

Radiation Absorbed Dose Rates from Selected Mobile Phone Base Stations in Ibadan, Oyo State, Nigeria.

ABSTRACT

The aim of this study is to measure the radiation dose from Mobile Phone Base Stations relative to human exposure at various locations within Ibadan metropolis, Southwestern Nigeria by measuring the radiation dose at 10 - 100 metres distance away from the randomly selected base stations and compare the results with other studies/recommended exposure limit. A Victoreen radiation survey meter (fluke 451 model) was used to measure the radiation dose. The meter was calibrated with a calibration factor of 1.1 to standardized the values measured with international recommended standards. The average radiation dose reported for the studied area were 9.36, 11.28, 8.73, 10.17, 8.58, 9.80, 7.13, 10.05, 8.14 and 8.81 $\mu\text{Sv/hr}$ respectively. The mean value of radiation dose from the study area was 9.21 $\mu\text{Sv/hr}$ which is higher than the maximum permissible level of 5.7 $\mu\text{Sv/hr}$ recommended by the American Nuclear Society for persons within 0 – 100 m from a mobile phone base station. The values vary according to distance which shows that the strength of the radiation field is greatest at the source and diminished quickly with distances. Results obtained for the present study showed that radiation emitted at mobile phone base station are at intensities that are thousands of times less than intensities that can produce heating effect. Hence, the assumption from the results obtained for the present study area is that the radiation exposures from mobile phone base stations impose no health hazard as the limits recommended in the guidelines by International Commission of Non-Ionizing Radiation Protection do not appear to have any known adverse consequence on human health.

Keywords: Radiation, Absorbed Dose Rates, Mobile Phone Base Stations, Ibadan, Nigeria.

1.0 Introduction

Human in modern society are exposed to an ever increasing dose of radiation generated from the production and supply of electricity, television (TV) sets, personal computer (PC), radio communication, security devices and most recently mobile phones and their base stations. Though, there have been numerous studies on health effects of chronic exposure to the radiation from mobile phone base stations and mobile phones, this is because all living creatures have been and are still being exposed to various degrees of radiation and its fields ⁽¹⁾. Most studies are still at early stages to fully understand the degree of damages caused by these radiation exposures.

In Nigeria, the advent of GSM since 2001 has led to the increased use of Mobile phones and citing of masts/Towers within residential areas. Since then public has raised concern on possible health issues due to radiation from the mobile phone base stations and the mobile handsets. The effect of mobile phones base stations and other wireless communication devices radiation and human health is a subject of interest and study worldwide as a result of enormous increase in mobile phone base stations and other wireless communication device usage throughout the world ⁽²⁾. Mobile phone use is ubiquitous with an estimated 6.9 billion subscriptions globally and over 150 million subscriptions in Nigeria ⁽³⁾.

World Health Organization in 2011 declared that no adverse health effects have been established with the use of mobile phone and from base stations. Many scientific studies have also investigated possible health effects that could emanate from mobile phone. These studies are occasionally reviewed by scientific committees to access overall risk. There is an increase in the health risk due to high radiation exposure levels from mobile phone base stations ⁽²⁾. Over the years, an area of concern in telecommunication is the radiation emitted by the fixed infrastructure used in mobile telephony, such as base station and their antennas which provide the link to and from mobile phones. Mobile handset emits radiation continuously into the environment. However, the intensity of the radiation reduces rapidly with distance away from the base of transmitter because of the power attenuation ⁽⁴⁾. The erection of mobile phone base stations in inhabited areas has raised concerns about possible health effects caused by emitted radiation ⁽⁵⁾. The area closer to the base antennas installations are prone to over exposure of radiofrequency ⁽⁶⁾. Health failure of residents around mobile phone base stations may not be attributed to radiofrequency or electromagnetic field exposures ⁽⁷⁾. However, the present belief is that radiofrequency signals employed in mobile phone communication systems are at intensities that can produce such heating effect ⁽⁸⁾.

