



## East African Journal of Health and Science

[eajhs.eanso.org](http://eajhs.eanso.org)

Volume 7 Issue 2, 2024

Print ISSN: 2707-3912 | Online ISSN: 2707-3920

Title DOI: <https://doi.org/10.37284/2707-3920>



EAST AFRICAN  
NATURE &  
SCIENCE  
ORGANIZATION

Original Article

### Spatial Exposure of EMF from Phone Base Stations in the North of Libreville, Gabon

Dr. Nadine Nicole Ndonghan Iyangui<sup>1,2\*</sup>, Sylvestre Biffot<sup>2</sup>, Igor Ndong<sup>2</sup> & Christian Ekogha<sup>2</sup>

<sup>1</sup> Université Omar Bongo, Libreville, BP 17 043 Libreville, Gabon.

<sup>2</sup> Observatoire Gabonais de la Pollution Electromagnétique (OGAPEM), 1238, Rue Missiliaka, Okala, Libreville, Gabon.

\*Author for Correspondence ORCID ID: <https://orcid.org/0009-0002-6608-6620>; Email: [n\\_ityangui@yahoo.fr](mailto:n_ityangui@yahoo.fr)

Article DOI: <https://doi.org/10.37284/eajhs.7.2.2472>

Date Published: **ABSTRACT**

02 December 2024

**Keywords:**

Gabon,  
Libreville,  
EMF Exposure,  
Mapping,  
Spatial Concentration.

The electromagnetic environment became dense with the spread of its artificial sources in urban and rural areas. More and more publications are describing their unfavourable effects, including human well-being deterioration, disruption of the nervous system functions or cancer occurrence. Also, there is a legal loophole related to electromagnetic fields (EMF) in many countries. The aim of this contribution is to map people's exposure to EMF from phone base stations in the north of Libreville, Gabon. Data on phone base station emissions have been collected with Spectran 6080HF, processed with MCS Spectrum Analyser 2.1.6, transferred in a WPS spreadsheet, and converted to a shape file before mapping them in ArcMap and examining spatial concentration in QGIS. Phone base station emissions vary in space and time between 0 to 488,09 V/m from June to December 2021. The threshold of phone base station emissions standards is exceeded at different periods for all mobile phone network operators, by the Salzburg Resolution and Gabonese standards. Furthermore, the concentration of EMF exposure varies in space and concerns more Akanda than Libreville. This fact explains the spatio-temporal variation of people at risk, as all types of districts and social classes are concerned. Based on the precautionary principle, and because this risk is a matter of accumulation of exposure, it is important to revise standards and raise awareness of EMF pollution as cancer cases and related diseases have grown amidst struggling health systems for years.

#### APA CITATION

Iyangui, N. N. N., Biffot, S., Ndong, I. & Ekogha, C. (2024). Spatial Exposure of EMF from Phone Base Stations in the North of Libreville, Gabon. *East African Journal of Health and Science*, 7(2), 84-95. <https://doi.org/10.37284/eajhs.7.2.2472>.

#### CHICAGO CITATION

Iyangui, Nadine Nicole Ndonghan, Sylvestre Biffot, Igor Ndong and Christian Ekogha. 2024. "Spatial Exposure of EMF from Phone Base Stations in the North of Libreville, Gabon". *East African Journal of Health and Science* 7 (2), 84-95. <https://doi.org/10.37284/eajhs.7.2.2472>

**HARVARD CITATION**

Iyangui, N. N. N., Biffot, S., Ndong, I. & Ekogha, C. (2024). "Spatial Exposure of EMF from Phone Base Stations in the North of Libreville, Gabon", *East African Journal of Health and Science*, 7(2), pp. 84-95. doi: 10.37284/eajhs.7.2.2472.

**IEEE CITATION**

N. N. N., Iyangui, S., Biffot, I., Ndong & C., Ekogha "Spatial Exposure of EMF from Phone Base Stations in the North of Libreville, Gabon", *EAJHS*, vol. 7, no. 2, pp. 84-95, Nov. 2024.

**MLA CITATION**

Iyangui, Nadine Nicole Ndonghan, Sylvestre Biffot, Igor Ndong & Christian Ekogha. "Spatial Exposure of EMF from Phone Base Stations in the North of Libreville, Gabon". *East African Journal of Health and Science*, Vol. 7, no. 2, Nov. 2024, pp. 84-95, doi:10.37284/eajhs.7.2.2472.

