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Measurement and Analysis of Electromagnetic Field in Areas of Douala, Cameroon

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Abstract

Chronic exposure to electromagnetic radiation from telecommunications installations is known to have significant harmful effects. Given the work being done to improve the quality of telecommunications in Cameroon, which involves an increase in the number of installations emitting electromagnetic radiation. Compliance with EMF exposure limits is being called into question. The objective is to measure electromagnetic fields in neighborhoods of Douala and compare them to the exposure limits set by the International Commission on Non-Ionizing Radiation Protection for public. We identified 85 points near installations (telecommunications towers and electricity transmission towers) emitting electromagnetic fields, using GPS coordinates in the city of Douala. We used the PCE EM29 radiometer to measure the electric field, magnetic field, and power density in accordance with its user manual, while complying with the data collection protocol (electromagnetic waves) according to ANFR/DR 15-4.1. The results of the exposure values measured based on the identified points compared to the ICNIRP exposure limit values in public show that six points could exceed 0.045 W/m², which represents 1% of the power density limit value, and that no point reaches 10% of the threshold values. The measured fields remain below the limits set by the ICNIRP for the public in the city of Douala for the frequency range between 700 and 2400 MHz.

Keywords: Measurement, Electromagnetic Fields, Radiometer, Exposition value.

1. Introduction

Electromagnetic fields from mobile phones and their antennas, and the Wi-Fi frequency band, among others, are generating social concern that has been accumulating over the years and is influencing risk management and perception at a national and international level, thus motivating the design and development of scientific studies to measure and monitor the levels of exposure to RF-EMF and search for a possible correlation on health[1]. Many studies have been conducted to explain biological effects, mainly, related to fields of low frequency (or extremely low frequency: ELF) including commercial frequency of power equipment and other devices, and to fields of high frequency (or radio frequency: RF) such as microwaves used in mobile phones and other radio communication systems[2].The microwaves, over the entire frequency range from 0 Hz to 300 GHz[3].

The constant growth of the telecommunication services available and the number of users require the use of higher frequency bands to achieve high quality service. Besides the characteristics of propagation of these fields, higher frequencies can penetrate and are partially absorbed into superficial layers of the cellular tissue, while fields in lower frequencies pass through the human body. A consequence of the increasing in frequency band use was a greater number of broadcasting towers through the cities, which put them close to the highly populated regions. This increase in the numbers of towers has an important visual impact in the city drawing the attention of the people for the possible health issues that can be caused by exposition of electromagnetic radiation on humans[4].

Cameroon had 23.92 million mobile phone subscribers, representing a penetration rate of 84.6% at the beginning of 2023, with Cameroonian

telecom operators experiencing difficulties in ensuring good service quality and optimal coverage of their telecom networks[5]. Furthermore, smartphone penetration, which facilitates mobile internet access, surged from 25% in 2016 to nearly 40% in 2020, a 15-point increase in four years, according to the National Telecommunications Observatory of the Telecommunications Regulatory Agency (ART)[6]. In Douala, the proliferation of base transceiver stations (BTS), radio links, and high-voltage transmission lines reflects the increasing demand for mobile networks, internet connectivity, and electrical power distribution[7]. This situation raises growing concerns among local communities regarding the exposure to electromagnetic fields (EMF),

In Cameroon, environmental regulatory structures and procedures for controlling electromagnetic fields (EMFs) are currently less developed and less precise than widely recognized international standards, such as those issued by the International Commission on Non-Ionizing Radiation Protection (ICNIRP)[8]. This regulatory gap, addition to the non-respect of distance between telecommunication masts[9], highlights the need for systematic field measurements and scientific assessments to characterize the actual levels of electromagnetic radiation emitted by communication systems operating in urban areas like Douala.

2. Objectives

the present study focuses on the collection and analysis of electromagnetic waves in the city of Douala using measurement equipment capable of capturing fields across both low-frequency and radio-frequency ranges, with the following specific objectives:

- To measure population exposure levels using a radiometer.