Radiofrequency (RF) which are used in mobile phone communication are in the lower energy part of the EM spectrum. They are classified as non- ionizing radiation because unlike X-rays and γ -rays etc, they do not have

54 enough energy to cause ionization in matter. The energy quanta of non-ionizing radiation of the operating frequency
55 of mobile phones are in the order of few μeV which extremely small compared to the energy of around 1eV needed
56 to break the weakest chemical bonds in the genetic molecules (DNA) ⁽⁹⁾. Non-ionizing EMR is therefore believed to
57 be of very low intensities, although it can be damaging through heat producing at high intensities ⁽¹⁰⁾. It is well
58 established however, that non-ionizing radiations have the ability to penetrate the human body and heat up the tissue
59 with the main effect of raising the temperature in the exposed tissue ⁽¹¹⁾. At low intensity, the homeostatic (thermo-
60 regulations) ability of the body can effectively cope with the heat produced. Homeostatic ability can breakdown at
61 very high intensities.

62 When radiation is absorbed in a living system, it initiates a complex series of reactions which sooner or later may
63 become manifest as an alteration in the normal functioning of the system. The damage takes the form of changes in
64 the construction and functioning of cell. In the human body, these changes manifest themselves as clinical
65 symptoms, such as radiation sickness, cataracts, or in the long term, cancer ⁽¹²⁾. Radiation may damage the cell when
66 it delivers extra energy to it, because the energy may be used to destroy parts or functions of the cell. For example,
67 as a result of irradiation, chromosomes or DNA molecules may break. The break may occur either by direct collision
68 with an incoming fast particles or as the result of chemical activity initiated by the radiation. The effects of radiation
69 on the human body are thus the result of damage to individual cells which may react in different ways. Another
70 effect of irradiation may be damage to the DNA molecules that carry the genetic code which may manifest in the
71 descendants of organism. The exposure of radiation in recent time is thousands times higher than before the
72 proliferation of mobile phone base station ⁽¹³⁾. In Nigeria, the populace has expressed concern over living or
73 working near a cell phone tower because of likely health risks ⁽¹⁴⁾. It is therefore necessary to assess whether or not
74 there is health effect due to exposure of EMF from Mobile Phone Base Stations and provide guidelines on horizontal
75 safety distance of the house/structure from base stations.

76 Thus, the aim of the study is to measure the level of radiation dose Mobile Phone Base Stations in various locations
77 within Ibadan metropolis. The study was limited to Ibadan, capital of Oyo state, Southwestern Nigeria due to
78 peculiarity of their population (third most populous city in Nigeria after Lagos and Kano) and spatial distribution of
79 base stations (about 90 % of base stations are in close proximity with human living quarters).
80

81

82 2.0 Materials and methods

83 2.1 Description of the study area

84 This study was carried out in Ibadan, the capital of Oyo state, Nigeria. Ibadan was selected as a study area due to the
85 population density and spatial distribution of mobile phone base stations in the city. Invariably, about 90% of the
86 base stations are in close proximity with human living quarters. Ibadan is the most populous city of Oyo state and it
87 is Nigeria's largest city by geographical area with urban density $464.71/\text{km}^2$ and population density $2,551.5/\text{sq.m}$.
88 Ibadan is situated at 7.3775°N latitude, 3.9470°E longitude. Its elevation is 273 meters' height, that is equal to 896
89 feet. The estimated population of Ibadan is over 3 million ⁽¹⁵⁾.
90

91



91

92 **Figure 1: Map of Nigeria (indicating Ibadan, the study area)**

93
94 **2.2 Measurement and methods**

95 **2.2.1 sampling selection/techniques**

96 A total of ten (10) base stations within Ibadan metropolis were considered for the study. The measurement in the
97 study was the radiation dose. The Radiation Survey meter was used to measure the radiation dose at different
98 distances to the base station and the coordinates of each base station and points of measurements were marked out a
99 with Global positioning system (GPS). Global positioning system (GPS) is a device that receives signals for the
100 purpose of determining the correct location of any object on the earth surface. GPS devices provide information
101 about latitude, longitude and elevation (altitude) of a location. Hence, coordinates of the base stations under study in
102 Ibadan were obtained with the aid of a hand held global positioning system (GPS). The radiation dose was measured
103 at distance such as 10 m, 20 m, 30 m, 40 m 50 m, 60 m, 70 m, 80 m, 90 m, and 100 m away respectively from 10
104 selected mobile phone base stations in Ibadan to check the radiation exposure within such distances.
105