**INTRODUCTION**

The use of technology is growing in Africa, and so is exposure to electromagnetic fields (EMF). Electric and magnetic fields are invisible areas of radiation, produced by electricity (NIH & NCI, 2022). Sources of exposure to EMF pollution in urban areas mainly include mobile communication, electric base stations, wireless and cable internet, radio equipment, high energy voltage transmission lines, medical devices, and others (Thulu et al., 2023). However, Electromagnetic Hyper-Sensitivity is characterized by awareness and/or symptoms triggered by EMF exposures. Symptoms like nausea, loss of appetite, sleep disturbance, loss of memory, lowering of libido, headaches, dizziness, heart palpitations, tinnitus, skin rashes, visual disturbance, sensory disturbance, and mood disturbance have been linked to phone base station (BSs) vicinity (ICBE-EMF, 2022; Raphael Yende, 2016; Carpenter, 2013; Khurana et al., 2010; Kundi & Hutter, 2009; Santini et al., 2002). Furthermore, cancers are significant in people living close to base stations (ICBE-EMF, 2022; Gómez-Perretta et al., 2013; Carpenter, 2013; Khurana et al., 2010; Wolf & Wolf, 2004; Eger et al., 2004). Moreover, the increase in the number and spread of phone base stations have raised public awareness. Therefore, the health risk due to exposure to radio-frequency electromagnetic fields (RF EMFs) is a topic today.

To try to protect people, the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and the Federal Communications Commission (FCC) from the United States, on the basis of animal experiences and thermal effects

mainly, adopted radio frequency radiation exposure limits in the late 90s (Hirata et al., 2021; Raphael Yende, 2016). In the Western world, standards vary between 61 V/m for the European Union and 0.6 V/m recommended by the Salzburg Resolution (Roth et al., 2024; Raphael Yende, 2016; Viel et al., 2009, Altpeter, 2000). As effects on the brain of those living near phone base stations, consequences in terms of sleep disturbance, fatigue or headaches have been established from 0.6 V/m, scientists suggested that residential exposure should not exceed 0.194 V/m or 0.01  $\mu\text{W}/\text{cm}^2$  (Raphael Yende, 2016).

In Africa, few studies exist about RF EMF exposure. Abdel-Rassoul et al. (2007) in Egypt, assessed neurobehavioral effects around phone base stations in Menoufiya governorate. They found out that people living near that kind of infrastructure are at risk for developing neuropsychiatric problems and some changes in their neurobehavioral functioning. In fact, the prevalence of headaches, memory problems, dizziness, tremors, depressive symptoms, and sleep disturbances was significantly higher among exposed inhabitants (Kundi & Hutter, 2009). Also, measures of RF EMFs emitted were lower than the Egyptian standards based on the American National Standards Institute (ANSI) and the Institute of Electrical and Electronics Engineers (IEEE) standards. The authors recommended the revision of standards guidelines for public health exposure to radiofrequency electromagnetic radiation (RER) from BSs.

In the Congo Democratic Republic (Beni City) the study demonstrated that people can use up to four

telecommunication networks and that there is a need for appropriation of the technology for development (Raphael Yende, 2016). In Ethiopia (Addis Ababa, Dessie and Kombolcha) and South Africa (Cape Town, Milernton, Muizenberg and Stellenbosch) radiofrequency electromagnetic field exposure levels were compared in different everyday microenvironments (Sagar et al., 2018). This study stated that the mean total RF-EMF exposure levels were below ICNIRP guidelines that there is a high variability of RF-EMF between selected microenvironments, and also that exposure tends to increase with the level of urbanity.

In Malawi (Blantyre City) EMF was assessed through electric and magnetic pollution measurements (Thulu et al., 2023). These measurements were found lower than international organisation standards, but considered a threat to people, in terms of cumulative doses. The majority of these countries use international exposure limits from ICNIRP recognized by the World Health Organization (WHO), ANSI and IEEE. However, more recently, international exposure limits have been considered not adequately protective of people from short-term or long-term RFR exposures, by the International Commission on Biological Effects of EMF (ICBE-EMF, 2022). In addition, given the One Health approach, to improve the understanding of health problems, it is essential to pay attention to EMF exposure, especially because EMF pollution is becoming one of the main concerns in terms of environmental quality.