- To analyze and compare the measured values with the ICNIRP public exposure limits.

3. Methods and material

The instrument used to measure electromagnetic fields is the PCE EM 29 show in Figure 1, a radiometer equipped with a spherical triaxial probe. It can measure electric, magnetic fields and power density in a range from 50 MHz to 3.5 GHz[10].

Since it is automatic and covers the mobile telecommunications frequency range in Cameroon, it can go up to 2400 MHz for 4G. In principle, this device measures the electrical component of the field by the probe, and converts the electric field strength to magnetic field strength and power density through formulae for electromagnetic radiation in the far-field region:

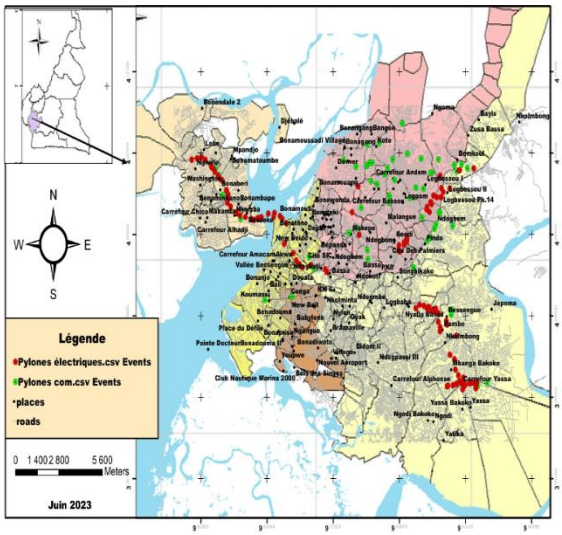
$$\begin{cases} H = E/\eta 0 \\ S = EH \end{cases} \quad (1)[10]$$

where η0 is the intrinsic impedance of free space. The instrument was calibrated before the measurements.

Figure 1: Picture of PCE EM 29

This study was conducted in the first five districts of the city of Douala, Cameroon (Districts I to V). These areas were chosen because they have a lot of people living there, a lot of different uses for the land (residential, commercial, and industrial), and infrastructure that gives off electromagnetic fields (GSM relays, high-voltage lines, 4G antennas). We took point around GPS coordinates as in the study on mapping electromagnetic radiation emissions[9] like represented in fig 2, to measure exposure values in accordance with the ANFR/DR 15-4.1 measurement protocol[11]. Taking into account the PCE EM 29 user manual[10], we were able to configure and perform the measurements.

Figure 2: Spatial distribution of measurement point around source[9].



We considered the average values during data collection, which consisted of taking measures based on the distance from the towers (0, 1.5, and 3 m) and the distance from the ground (1.1, 1.5, and 1.7 m). For a final selection of 1.5 m above the ground and 3 m away from the transmitting installation, representing the level at which the measuring device was positioned.

The collection conditions for the reliability of the measurements were as follows: the collector must not hold the device with sweaty hands; there must be no telephones near the collector also steel. While collecting, we used length meter and GPS application to be sure that it is same GPS position recorded, survey table form for data recording; after positioning we switched-on radiometer and just waited 6 minutes to have record value of Electric field and magnetic field of that point. we had done like that for each point in each GPS location. We did not collect any sample during the rain. In each of the points were measured the values of the electric field strength in millivolts per meter (mV/m), the magnetic field strength in micro ampere per meter (mA ⁄ m) and power density in microwatts per square meter (µW/m²).

4. **Results and discussion**.

- **Results**

After completing the data collection, we proceeded with data processing, excluding all incomplete data, and compiled and summarized them in Excel in the form of a table presenting the GPS coordinates, their electric fields, magnetic fields, and power density. whose 85 points are represented in the table below.

TABLE I: Measured value.