106 **2.2.2 Overview of the radiation survey meter**

107 The radiation survey meter used was Victoreen Radiation Survey Meter (Fluke 451 model). The meter was
108 calibrated with a calibration factor of 1.1 to standardized the values measured with international standards. The
109 radiation dose measured were in micro Sievert per hour ($\mu\text{Sv/hr}$). A micro Sievert per hour ($\mu\text{Sv/hr}$) is the SI derived
110 unit of radiation absorbed dose rate. The Sievert (Sv) is the SI derived unit of equivalent radiation dose, effective
111 dose, and committed dose. 1 Sievert is the energy absorbed by one kilogram of biological tissue, which has the same
112 effect as one gray of the absorbed dose of gamma radiation. Therefore, the Sievert can be expressed in terms of
113 other SI units as:

114 $1 \text{ Sv} = 1 \text{ J/kg}$ (1)

115 $1 \text{ J/kg} \cdot \text{s} = 1 \text{ Sv/s} = 3.6 * 10^7 \mu\text{Sv/hr}$ (2)

116 The Fluke 451 model used is an ion chamber radiation survey meter which features a pressurized ionization
117 chamber, providing enhanced sensitivity (μR resolution) and improved energy response to measure radiation rate
118 and dose from x-ray and gamma sources. Originally designed to measure leakage and scatter around diagnostic x-
119 ray and radiation therapy suites, the 451P's radiation measurements surveying capabilities make it well-suited for a
120 wide range of end users, including: x-ray manufacturers, government agencies, state inspectors, biomedical
121 technicians, and maintenance technicians for airport baggage scanners.

122 The ion chamber detector allows for a fast response time to radiation from leakage, scatter beams and pinholes.
123 Additionally, the low noise ionization chamber bias supply provides for fast background settling time. The digital
124 display features an analog bar graph, 2.5-digit digital readout, low battery and freeze (peak hold) mode indicators,
125 and an automatic backlight function. User controls consist of an ON/OFF button and a MODE button. The case is
126 constructed of lightweight, high strength materials and is sealed against moisture. The RS-232 interface can be
127 connected directly to a computer for use with the Excel add-in for Windows (451EXL), enhancing the functionality
128 of the instrument. This software allows for data retrieval, user parameter selection and provides a virtual instrument
129 display with audible (requires sound card) and visual alarm indication.



130
131 **Figure 2: Radiation Survey Meter (Fluke 451 model).**

132
133 **2.2.3 Radiation dose from mobile phone base station**

134 Radiation dose is a measure of the amount of exposure to radiation. The energy from a mobile phone base station
 135 antenna, like that of other telecommunication antennas, is directed toward the horizon (parallel to the ground), with
 136 some downward scatter. Base station antennas use higher power levels than other types of land-mobile antennas, but
 137 much lower levels than those from radio and television broadcast stations. The amount of energy decreases rapidly
 138 as the distance from the antenna increases. As a result, the level of exposure to radiation at ground level is very low
 139 compared to the level close to the antenna. Public exposure to radiation from mobile phone base station antennas is
 140 slight for several reasons. The radiation levels are relatively low, the antennas are mounted high above ground level,
 141 and the signals are transmitted intermittently, rather than constantly.

142
 143 **3.0 Results and Discussion**

144 The radiation dose from various mobile phone base station in Ibadan, Oyo State, Nigeria were measured and were
 145 tabulated in Tables 1-10. The maximum average radiation dose was reported for MPSB-2 and the lowest was
 146 reported for MPSB-7. The average radiation dose from the base stations were 9.36, 11.28, 8.73, 10.17, 8.58, 9.80,
 147 7.13, 10.05, 8.14 and 8.81 $\mu\text{Sv/hr}$ at the sampling locations within Ibadan, Southwestern Nigeria.

