246	0.007166	0.009783	0.118196	0.302483	0.093909	0.261139	0.894923

6	Tecno WF1	0.261693	0.018342	0.025039	0.302515	0.774186	0.240353	0.668370	2.290498
7	Tecno CG8J	0.190752	0.013370	0.018252	0.220508	0.564316	0.175197	0.487185	1.669581
8	Tecno L8 lite	0.055144	0.003865	0.005276	0.063746	0.163137	0.050647	0.140839	0.482656
9	Tecno KC8	0.067526	0.004733	0.006461	0.078066	0.199767	0.062020	0.172463	0.591029
10	Tecno spark 16	0.214022	0.015001	0.020478	0.247408	0.633157	0.196570	0.546617	1.873253
11	Tecno camon 12	0.273917	0.019199	0.026209	0.316646	0.81035	0.251581	0.699591	2.397493
12	Tecno spark K7	0.248064	0.017387	0.023735	0.286760	0.733866	0.227836	0.633561	2.171209
13	Tecno pourvoir	0.280432	0.019655	0.026832	0.324177	0.829622	0.257564	0.716229	2.454512
14	Tecno pop 2F	0.167437	0.011736	0.016021	0.193557	0.495343	0.153784	0.427639	1.465516
15	Tecno pop 2	0.265737	0.018625	0.025426	0.307199	0.786149	0.244067	0.678698	2.325892
16	Tecno pop 2+	0.193711	0.013577	0.018535	0.223929	0.573071	0.177915	0.494743	1.695482
17	Tecno spark 5 Air	0.212464	0.014892	0.020329	0.245606	0.628547	0.195138	0.542637	1.859613
18	Tecno Camon C X air	0.129785	0.009097	0.012418	0.150031	0.383953	0.119202	0.331474	1.135960
19	Tecno 350	0.117719	0.008251	0.011264	0.136082	0.348257	0.108120	0.300657	1.030349

20	Tecno Camon C 8	0.171373	0.012012	0.016397	0.198106	0.506985	0.157398	0.437690	1.499962
21	Tecno K9	0.091062	0.006382	0.008713	0.105264	0.269389	0.083634	0.232568	0.797011
22	Tecno CAMON G621	0.155018	0.010865	0.014832	0.179200	0.458602	0.142377	0.395920	1.356815
23	Tecno Pop 4	0.196693	0.013786	0.018820	0.227376	0.581893	0.180654	0.502360	1.721583
24	Tecno Spark 5 Pro	0.198193	0.013891	0.018963	0.229110	0.586329	0.182032	0.506190	1.734708
25	Tecno Pop 3	0.244158	0.017113	0.023361	0.282244	0.722311	0.224248	0.623584	2.137018
26	Tecno Camon 11	0.195200	0.013682	0.018677	0.225649	0.577474	0.179282	0.498544	1.708508
27	Techno A31	0.263711	0.018483	0.025232	0.304848	0.780156	0.242207	0.673524	2.308161
28	Tecno J8	0.227767	0.015964	0.021793	0.263297	0.673819	0.209194	0.581721	1.993555
29	Tecno Camon 11Pro	0.189281	0.013267	0.018111	0.218808	0.559964	0.173846	0.483428	1.656705
30	Infinix not 3	0.056073	0.003935	0.005365	0.064824	0.165884	0.0515	0.143211	0.490782
31	Infinix S-lite	0.126763	0.008885	0.012129	0.146538	0.375014	0.116427	0.323757	1.109512
32	Infinix X-hot	0.089034	0.006249	0.008519	0.102923	0.263397	0.081774	0.227396	0.779283
33	Infinix not-4	0.111249	0.007797	0.010645	0.128603	0.329116	0.102177	0.284132	0.973720