Point	Latitude	longitude	E (mV/m)	H (mA/m)	S (µW/m²)
1	4.049999	9.732239	1512	4.01	6064
2	4.052079	9.732421	1411	3.742	5280
3	4.047216	9.732360	1554	4.123	6411
4	4.731559	9.414733	2163	5.75	12460
5	4.072222	8.900523	4104	10.88	44690
6	4.399823	8.900509	2719	7.214	19620
7	4.400075	8.900 44	1586	4.181	6592
8	4.403064	8.901855	986.2	2.615	2579
9	3.999834	9.805059	2562	6.796	17410
10	4.002073	9.804049	4696	12.45	58500
11	4.000434	9.807 08	3465	9.191	31840
12	4.010352	9.798 55	2047	5.431	4295
13	4.016308	9.796803	3.404	9.029	30740
14	4.023836	9.793369	1935	5.134	9939

Point	Latitude	longitude	E (mV/m)	H (mA/m)	S (μW/m²)
15	4.031358	9.783449	1615	4.284	6921
16	4.036393	9.762428	3195	8.476	27080
17	4.036583	9.762428	911	2.416	2201
18	4.036505	9.762906	2929	7.77	22760
19	4.04134	9.745284	480.6	1.274	612.6
20	4.032414	9.790022	1581	4.195	6635
21	4.031897	9.7899	1950	5.173	10080
22	4.031574	9.785714	5699	15.11	86150
23	4.033755	9.783369	2345	6.622	14590
24	4.049772	9.761576	3380	8.366	30310
25	4.046406	9.7658	3021	8.014	24100
26	4.036743	9.768883	2044	5.422	11080
27	3.999646	9.806088	1837	4.874	8956
28	4.000746	9.807412	2262	6.2	13570
29	4.00155	9.810679	2443	6.48	15830
30	4.001563	9.813956	3240	8.594	27840
31	4.056752	9.768798	2816	7.469	21030
32	4.000913	9.805453	2760	7.322	20210
33	3.999898	9.805735	1084	2.876	3119
34	4.001672	9.813985	2550	6.716	17250
35	4.000374	9.814753	4.064	10.78	43820
36	3.999494	9.813537	3688	9.784	36090
37	4,010	9,800	911.6	2.418	2204
38	4,002	9,804	870.2	2.1308	2008
39	40,021	9,8038	823.9	2.185	1800
40	4,030	9,799	3018	8.007	24170
41	4,045	9,729	1915	5.08	9732
42	4,048	9,757	1969	4.974	10280
43	4,039	9,763	391.4	1.038	496.3
44	4,039	9,764	1024	2.717	2784
45	4,040	9,747	120.6	0.3198	38.5
46	4,037	9,762	277.9	0.7371	204.8
47	4,036	9,763	81.4	0.2159	17.5
48	4,072	9,794	1597	4.236	6766
49	4,066	9,791	1499	3.977	5964
50	4,023	9,794	1067	2.831	3022

Point	Latitude	longitude	E (mV/m)	H (mA/m)	S (μW/m²)
51	4,016	9,797	287.2	0.7618	218.7
52	4,013	9,799	473.8	2.052	1588
53	4,031	9,788	1010	2.679	2707
54	4.066667	9.766667	8082	21.44	124900
55	4.081944	9.771389	7841	20.79	163000
56	4.341354	9.674581	1154	3.061	3532
57	4.104959	9.619143	1594	4.228	6741
58	4.09463	9.64776	1909	5.064	9671
59	4.095605	9.651379	4.539	12.03	54640
60	4.09579	9.653823	2599	6.895	17920
61	4.094977	9.656175	1680	4.456	7486
62	4.093415	9.658177	1988	5.301	10590
63	4.091815	9.659772	1429	3.79	5418
64	4.089816	9.661757	1837	4.875	8959
65	4.089797	9.661742	681.4	1.807	1231
66	4.086753	9.664855	0.186	0.4933	81.7
67	4.086016	9.666393	0.186	0.4933	81.7
68	4.085497	9.75955	1879	4.984	9367
69	4.084198	9.745038	1814	4.811	8729
70	4.011815	9.661757	1680	4.456	7486
71	4.089816	9.661751	1988	5.301	10590
72	4.089797	9.661742	1428	3.79	5418
73	4.086753	9.664855	1835	4.875	8959
74	4.086016	9.666393	681.4	1.807	1231
75	4.072356	9.674581	2509	6.655	16700
76	4.073488	9.673112	3069	8.141	24790
77	4.075091	9.671087	2140	5.677	12150
78	4.076693	9.66927	2672	7.089	18950
79	4.080046	9.669418	2686	7.124	19130
80	4.078719	9.669317	4604	12.21	56230
81	4.08186	9.668617	2040	5.411	11040
82	4.070781	9.680952	2114	5.609	11860
83	4.070982	9.678873	2458	6.521	16030
84	4.071685	9.676478	3928	1.041	40926
85	4.030022	9.772132	2061	5.466	11260