148 The mean value of radiation dose from the study area was 9.21 $\mu\text{Sv/hr}$ which is higher than the maximum
 149 permissible level of 5.7 $\mu\text{Sv/hr}$ recommended by the American Nuclear Society. The intensity of radiation dose from
 150 the mobile phone base station decreases as the distance of measurement increases (*see* Table 11) implying that to
 151 have minimum dose exposure within the studied area, all residential homes and business outlets sited closer to the
 152 mobile phone base stations up to 200 m away needs to be relocated for health safety purposes. This may be difficult
 153 considering the nature and population of Ibadan. However, considering the long term health effect of the people
 154 could serve as a motivation for the residential relocations. The values reported for the present study were higher than
 155 the average values of radiation dose reported for Mubi North Adamawa Nigeria which were 1.87, 2.26 and 1.48
 156 $\mu\text{Sv/h}$ at 100 m for mobile phone base station respectively⁽¹⁶⁾. The radiation dose value measured in the study varies
 157 in conformity that the strength of the radiation field is greatest at the source and diminished quickly with distance.

158
 159
 160 Table 1: Radiation Dose from MPBS (SP 1)

S/N	Distance (m)	Radiation Dose $\mu\text{Sv/hr}$	Base Station Location (GPS)	
			Northing	Easting
1	10	18.23	0596147	0813597
2	20	16.06	0596142	0813603
3	30	13.45	0596138	0813607
4	40	10.23	0596134	0813612
5	50	9.64	0596129	0813616
6	60	9.52	0596125	0813620
7	70	6.08	0596123	0813622
8	80	5.19	0596122	0813625
9	90	3.92	0596120	0813629
10	100	1.26	0596115	0813633
Average		9.36		
Range		1.26 -18.23		

161
 162
 163 Table 2: Radiation Dose from MPBS (SP 2)

S/N	Distance (m)	Radiation Dose $\mu\text{Sv/hr}$	Base Station Location (GPS)	
			Northing	Easting
1	10	16.83	0594928	0815061
2	20	15.07	0594925	0815056

3	30	14.96	0594921	0815058
4	40	14.85	0594917	0815057
5	50	14.52	0594912	0815056
6	60	12.63	0594905	0815054
7	70	10.45	0594902	0815052
8	80	6.23	0594897	0815051
9	90	5.07	0594891	0815049
10	100	2.15	0594886	0815047
Average		11.28		
Range		2.15 -16.83		

164
165
166

Table 3: Radiation Dose from MPBS (SP 3)

S/N	Distance (m)	Radiation Dose μ Sv/hr	Base Station Location (GPS)	
			Northing	Easting
1	10	16.43	0594742	0815186
2	20	13.09	0594740	0815191
3	30	10.94	0594738	0815194
4	40	10.78	0594735	0815197
5	50	9.13	0594733	0815202
6	60	6.82	0594730	0815207
7	70	6.15	0594728	0815212
8	80	5.43	0594726	0815214
9	90	5.06	0594724	0815221
10	100	3.48	0594721	0815225
Average		8.73		
Range		3.48-16.43		

167
168
169

Table 4: Radiation Dose from MPBS (SP 4)

S/N	Distance (m)	Radiation Dose μ Sv/hr	Base Station Location (GPS)	
			Northing	Easting
1	10	18.25	0595014	0814278
2	20	14.96	0595011	0814283
3	30	14.74	0595007	0814285
4	40	14.52	0595003	0814288
5	50	9.33	0595000	0814291
6	60	9.33	0595996	0814294
7	70	8.39	0595992	0814296
8	80	5.60	0595987	0814298
9	90	4.68	0595986	0814301

10	100	1.93	0595983	0814305
Average		10.17		
Range		1.93-18.25		

170

171 Table 5: Radiation Dose from MPBS (SP 5)

S/N	Distance (m)	Radiation Dose $\mu\text{Sv/hr}$	Base Station Location (GPS)	
			Northing	Easting
1	10	13.37	0595633	0813788
2	20	11.60	0595636	0813790
3	30	11.32	0595641	0813793
4	40	10.93	0595644	0813795
5	50	10.16	0595647	0813798
6	60	8.91	0595651	0813801
7	70	8.35	0595656	0813802
8	80	4.63	0595658	0813805
9	90	4.18	0595662	0813806
10	100	2.34	0595665	0813811
Average		8.58		
Range		2.34-13.37		