In Gabon, a coastal country in central-west Africa, more and more cancer cases are notified and health systems have been struggling for years. In other respects, since 2010 Gabon has a limit exposure to EMF of 6V/m and a security distance of 100 meters, only for nurseries, schools and health facilities (MCPEN, 2010). This value of 6 V/m seems based on technical reasons more than medical ones (Ndonghan Iyangui, 2016).

Also, the first study related to EMF in Gabon assessed for 2015, the proximity of phone base

stations and schools in some districts of Libreville, the capital (Ndonghan Iyangui, 2016). Some base stations were found too close to some schools. However, because not all the schools' establishment dates were available, it was not possible to determine if base stations were established before or after schools started. At that time, data on measurements of exposure were not available anywhere, as the Regulatory Authority for Electronic Communications and Posts (ARCEP) was not willing to collaborate, let alone the major cell phone companies. This subject is really sensitive in Gabon.

This study was the start of the collaboration with the NGO Gabonese Observatory of Electromagnetic Pollution (OGAPEM) to exploit data on phone base station emissions they collected. Indeed, to motivate decision-makers to reduce exposure limits to less than 0.6 V/m, it is important to provide them with sufficient scientific arguments, mainly based on local studies. In 10 years, Gabonese standards should be 0.194 V/m, as scientists already suggested (Raphael Yende, 2016). But for instance, moving standards from 6 V/m to 0.6 V/m as recommended by the Salzburg Resolution to improve inhabitants and environmental biodiversity protection will be a good start.

This work on mapping EMF exposure is the start of a series of studies to produce information for the decision-making process. It is the first time EMF exposure has been studied in Gabon. So, the purpose of this paper is to assess spatial exposure of EMF from phone base stations in the north of Libreville. To this end, the first step is to map EMF emissions by phone base stations in comparison with local and the Salzburg Resolution exposure limits. A second step is to examine the spatial concentration of this exposure.

Mapping EMF exposure can not only help change the standards but also contribute to the improvement of population health. In a broader context, this study can raise awareness of the African scientific community mainly, to pay attention to this

exposure, as cancer prevalence is rising but the health systems are still struggling.