	pro								
34	Infinix smart 5	0.131819	0.009239	0.012613	0.152382	0.389971	0.121070	0.336670	1.153764
35	Infinix note 5	0.153692	0.010772	0.014706	0.177667	0.454679	0.141164	0.392534	1.345210
36	Infinix hot 8	0.202979	0.014227	0.019421	0.234643	0.600489	0.186427	0.518414	1.776600
37	Infinix smart 2	0.204503	0.014334	0.019567	0.236404	0.604995	0.187827	0.522304	1.789933
38	Infinix .not 8 I	0.14244	0.009984	0.013629	0.164660	0.421391	0.130825	0.363795	1.246722
39	Infinix hot 6	0.217418	0.015239	0.020803	0.251334	0.643204	0.199689	0.555291	1.902978
40	Infinix hot 7	0.051508	0.003610	0.004928	0.059543	0.152380	0.047308	0.131552	0.450829
41	Infinix hot 4	0.114842	0.008049	0.010988	0.132757	0.339746	0.105477	0.293309	1.005168
42	Infinix hot S4	0.265737	0.018625	0.025426	0.307190	0.786149	0.244067	0.678698	2.325892
43	Infinix note 8I	0.122987	0.008620	0.011768	0.142172	0.363842	0.112958	0.314112	1.076459
44	Infinix hot 8 Lite	0.116564	0.008170	0.011153	0.134747	0.344840	0.107059	0.297707	1.020239
45	Infinix hot 6 Lite	0.253698	0.017782	0.024274	0.293274	0.750535	0.233011	0.647952	2.220526
46	Infinix hot 5	0.210911	0.014783	0.020180	0.243812	0.623953	0.193712	0.538671	1.846022
47	Infinix Smart	0.155018	0.010865	0.014832	0.179202	0.458602	0.142377	0.395920	1.356815

5

48	Infinix hot 7	0.196693	0.013786	0.018820	0.227376	0.581893	0.180654	0.502360	1.721583
49	Nokia 5.3	0.163548	0.011463	0.015649	0.189065	0.483835	0.150211	0.417704	1.431470
50	Nokia 2.0	0.202979	0.014227	0.019421	0.234643	0.600489	0.186427	0.518414	1.776600
51	Nokia TA-1053	0.271860	0.019055	0.026012	0.314269	0.804265	0.249692	0.694338	2.379491
52	Nokia 5.0	0.238631	0.016726	0.022833	0.275855	0.705959	0.219172	0.609468	2.088643
53	Itel P 33+	0.141380	0.009909	0.013528	0.163435	0.418256	0.129852	0.361089	1.237449
54	Itel A56	0.273623	0.019178	0.026181	0.316306	0.809479	0.251311	0.698839	2.394917
55	Itel A16 plus	0.267770	0.018768	0.025621	0.309541	0.792165	0.245935	0.683891	2.343690
56	Itel A56	0.231270	0.016218	0.022128	0.267346	0.684183	0.212411	0.590668	2.024216
57	Itel 1507	0.195200	0.013682	0.018677	0.225649	0.577474	0.179282	0.498544	1.708508
58	Itel P 33	0.167437	0.011736	0.016021	0.193557	0.495343	0.153784	0.427639	1.465516
59	Itel A 33	0.091060	0.006382	0.008713	0.105264	0.269389	0.083634	0.232568	0.797011
60	Samsung S7 edge	0.064491	0.004520	0.006171	0.074552	0.19079	0.059233	0.164713	0.564469
61	Samsung A50	0.079884	0.005599	0.007643	0.092345	0.236326	0.073370	0.204025	0.699192

62	Samsung J6 plus	0.198193	0.013891	0.018963	0.229119	0.586329	0.182032	0.506190	1.734708
63	Samsung A31	0.089707	0.006288	0.008583	0.103701	0.265387	0.082392	0.229113	0.785170
64	Samsung A30	0.016736	0.001173	0.001601	0.019346	0.049510	0.015371	0.042743	0.146481
65	Samsung A10	0.031691	0.002221	0.003032	0.036634	0.093753	0.029107	0.080939	0.277378
66	Samsung A51	0.244158	0.017113	0.023361	0.282244	0.72231	0.224248	0.623584	2.137018
67	Samsung A205F	0.143503	0.010058	0.013731	0.165889	0.424536	0.131801	0.366511	1.256029
68	Samsung GG	0.280432	0.019655	0.026832	0.324177	0.829622	0.257564	0.716229	2.454512
69	Samsung A32	0.217418	0.015239	0.020803	0.251334	0.643204	0.199689	0.555291	1.902978
70	Samsung C9 Pro	0.251719	0.017643	0.024085	0.290986	0.74468	0.231193	0.642897	2.203202
71	Samsung	0.099922	0.007003	0.009561	0.115509	0.295605	0.091774	0.255202	0.874575
72	Samsung S 9 Plus	0.087697	0.006147	0.008391	0.101377	0.25944	0.080546	0.223979	0.767576
73	Samsung T231	0.164915	0.011559	0.015779	0.190641	0.487881	0.151467	0.421197	1.443441