172

Table 6: Radiation Dose from MPBS (SP 6)

S/N	Distance (m)	Radiation Dose $\mu\text{Sv/hr}$	Base Station Location (GPS)	
			Northing	Easting
1	10	14.93	0596036	0813816
2	20	14.08	0596035	0813813
3	30	13.82	0596034	0813808
4	40	13.77	0596034	0813803
5	50	13.09	0596037	0813799
6	60	7.54	0596040	0813796
7	70	7.16	0596043	0813793
8	80	5.22	0596048	0813792
9	90	5.08	0596053	0813788
10	100	3.26	0596055	0813786
Average		9.80		
Range		3.26-14.93		

173

174 Table 7: Radiation Dose from MPBS (SP 7)

175

S/N	Distance (m)	Radiation Dose $\mu\text{Sv/hr}$	Base Station Location (GPS)	
			Northing	Easting
1	10	12.76	0596052	0813841
2	20	12.68	0596056	0813844

3	30	10.34	0596060	0813846
4	40	8.91	0596063	0813849
5	50	8.36	0596068	0813852
6	60	6.41	0596071	0813857
7	70	4.03	0596073	0813860
8	80	3.48	0596078	0813863
9	90	3.09	0596080	0813866
10	100	1.26	0596085	0813870
Average		7.13		
Range		1.26-12.76		

176

177

Table 8: Radiation Dose from MPBS (SP 8)

S/N	Distance (m)	Radiation Dose $\mu\text{Sv/hr}$	Base Station Location (GPS)	
			Northing	Easting
1	10	15.63	0596810	0812277
2	20	14.08	0596807	0812275
3	30	13.86	0596806	0812272
4	40	13.31	0596805	0812271
5	50	12.98	0596803	0812269
6	60	10.04	0596801	0812267
7	70	8.43	0596800	0812266
8	80	4.86	0596798	0812264
9	90	4.22	0596797	0812263
10	100	3.04	0596796	0812261
Average		10.05		
Range		3.04-15.63		

178

179

Table 9: Radiation Dose from MPBS (SP 9)

S/N	Distance (m)	Radiation Dose $\mu\text{Sv/hr}$	Base Station Location (GPS)	
			Northing	Easting
1	10	12.98	0596864	0812198
2	20	12.76	0596863	0812200
3	30	12.21	0596860	0812202
4	40	11.88	0596857	0812204
5	50	11.55	0596854	0812208
6	60	8.43	0596852	0812212
7	70	6.27	0596850	0812214
8	80	3.11	0596848	0812216
9	90	1.45	0596845	0812218
10	100	0.72	0596842	0812222
Average		8.14		

Range 0.72-12.98

180

181 Table 10: Radiation Dose from MPBS (SP 10)

S/N	Distance (m)	Radiation Dose $\mu\text{Sv/hr}$	Base Station Location (GPS)	
			Northing	Easting
1	10	15.57	0596813	0812101
2	20	13.64	0596817	0812100
3	30	13.31	0596821	0812099
4	40	12.65	0596825	0812099
5	50	12.21	0596827	0812096
6	60	7.74	0596832	0812095
7	70	4.88	0596835	0812093
8	80	3.46	0596739	0812089
9	90	3.01	0596741	0812087
10	100	1.63	0596742	0812082
Average		8.81		
Range		1.63-15.57		

182 *MPBS (Mobile Phone Base Station)