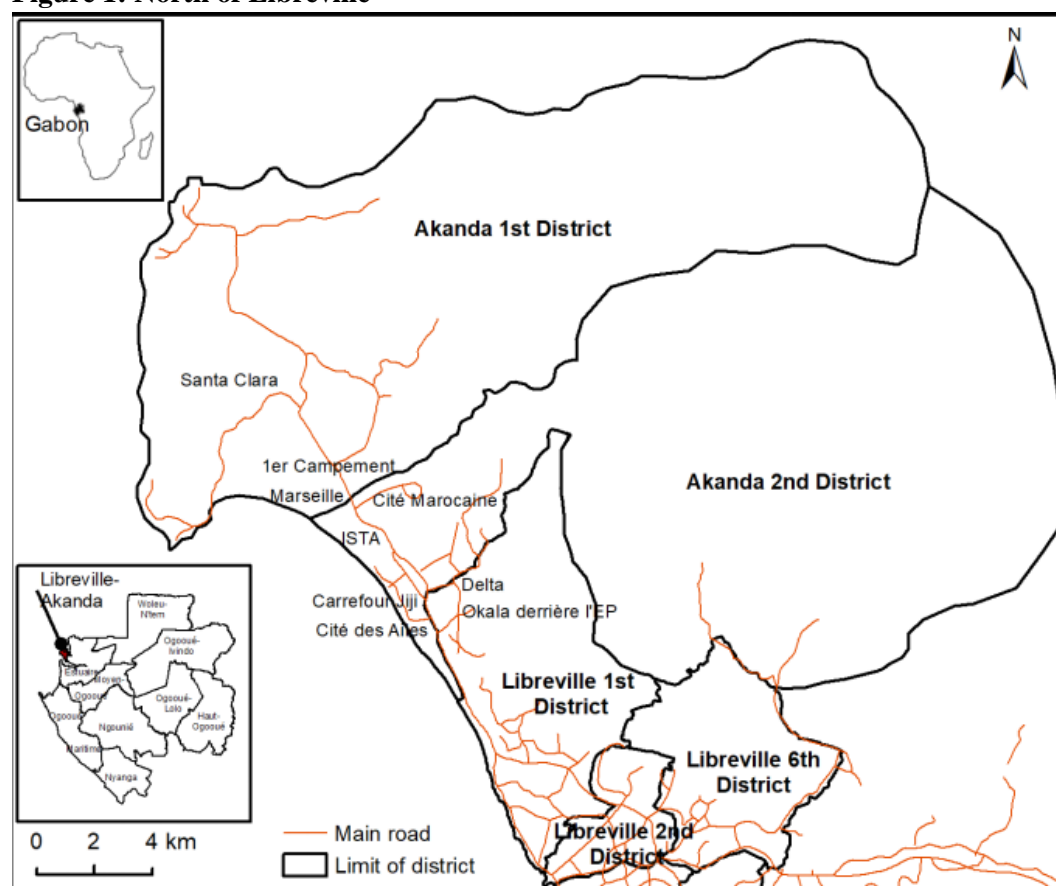
## MATERIALS AND METHOD

### Study design

North of Libreville has been chosen essentially because of the availability of data. This area, indicated in *Figure 1* below, is concerned with two districts of Libreville, the administrative capital of the country and two districts for Akanda, the

administrative capital of the Estuary region. In 2013 this part of Libreville counted 35.5% (227474 inhabitants) of its population, while in Akanda the two districts represent the total of the population (34548 inhabitants), but 4.7% of Libreville-Akanda area. For all these districts, there are more males than females and 32.44% of the population is less than 15 years old (85 010 inhabitants) based on the 2013 National Census (DGS, 2015). But today, since many housing estates have been built in Akanda, its population seems to increase.

**Figure 1: North of Libreville**



**Source:** Roads, limits of regions and districts from the National Institute of Mapping (INC)

Mobile phone has been in Libreville since 1992 (Ndonghan Iyangui, 2016). Since 2022 Airtel Gabon and Moov Africa have been the only operators. It is only in 2010 that Standards of EMF appear for emissions of phone base stations with the former Telecommunication Regulatory Agency (ARTEL)'s Order No. 025/MCPEN/CAB/2010 in

the regulation of the location of phone base stations in the Gabonese Republic. In Article 3, EMF emissions have to be not more than 6 V/m (MCPEN, 2010). Also, Article 4 stipulates that operators have to locate their antennas 100 meters from sensitive establishments: nurseries, schools and health facilities. Moreover, in Gabon, operators are

allowed to install phone base stations in family concessions. So it is not rare to walk or live close to mobile phone base station antennas across the country.

### Data collection

Different types of data have been used: phone base station emissions, Gabonese standards on electromagnetic field emissions, Salzburg Resolution standards, main roads and limits of districts and regions. Data on phone base station emissions have been collected from June to December 2021, with Spectran 6080HF in a car, saving information at least every 20 seconds. Routes have been identified mainly because of traffic, human density, proximity to phone base stations and because personal activities took place there. Gabonese standards on electromagnetic field emissions have been collected in the Telecommunication Regulatory Agency Orders. Salzburg Resolution standards have been collected in the literature. Roads and limits of districts and regions come from the National Institute of Mapping (INC).

### Data processing and analysis

After collection, phone base station emissions data have been processed with MCS Spectrum Analyser 2.1.6, to save and transfer data in a spreadsheet file. Emissions data are collected in decibels milliwatt (dbm) format and converted into volt per meter

(V/m) format. Through GPS points collected by the Analyser, this file has been converted into a shape file in ArcCatalog, to be used in QGIS and ArcMap for map production and layout respectively.

EMF exposures have been mapped to highlight three measures of standards; so less than 0.6 V/m, between 0.6 V/m and 6 V/m and more than 6 V/m. The first one is to identify the Salzburg Resolution standards and the second helps to delimit Gabonese standards with the first category and the last level allows to show if operators overrun the standards. Kernel Density Estimates (KDE) or Heatmap in QGIS have been performed, using the mean centre and spatial standard distance, to identify places which might have the highest concentration of exposure.

### RESULTS

BS emissions have been recorded for 172 days from June to December 2021 as shown in *Table 1* below, where a variability in data can be identified, as the standard deviation stays higher than the mean, especially in June, July, October and December. This means that values oscillate between the minimum and the maximum limits numerous times throughout measurements and describe a spatio-temporal variation of EMF emissions. It is important to note that the maximum value in June has not been mapped, because of the lack of GPS points for this particular information.