Table3: SAR values to various tissues of the head and neck region of different phones at 1800MHz

S/N	PHONE MODELS	SARs TO TISSUES OF THE HEAD AND NECK REGION (W/kg)							
		skin	Fat	Bone (skull)	Dura	CSF	Brain	Eye ball	Localized SAR (head and neck)
1	Tecno pop-1	0.220283	0.01741	0.03108	0.258153	0.58016	0.222784	0.414805	1.744676
2	Tecno K7	0.155763	0.012311	0.021977	0.182540	0.410232	0.157531	0.293309	1.233663
3	Tecno F1	0.333800	0.026382	0.047096	0.391185	0.87913	0.33759	0.628563	2.643744
4	Tecno Cammon 15	0.113585	0.008977	0.016026	0.133111	0.299148	0.114874	0.213886	0.899607
5	Tecno spark 4	0.138679	0.01096	0.019566	0.16252	0.365239	0.140253	0.261139	1.098356
6	Tecno WF1	0.35494	0.028053	0.050079	0.415959	0.934805	0.358969	0.66837	2.811174
7	Tecno CG8J	0.258721	0.020448	0.036503	0.303199	0.681395	0.261659	0.487185	2.049110
8	Tecno L8 lite	0.074793	0.005911	0.010553	0.087651	0.196983	0.075642	0.140839	0.592373
9	Tecno KC8	0.091587	0.007239	0.012922	0.107332	0.241212	0.092627	0.172463	0.725381
10	Tecno spark 16	0.290283	0.022942	0.040956	0.340186	0.764518	0.293578	0.546617	2.299080
11	Tecno camon 12	0.371520	0.029363	0.052418	0.435389	0.978472	0.375738	0.699591	2.942490
12	Tecno spark K7	0.336455	0.026592	0.04747	0.394295	0.886121	0.340274	0.633561	2.664768
13	Tecno pourvoir	0.380356	0.030061	0.053664	0.445744	1.001743	0.384674	0.716229	3.012471
14	Tecno pop 2F	0.227099	0.017949	0.032041	0.26614	0.598111	0.229677	0.427639	1.798657
15	Tecno	0.36042	0.02848	0.05085	0.42238	0.94925	0.36451	0.67869	2.854613

	pop 2	4	6	2	6		6	8
16	Tecno pop 2+	0.262735	0.020765	0.037069	0.307903	0.691966	0.265718	0.494743	2.080899
17	Tecno spark 5 Air	0.288169	0.022775	0.040658	0.337709	0.758951	0.29144	0.542637	2.282339
18	Tecno Camon C X air	0.176030	0.013912	0.024836	0.206292	0.463611	0.178029	0.331474	1.394185
19	Tecno 350	0.159665	0.012619	0.022527	0.187113	0.420509	0.161477	0.300657	1.264567
20	Tecno Camon C 8	0.232437	0.018371	0.032795	0.272396	0.612169	0.235076	0.437690	1.840933
21	Tecno K9	0.123506	0.009761	0.017426	0.144739	0.325278	0.124908	0.232568	0.978187
22	Tecno CAMON G621	0.210255	0.016617	0.029665	0.246400	0.553748	0.212642	0.395920	1.665246
23	Tecno Pop 4	0.266780	0.021085	0.037640	0.312643	0.702618	0.269808	0.502360	2.112933
24	Tecno Spark 5 Pro	0.268814	0.021246	0.037927	0.315026	0.707974	0.271865	0.506190	2.129042
25	Tecno Pop 3	0.331156	0.026173	0.046723	0.388086	0.872166	0.334916	0.623584	2.622804
26	Tecno Camon 11	0.264753	0.020925	0.037354	0.310268	0.697281	0.267759	0.498544	2.096885
27	Techno A31	0.357677	0.028269	0.050465	0.419166	0.942014	0.361737	0.673524	2.832852
28	Tecno J8	0.308925	0.024416	0.043586	0.362033	0.813616	0.312432	0.581721	2.446730
29	Tecno Camon 11Pro	0.256726	0.02029	0.036222	0.300861	0.676140	0.259641	0.483428	2.033307
30	Infinix not 3	0.076053	0.006011	0.010733	0.089127	0.200300	0.076916	0.143211	0.602347
31	Infinix S-lite	0.171932	0.013589	0.024258	0.201489	0.452817	0.173884	0.323757	1.361726
32	Infinix X-hot	0.120759	0.009544	0.017038	0.141519	0.318044	0.122130	0.227396	0.956430