The data was then compared with the International Commission on Non-Ionizing

Radiation Protection (ICNIRP) threshold values for the public, as shown in the table below.

TABLE II Limits for public exposure to electromagnetic fields at radio frequencies [12]

Radio Frequency Range	**Electric Field Strength E(V/m)**	**Magnetic Field Strength H(A/m)**	**Equivalent Plane Wave Power Density Seq(W/m2)**
0.1-30 MHz	$300/f_M^{0.7}$	$2.2/f_M$	/
30-400 MHz	27.7	0.073	2
400-2000 MHz	$1.375f_M^{0.5}$	$0.0037f_M^{0.5}$	$f_M/200$
2-300 GHz	61	0.16	10

Discussion.

The set of measurements collected shows electric fields ranging from approximately 0.08 to 8.08 V/m, magnetic fields varying from 0.0002 to 0.0214 A/m, and power densities up to 0.2 W/m².

In fact, the electric fields measured, ranging from approximately 0.18 to 7841 mV/m, remain well below the reference limit set at 61 V/m for the most common mobile phone frequencies, representing a considerable safety margin. Similarly, the power densities observed, ranging from a few µW/m² to a maximum of approximately 124,900 µW/m², in the 900 MHz range, the power density limit is 4.5 W·m⁻², with a maximum observed value of 0.163 W·m⁻², representing 3.6% of the limit; at frequencies ≥ 2 GHz, we are at almost 1.6% of the limit of 10 W·m⁻², confirming that exposure is within thresholds compatible with international standards. Thus, although some points show values significantly higher than the average, none come close to levels that could pose a health risk according to current recommendations. These results confirm that the overall exposure of the public in the area studied remains well within regulatory requirements. But is this sufficient to draw conclusions, given that these are only spot measurements taken over a short period of time that do not reflect chronic exposure at the site, without considering cumulative factors or other frequency ranges below 700-2400 MHz?

We note that the values remain below the threshold values, however we must consider the crowding factor due to a dense population and multiple infrastructures that may interfere with the sampling data. Furthermore, data collection was always carried out during the day. These factors may constitute biases.

5. Conclusion

This study on electromagnetic radiation in the city of Douala, in a context of steady growth of telecommunication services and facilities for better service quality but also growth of populations and dwellings, raises increasing concern regarding compliance with exposure values according to international standards. The objective of the study focused on measuring the actual exposure values of the population in the city of Douala and subsequently on a comparative analysis of these values with the limits set by the ICNIRP. To this end, we conducted measurements using the PCE EM 29 radiometer in the vicinity of electromagnetic radiation emitting installations following the ANFR/DR 15-4.1 protocol. The results were processed for 85 points materialized by GPS coordinates, documenting their electric fields, magnetic fields, and power density. Among these, we note six points that may exceed 0.045 W/m², which represents 1% of the power density limit value, and no points reaching 10% of the threshold values. We can conclude that the fields measured remain below the ICNIRP limit levels for the public in the city of Douala for the frequency range between 700 and 2400 MHz. This does not guarantee a healthy development and exposure of the population of Douala, knowing that this is not low frequency and that a specific absorption rate (SAR) analysis of the populations will need to be carried out to rule out any suspicion.

Data availability

The data used to support the findings of this study are included within the article.

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Conflicts of interest

The author declares no conflict of interest.

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