**Table 1: Statistical description of emissions data from phone base stations.**

	Day of record	Mean	Standard Deviation	the Salzburg Resolution atypical days (> 0.6v/m)	Gabon atypical days (> 6v/m)
Jun-21	27	0.043	4.42	5	0
Jul-21	29	0.067	5.58	9	1
Aug-21	22	0.003	0.10	2	0
Sep-21	23	0.004	0.08	9	0
Oct-21	20	0.062	5.42	5	1
Nov-21	25	0.002	0.03	5	0
Dec-21	26	2,18E+15	1,63E+17	15	2
Total	172	4,20389E+14	7,17913E+16	50	4

**Source:** OGAPEM data collected in the field from June to December 2021



On average, emissions have been recorded 24.57 days a month, (standard deviation 3.10). An atypical day is a day where a value above a standard is recorded. For the Salzburg Resolution standard of 0.6 V/m, 50 days of values above this standard have been recorded in all months and for Gabonese standards of 6 V/m only fourth days in July, October and December have been registered, as noticed in *Table 1* above. For levels above the Salzburg Resolution standards, the two operators are concerned with GSM and UMTS bands, and for those above Gabonese standards, it is just one of them for the same bands. When Spectran 6080HF detected unexpected values, like in July, October and December, a default value of 488.09 V/m was recorded for the UMTS band and 1,226035e+019 V/m for the GSM band.