33	Infinix not-4 pro	0.150889	0.011925	0.021289	0.176829	0.397398	0.152602	0.284132	1.195065
34	Infinix smart 5	0.178789	0.014131	0.025225	0.209526	0.470878	0.180819	0.33667	1.416038
35	Infinix note 5	0.208456	0.016475	0.029411	0.244293	0.549011	0.210823	0.392534	1.651003
36	Infinix hot 8	0.275305	0.021759	0.038843	0.322634	0.725071	0.278431	0.518414	2.180456
37	Infinix smart 2	0.277371	0.021922	0.039134	0.325055	0.730513	0.280520	0.522304	2.196820
38	Infinix .note 8 I	0.193194	0.015269	0.027258	0.226407	0.508816	0.195388	0.363795	1.530126
39	Infinix hot 6	0.294889	0.023306	0.041606	0.345584	0.776649	0.298237	0.555291	2.335562
40	Infinix hot 7	0.069861	0.005521	0.009857	0.081871	0.183994	0.070654	0.131552	0.553311
41	Infinix hot 4	0.155763	0.012311	0.021977	0.18254	0.410232	0.157531	0.293309	1.233663
42	Infinix hot S4	0.360424	0.028486	0.050852	0.422386	0.94925	0.364516	0.678698	2.854613
43	Infinix note 8I	0.166810	0.013184	0.023535	0.195487	0.439328	0.168704	0.314112	1.321159
44	Infinix hot 8 Lite	0.158098	0.012495	0.022306	0.185277	0.416383	0.158893	0.297707	1.252160
45	Infinix hot 6 Lite	0.344097	0.027196	0.048549	0.403251	0.906248	0.348003	0.647952	2.725295
46	Infinix hot 5	0.286063	0.022609	0.040361	0.335241	0.753404	0.289311	0.538671	2.265660
47	Infinix Smart 5	0.210255	0.016617	0.029665	0.246400	0.553748	0.212642	0.39592	1.665246
48	Infinix hot 7	0.266780	0.021085	0.03764	0.312643	0.702618	0.269808	0.502360	2.112933
49	Nokia 5.3	0.221823	0.017532	0.031297	0.259958	0.584216	0.224342	0.417704	1.756872
50	Nokia 2.0	0.275305	0.021759	0.038843	0.322634	0.725071	0.278431	0.518414	2.180456
51	Nokia TA-	0.368730	0.029142	0.052024	0.432125	0.971125	0.372916	0.694338	2.920396

	1053							
52	Nokia 5.0	0.323660	0.025580	0.045665	0.379301	0.852423	0.327334	0.609468	2.563433
53	Itel P 33₊	0.191757	0.015155	0.027055	0.224723	0.505032	0.193934	0.361089	1.518746
54	Itel A56	0.371121	0.029331	0.052362	0.434921	0.977421	0.375334	0.698839	2.939329
55	Itel A16 plus	0.363183	0.028704	0.051242	0.425618	0.956514	0.367306	0.683891	2.876457
56	Itel A56	0.313676	0.024791	0.044257	0.367601	0.826129	0.317237	0.590668	2.484360
57	Itel 1507	0.264753	0.020925	0.037354	0.310268	0.697281	0.267759	0.498544	2.096885
58	Itel P 33	0.227099	0.017949	0.032041	0.266141	0.598111	0.229677	0.427639	1.798657
59	Itel A 33	0.123506	0.009761	0.017426	0.144739	0.325278	0.124908	0.232568	0.978187
60	Samsung S7 edge	0.087471	0.006913	0.012341	0.102509	0.230373	0.088464	0.164713	0.692784
61	Samsung A50	0.108348	0.008563	0.015287	0.126975	0.285357	0.109578	0.204025	0.858133
62	Samsung J6 plus	0.268814	0.021246	0.037927	0.315026	0.707974	0.271865	0.50619	2.129042
63	Samsung A31	0.121671	0.009616	0.017167	0.142588	0.320446	0.123053	0.229113	0.963655
64	Samsung A30	0.022699	0.001794	0.003203	0.026601	0.059782	0.022957	0.042743	0.179779
65	Samsung A10	0.042983	0.003397	0.006064	0.050372	0.113204	0.043471	0.080939	0.340431
66	Samsung A51	0.331156	0.026173	0.046723	0.388086	0.872166	0.334916	0.623584	2.622804
67	Samsung A205F	0.194637	0.015383	0.027461	0.228097	0.512615	0.196846	0.366511	1.541550
68	Samsung GG	0.380356	0.030061	0.053664	0.445744	1.001743	0.384674	0.716229	3.012471
69	Samsu	0.29488	0.02330	0.04160	0.34558	0.77664	0.29823	0.55529	2.335562