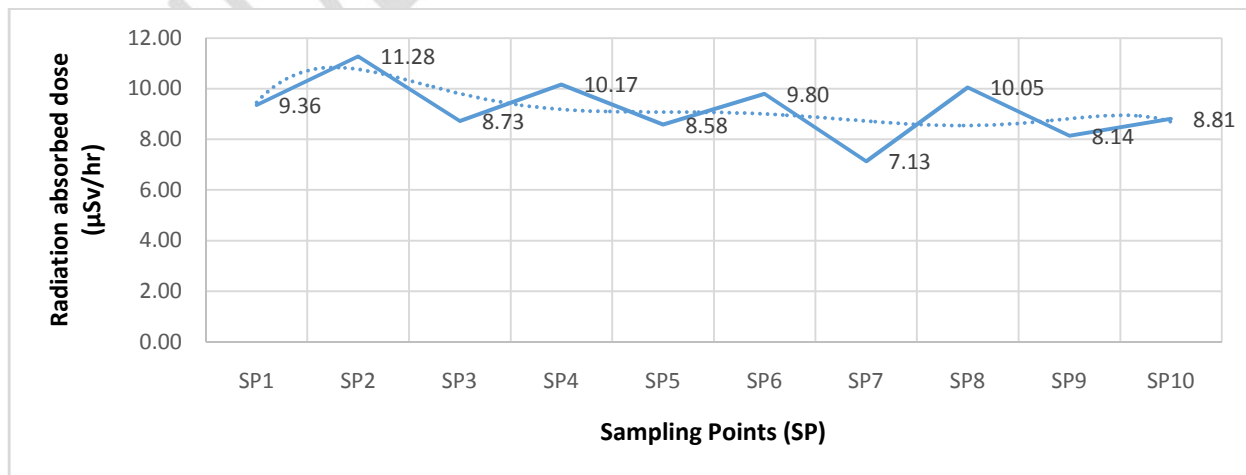
*SP (Sampling Point)

183

184 The values reported were also higher than 0.3 $\mu\text{Sv/hr}$ reported for radiation dose during the day at Yalvac, Turkey¹⁷,
185 the present values were also higher than 0.50 $\mu\text{Sv/hr}$ reported for Public Health of England¹⁸. The mean value from
186 the study was higher than reported values of 0.29 $\mu\text{Sv/hr}$ ¹⁹ but was lower than the values of 50 $\mu\text{Sv/hr}$ reported by
187 Farai and Ayinmode⁽²⁰⁾. The assumption from the result is that the radiation exposures from MPBS impose no
188 health hazard as the limits recommended in the guidelines by International Commission of Non-Ionizing Radiation
189 protection (ICNIRP) do not appear to have any known adverse consequence on human health.

190 However, the continuous exposure of human body to radiation has reported to cause weakness of immune system¹²
191 and such disturbances increase the probability of causing diseases. Generally, the variations of radiation dose with
192 distance from mobile phone base stations were observed to obey inverse square law i.e. intensity diminishes quickly
193 with distance from the tower. The observation was in agreement with other international and national studies.
194 Therefore, there is no reason to entertain that mobile phone base stations could constitute any potential health hazard
195 to human. There are need for human to operate devices in accordance with established safety standard to avoid any
196 adverse health effect.

197



198

199

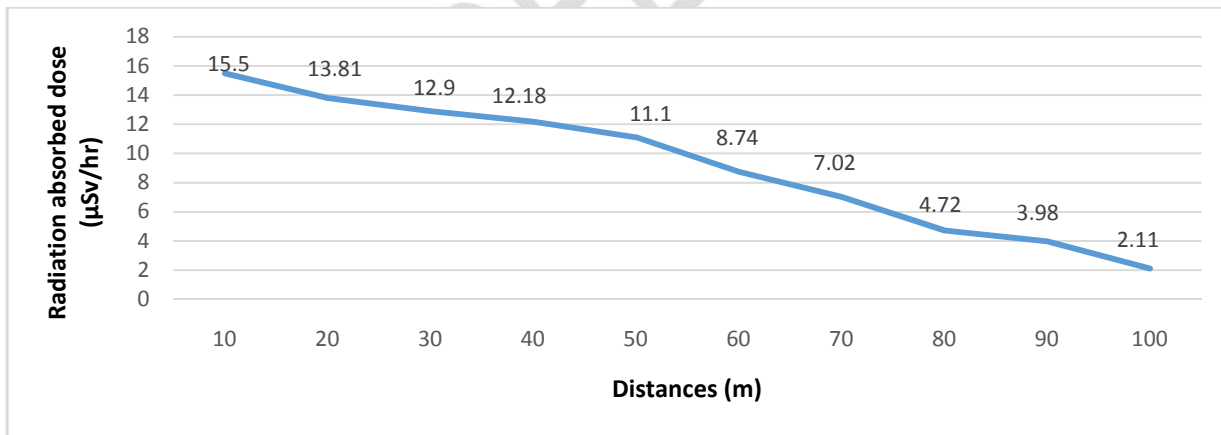
Figure 3: Mean radiation absorbed doses from sampling points 1- 10 in the study area.