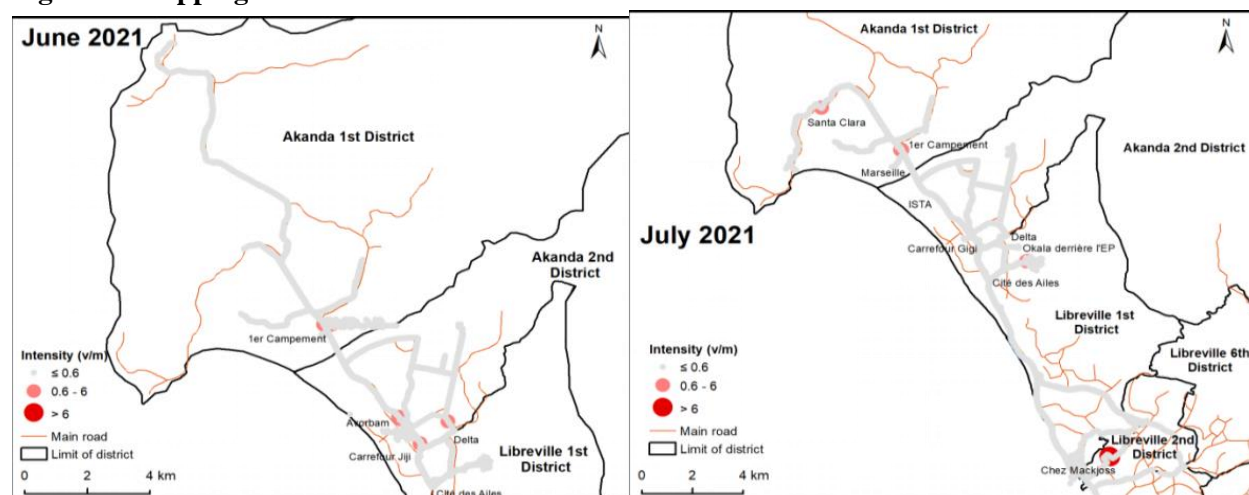
### Mapping of EMF emissions

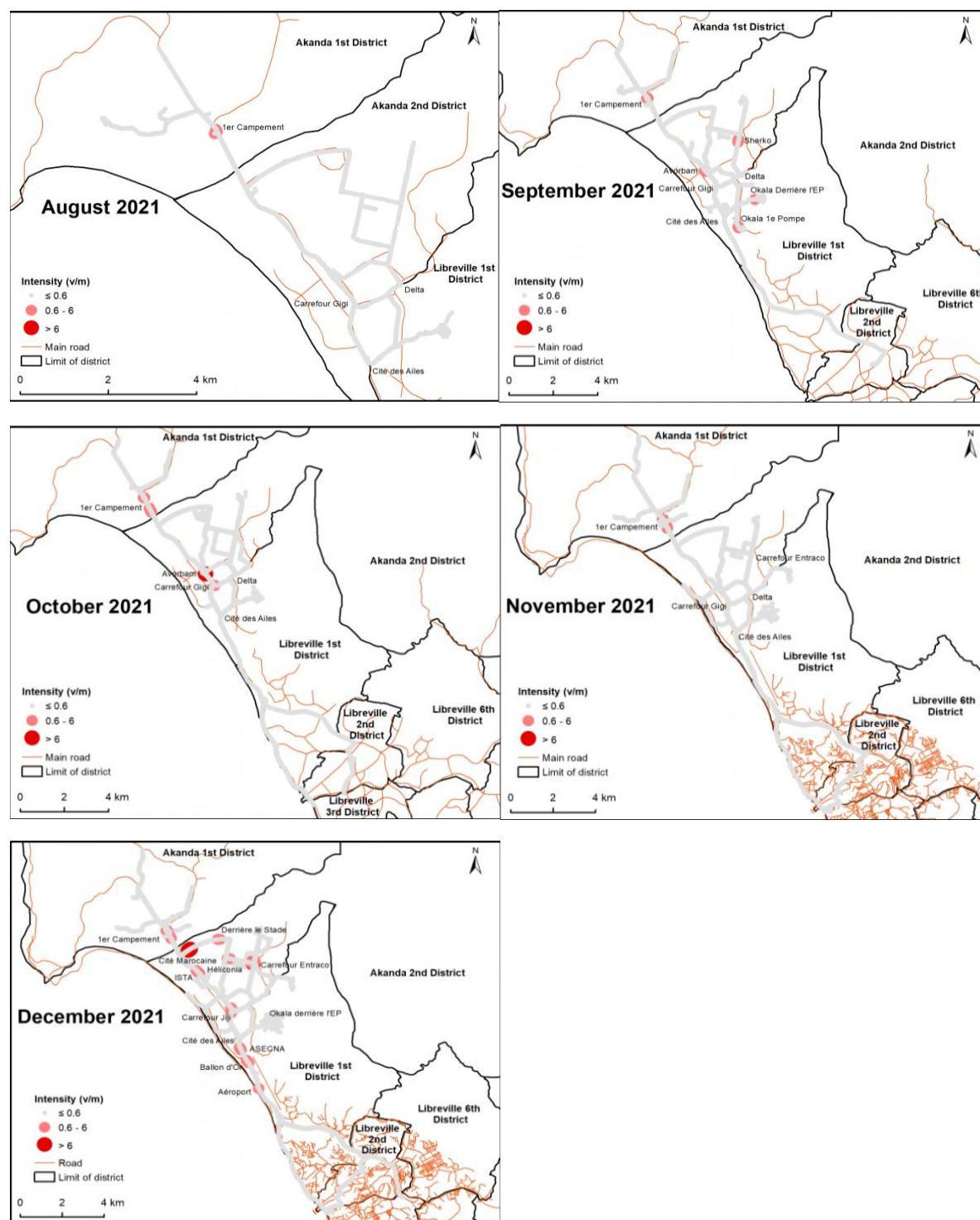
The spatiotemporal variation of EMF emissions can be visualized in *Figure 2* below. Most of the time people's exposure along routes was less than 0.6 V/m from June to December 2021. Between 0.6 V/m and 6 V/m, exposure varies depending on places and days. Furthermore, in Akanda, there are

more places where emissions are above 0.6 V/m. One place counts 31 days of emission above 0.6 V/m: *1er Campement*. *Jiji* is coming in second place with six (6) days, then *ISTA*, *Avorbam* and *Carrefour Entraco* with three (3) days each before *Okala derrière l'Ecole Publique* with two (2) days. Eleven other places have one day of emission above the Salzburg Resolution standards. Around *ISTA*, there is a GSM base station and for other places, there are UMTS ones. For UMTS and GSM EMF exposure, most of the time emissions above the standards are recorded between 3:00 pm and 8:00 pm. For the GSM band, there is also a record at 7 am.

Then, compared to the Gabonese standards, *Chez Mackjoss* in Libreville in July, *Avorbam* in October, *Cité Marocaine* and *Carrefour Entraco* in December in Akanda, are the four places where emissions values are above Standard as shown in *Figure 2* below. For each place, these values are recorded only one day. Higher values are recorded in the morning, but also in the afternoon and the evening, mainly from UMTS.