	ng A32	9	6	6	4	9	7	1
70	Samsung C9 Pro	0.341412	0.026983	0.048177	0.400105	0.899178	0.345288	0.642897	2.7040033
71	Samsung	0.135526	0.010711	0.019121	0.158824	0.356934	0.137064	0.255202	1.073384
72	Samsung S 9 Plus	0.118945	0.009401	0.016782	0.139393	0.313265	0.120295	0.223979	0.942061
73	Samsung T231	0.223678	0.017678	0.031559	0.262131	0.589102	0.226218	0.421197	1.771563

Table 4: Average SAR values to the head and neck for various phone operating at 900MHz and 1800MHz

PHONE MODELS	AVERAGE SAR VALUES TO THE HEAD AND NECK REGION (W/kg)	
	900MHz	1800MHz
TECNO	1.61	1.97
INFINIX	1.35	1.65
NOKIA	1.92	2.36
ITEL	1.71	2.10
SAMSUNG	1.23	1.51
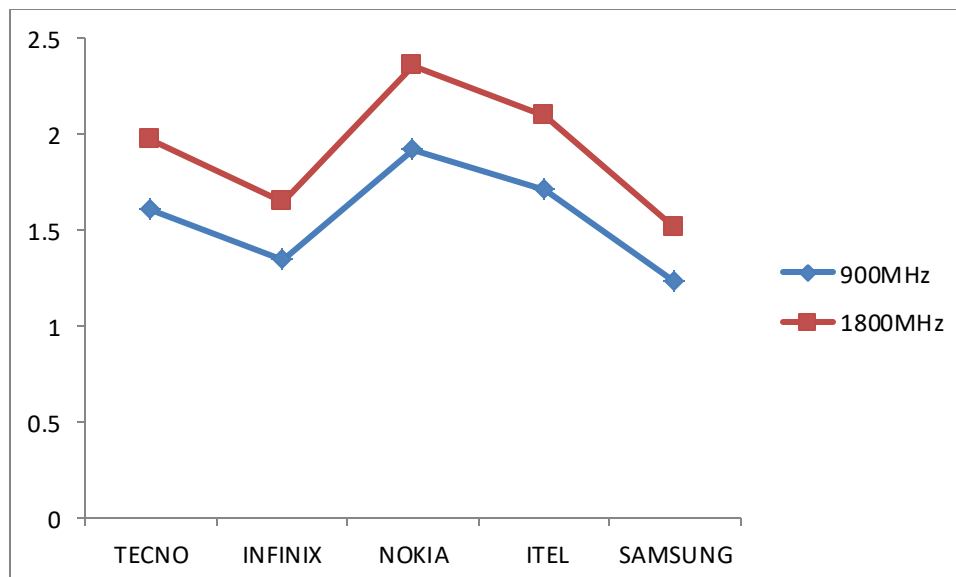
Figure 1: Comparison of the average SAR values for various phone models operating at 900MHz and 1800MHz to ICNIRP reference levels/recommended limits.