200
 201 The values reported for this present study showed that all mean radiation dose from various locations ranged
 202 between 7.13 $\mu\text{Sv/hr}$ at sampling point 7 to 11.28 $\mu\text{Sv/hr}$ at sampling point 2 of the sampling points respectively. All
 203 values reported were higher than the recommended average value of 0.71 $\mu\text{Sv/hr}$ and maximum value of 5.7 $\mu\text{Sv/hr}$
 204 given by the American Nuclear Society for Mobile Phone Base Stations. However, the values reported are not high
 205 enough to cause heating effect to people living close to the base stations.
 206

207 Table 11: Radiation from all sampling locations

Distance	Radiation Dose ($\mu\text{Sv/hr}$)										
(m)	SP1	SP2	SP3	SP4	SP5	SP6	SP7	SP8	SP9	SP10	Mean Dose
10	18.23	16.83	16.43	18.25	13.37	14.93	12.76	15.63	12.98	15.57	15.50
20	16.06	15.07	13.09	14.96	11.6	14.08	12.68	14.08	12.76	13.64	13.81
30	13.45	14.96	10.94	14.74	11.32	13.82	10.34	13.86	12.21	13.31	12.90
40	10.23	14.85	10.78	14.52	10.93	13.77	8.91	13.31	11.88	12.65	12.18
50	9.64	14.52	9.13	9.33	10.16	13.09	8.36	12.98	11.55	12.21	11.10
60	9.52	12.63	6.82	9.33	8.91	7.54	6.41	10.04	8.43	7.74	8.74
70	6.08	10.45	6.15	8.39	8.35	7.16	4.03	8.43	6.27	4.88	7.02
80	5.19	6.23	5.43	5.6	4.63	5.22	3.48	4.86	3.11	3.46	4.72
90	3.92	5.07	5.06	4.68	4.18	5.08	3.09	4.22	1.45	3.01	3.98
100	1.26	2.15	3.48	1.93	2.34	3.26	1.26	3.04	0.72	1.63	2.11

208
 209 Table 11 shows that radiation dose measured at a given distance irrespective of the location of the mobile phone
 210 base station were slight similar with insignificance differences on many occasion. This is in conformity that the
 211 amount of radiation decreases rapidly as the distance from the mobile phone base station increases.
 212



213
 214 Figure 4: Mean radiation absorbed doses with respect to distances from the mobile phone base stations.
 215

216 **4.0 Conclusion**

217 The study has provided data on the radiation dose from Mobile Phone Base Stations in Ibadan, Oyo state,
 218 Southwestern Nigeria. The results showed that the maximum radiation dose in Ibadan is 16.94 $\mu\text{Sv/hr}$ and the mean
 219 radiation dose 13.53 $\mu\text{Sv/hr}$ for all locations under studied. The result from the study indicated that exposure of
 220 people to radiofrequency radiation from mobile phone base station in Ibadan is higher than the average and
 221 maximum values recommended by the American Nuclear Society but far less than the levels recommended by
 222 International Guidelines for Protection against Established Health Effects (ICNIRP reference level). However, the
 223 effect of exposure to low radiations from base stations can only be heating effect of the body tissues. Therefore, the
 224 populace from the study area should not raise any anxiety on the health impact due to the radiation exposure from
 225 mobile phone base stations.