**Figure 2: Mapping of EMF in the north of Libreville from June to December 2021.**





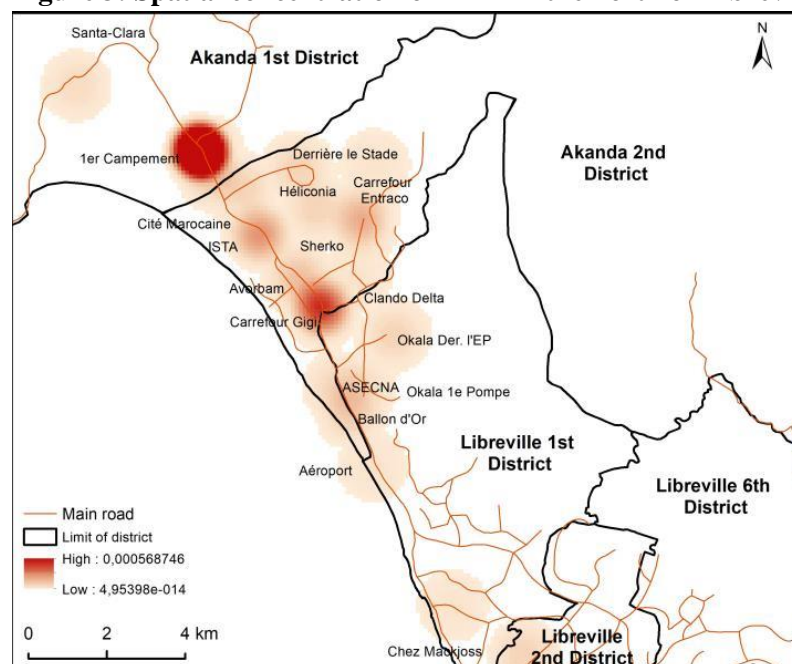
**Source:** Roads, limits of districts from the National Institute of Mapping (INC), OGAPEM data collected in the field from June to December 2021.

### Spatial concentration of EMF exposure

There is a spatial concentration of EMF exposure between June and December 2021 as it is shown in *Figure 3* below. In fact, the results reveal a main peak of EMF exposure at *1er Campement* and a second at *Carrefour Jiji* in Akanda mainly, although

*Carrefour Jiji* has a part in Libreville. Then there is Akanda and between ASECNA and *Ballon d'Or* in ISTA, *Cité Marocaine*, *Carrefour Entraco* in Libreville.

**Figure 3: Spatial concentration of EMF in the north of Libreville from June to December 2021.**



## DISCUSSION

This study assesses the spatial exposure of the population to electromagnetic waves emitted by cell phone antennas. This assessment is the first in Central Africa and in Gabon. The first step was based on the mapping of the emission values of the antennas, according to the Salzburg Resolution standards, the lowest in the world on the one hand, and Gabonese standards on the other hand. The second step was focused on the spatial concentration assessment of the exposure to the waves. The study revealed a spatial variation of exposure to electromagnetic waves' concentration.

These results were expected, in a context where the policy for the establishment of cell phone antennas is somewhat lax. Indeed, cell phone operators can request plots of land from private individuals to install their cell phone antennas. In addition, these individuals do not seem to be well informed about the long-term risks related to their proximity to these infrastructures. Moreover, the subject of the

relationship between the health of the populations and their proximity to these infrastructures, although important and current, seems inappropriate. These results can also be justified, to some extent, by the lack of emission audits of each functional cell phone antenna. It should also be noted that long-term impacts of exposure to electromagnetic waves are almost non-existent in impact studies. The OGAPEM report has been presented to the ARCEP, and the operator that overran the standards was the subject of a formal notice and adjusted the level of exposure.

Therefore, the spatio-temporal variation of exposure to electromagnetic waves has already been demonstrated in Tamazunchale, San Luis Potosi in Mexico (Ramirez-Vasquez et al., 2021), in Paris (Regain et al., 2020) and in the Doubs department in France (Viel et al., 2009). In Gabon, cell phone operators are not accessible when it comes to electromagnetic pollution. It is certainly possible to link this spatio-temporal variation with that of the accumulation of exposures, linked for example to



the proximity of high-voltage power lines or the widespread use of WiFi in Libreville and Akanda. In fact, it's not uncommon to find people living below high-voltage lines, especially in urban areas. On this subject, Beka Beka and Ada Nzoughe Epse Abounou (2021) state that, in Gabon, seven out of ten homes are built on high-risk land, but exposure to risks is greatest in urban areas. In addition, Bivigou Ilama (2020) identifies banned pesticides among those used by market gardeners in Libreville. Pesticides with Cadmium (Cd) or Lead (Pb) are at risk of cancer development (Basu et al., 2021; Chaza, 2017). All these different types of exposure must be studied and related to the increase in cancer prevalence in the country.