Exposing humans to cell phone radiation can have health implications. Cell phone radiation can affect memory and learning, hence, change the brainwave activity. Changes in the way in which the brain and nervous system react depend very much on the specific exposures. The ICNRP has developed exposure guidelines for workers and for the general public stating reference levels and recommended limits for general public exposure to time-varying Electric (E) field, Magnetic (H) field, Power density and SAR at different frequency. Table 6 shows the Phone network band, electric field intensity magnetic field intensity, and power density of 73 mobile phones.
The recommended limits are 58.34V/m, 0.157A/m (157mA/m) and 9.0W/m^2 (9000mW/m^2) for Electric (E) field, Magnetic (H) field Power density respectively. These limits were used in assessing the results obtained in Table 1 above which shows the Electric (E) field, Magnetic (H) field and Power density of seventy three phones studied. The highest E-field value was observed on phone model, Tecno pourvoir, with a value of 18.83V/m while the least was Samsung A30 with a value of 4.60V/m. The magnetic field ranges from12.2022 mA/m to 51.30mA/m while the power density value ranges from 56.13 mW/m^2 to 940.40mW/m^2 corresponding to phone model Samsung GG and Samsung A30 having the most and least power densities respectively. It was observed that all the studied mobile phones fall below the recommended E-field, H-field and Power density limits and hence, operates within the recommended limit.

During cell phone use, a relatively constant mass of tissue in the brain is exposed to the radiation at relatively high intensity measured by the specific absorption rate (SAR) in watt per kilogram (W/Kg) as recommended by ICNIRP with an allowable level of 2.0 W/Kg (in 10 g of tissue). From table 2 and 3 above, all the seventy three phones studied when operating at 1800MHz has SAR for the organs of the head and neck ranges from 1.51 W/Kg to 1.97 W/Kg and when operating at 900MHz has SAR values ranging from 1.23W/Kg to 2.36W/Kg. As shown in table 4 and figure 3above, the maximum average SARs was 2.36W/Kg while the minimum was 1.23W/Kg corresponding to phone models ITEL and SAMSUNG respectively. The average SAR values for the five phone models when operating at 900MHz were 1.61W/Kg, 1.35W/Kg, 1.92W/Kg, 1.71W/Kg, 1.23W/Kg representing phone models, TECNO, INFINIX, NOKIA, ITEL and SAMSUNG respectively. And when operating at 1800MHz, the average SAR values were, 1.97W/Kg, 1.65W/Kg, 2.36W/Kg, 2.10W/Kg and 1.51W/Kg corresponding to phone models, TECNO, INFINIX, NOKIA, ITEL and SAMSUNG respectively. The average SAR values for NOKIA and ITEL operating at 1800MHz were seen to be higher than the ICNIRP recommended limit. All the cellular phones operating at 900MHz studied conformed to recommended 2.0W/Kg limit by ICNIRP while only 60% of phones operating at 1800MHz conformed to the recommended limit by ICNIRP international standard. Many studies suggested that potential health hazards could be linked to excessive exposure to high-power densities of non-ionizing radiation. These health hazards include, Cancer, Tumors, Headaches, Fatigue, Alzheimer Disease and Parkinson Disease (Guidance for Industry and FDA-Regulation of Medical Devices, U.S Department of Health and Human Services, Food and Drug Administration, Centre for Devices and Radiological Health).This studies revealed that all the 21st century phones studied in this work operating using the 900MHZ have SAR below 2.0W/Kg

are safe and pose no effects. However , phones operating at 1800MHZ frequency network at Plateau shows that only 60% users of such phones face no cancer risk and all other related radiation risk while 40% may come down with cancer and all other radiation related effect.

CONCLUSION

The wide deployment of cellular communications technologies makes the cell phone one of the common sources of radio frequency (RF) radiations that causes concerns about the probable health effects due to exposure to wireless radiations. To ascertain the health risk, the E-field strengths together with available data on dielectric properties and density of various tissues of the head and neck were used to evaluate the specific absorption rate (SAR) to the head and neck region. The average SAR value of all the cellular phones studied conformed to the 900MHz recommended limit by ICNIRP while only 60% conformed to the 1800MHz recommended limit by ICNIRP international standard. The rate of non-conformity according to ICNIRP standard at 1800MHz may be as a result of poor network signal or proximity to network base station.

A number of countries have developed and/or adopted national or international guidelines for checking and ensuring that emissions from installed wireless communication systems conform to electromagnetic field (EMF) safety levels and Nigeria is not an exception.

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