226
227
228
229
230
231
232
233
234
235
236
237
238
239
240
241
242
243
244
245
246
247
248
249
250
251
252
253
254
255
256
257
258
259
260
261
262
263
264
265
266
267
268
269
270
271
272
273
274
275
276
277

5.0 References

1. Godfrey E.E. (2015). A model for assessing base stations for compliance with safety limits for human exposure to electromagnetic fields in Nigeria. *Nigerian Journal of Scientific Research*, 16(2), 184-186.
2. Dianah A.R.S.N., Umar R., Kamarudin M.K.A., Dagang A.N. and Hazmin S.N. (2017). Exposure level from selected base station towers around Kaula Neru: A preliminary analysis. *Journal of Fundamental and Applied Sciences*.
3. WHO (2014). Electromagnetic fields and public health: mobile phone. World Health Organization publication of October 2014. Retrieved on 22nd November, 2018.
4. Wolf R. and Wolf D. (2004). Increase incidence of cancer near a cell phone transmitted station, *International Journal of Cancer Prevention*, 2004; 1: 123-8, April 2004.
5. IEGMP (2003). Health effects from radiofrequency electromagnetic fields: report of an independent advisory group on non-ionizing radiation, Independent Expert Group on Mobile Phones (IEGMP). Doc. NRRPB 14(2).
6. Van Wyk M.J. and Bingle Meryer, F.J.C. (2005). Antenna modeling consideration for accurate SAR calculations in human phantoms in close proximity to GSM cellular base station antennas, Nilay-Liss Inc. *Bio-electromagnetics*, 26:502-509.
7. Roosli M., Moser M., Meiser M. and Brown F.C. (2003). Health symptoms associated with electromagnetic radiation-A questionnaire survey mobile phone base station and health, 15-16 May (Dublin).
8. Lonn S., Ahlbom A. and Hall P. (2004). Mobile phone use and the risk of acoustic neuroma *Epidemiology* 2004, 15:653-659 (PubMed).
9. Avwiri O.G. (2014). Health effect of radiofrequency to the general population. International conference knowledge based organization 2014 (vol.1).
10. Farai I.P. and Vincent U.E. (2006). Outdoor radiation level measurement in Abeokuta, Nigeria. *Nigeria Journal of Physics* 18, pp.121-126.
11. Litrak E., Foster K.R. and Repacholi M.H. (2005). Health and safety implications of exposure to EMFs in the frequencies range 300Hz-10MHz. *Bio-electromagnetics*, 23(1):68-82.
12. Johansson O. (2009). Disturbance of the immune system by electromagnetic field, *Pathophysiology* 2009. Retrieved March 7, 2018 from <http://www.ncbi.nlm.nih>.
13. Cherry N. (2000). Criticism of the proposal to adopt the ICNIRP guidelines for cell sites in New Zealand, ICNIRP Guidelines, Critique, Lincoln University, Environmental Management and Design Division, Canterbury, NZ.
14. Umar S., Garba N.N. and Zakari Y.I. (2017). Assessment of radiofrequency radiation exposure from selected mobile base stations in Kaduna state, Nigeria. *Nigerian Journal of Scientific Research*, 16(2): 184-186.
15. NPCR (2006). Reports of the National Population Census, Federal Republic of Nigeria. web.archive.org. Retrieved February 24, 2018.
16. Shalangwa, D.A. (2010). Measurement of exposure of radio frequency field radiation from global system for mobile communicate on masts. *Journal of Electrical and Electronics Engineering Research* Vol. 2, Issue 3, 75-84.
17. Halim B., Abdullah K. and Gürcan Y. (2009). Natural background radiation measurements of a base station in Yalvaç County. *Çankaya Üniversitesi Fen-Edebiyat Fakültesi, Journal of Arts and Sciences* Sayı: 12 / Aralık.
18. Public Health in England (2011). Guidance Ionizing radiation: dose comparisons. Published 18 March 2011. Assessed on 30th April 2018.
19. Ayinmode B.O. and Farai I.P. (2013). Variations of radiofrequency power density from mobile phone base station with distances. *Oxford Journal of Radiation Protection Dosimetry*, 156 (4), PubMed, 156, 424 – 428.
20. Farai I.P. and Ayinmode B.O (2011). Review of variation EMF with distance from mobile phone base station. *Radial Pros Dosimetry* 2011: 154 (4).