Accumulated exposure may, to some extent, account for the increase in cancers in Gabon, since numerous authors have demonstrated the link between proximity to cell phone antennas and the development of leukemia in children (Gómez-Perretta et al., 2013; Carpenter, 2013; Kundi & Hutter, 2009; Santini et al., 2002), as well as cancers in general (Gómez-Perretta et al., 2013; Khurana et al., 2010; Eger et al., 2004). It has been shown on the one hand that there is three (3) times more risk of developing cancer after five (5) years of exposure within a radius of 400m around a base station (Ndonghan Iyangui, 2016; Eger et al., 2004), and on the other hand that there is more than four (4) times more risk of developing cancer after three (3) to seven (7) years of exposure to 350m from the base station (Ndonghan Iyangui, 2016; Khurana et al., 2010). More recently, various cases of cancer deaths have been linked to the proximity (91 meters) of mobile phone antennas (Jayaraju et al., 2023).

Indeed, cervical cancer, between 1984 and 1993, i.e. 9 years, had a prevalence of 26.4% and between 2013 and 2017, i.e. 4 years it was 23% (Ivanga et al., 2021). Over the same period and based on data from the Libreville Cancer Institute (ICL), breast cancer appears as the first female cancer, and represents between 18% and 20% of female cancers (Assoumou Obiang et al., 2020). In addition, until

2019, digestive cancers were on the rise at the Centre Hospitalier Universitaire de Libreville, with hospital frequencies of 2.5% in 2017, 3.7% in 2018 and 7.1% in 2019 (Maganga Moussavou et al., 2021). Also, because children are the main population at risk, it would be important to assess their exposure, in a context where many families expose their children by giving them access to cell phones for hours.

This draws attention to the fact that the weakened healthcare systems, for the most part, will certainly not be able to cope with what looks like an epidemic outbreak of cancer. Measures must therefore be taken, based on studies and the experience of other countries. Reducing exposure standards is one of them. Particularly because most emissions are below 0.6 V/m. So, if the Salzburg Resolution has recommended this standard, it goes without saying that Gabon can adopt it, as many other countries, because since 2007 BioInitiative also has proposed a limit of 0.614 V/m for cumulative outdoor exposure and more recently, in 2022, ICBE-EMF declared that the FCC's and ICNIRP's exposure limits continue to present public health harm (BioInitiative, 2007; ICBE-EMF, 2022). The Pink October and Blue November campaigns would continue to help to improve the environment through screening and awareness-raising.

Also, because society is increasingly dependent on technology, reducing exposure to electromagnetic waves is becoming complicated at the individual level. Nevertheless, there are a few questionable tips. Indeed, it is possible to choose the connection times and the duration outside working hours, avoid 5G technology which is the most aggressive, live as far as possible from mobile phone antennas and high-voltage lines, turn off the modem at bedtime, and avoid giving connected devices to children.

## CONCLUSION

The demonstration made by ICBE-EMF that international EMF exposure limits do not adequately protect people, the increase of cancers in

Gabon and the availability of EMF emission data collected by OGAPEM enabled an assessment of the spatial exposure of EMF from phone base stations in the north of Libreville.

First, the mapping of EMF exposure has been made comparatively to both the Gabonese and the Salzburg Resolution standards, less than 6 V/m and less than 0.6 V/m respectively. It revealed a spatio-temporal variation of exposure, characterized by the overruns of the two standards in time and space. The sharing of this information with the Regulatory Authority for Communications and Posts has given rise to a formal notice for the company concerned. Now that mobile phone operators know that OGAPEM can unexpectedly measure EMF exposure, they are doing their best to respect the standards. It also appeared that most of the time, telephonic companies emitted at less than 0.6 V/m. So this limit can be easily adopted.

Secondly, the examination of the spatial concentration of EMF exposure demonstrated that there is a spatial variation of exposure concentration in Akanda. This result implies the need for more funds to medically follow up on people living around those places where the exposure is concentrated. The OGAPEM has to continue to collect data, collaborate with the ARCEP and sensitize people, notably about the danger of giving phones to children, who are more at risk of early development of cancers. In addition, the African scientific community has to embrace this problem to help authorities to reduce exposure in our countries, as in Western countries.

## REFERENCES

- Abdel-Rassoul, G., Abou El-Fateh, O., Abou Salem, M., Michael, A., Farahat, F., El-Batanouny, M., & Salem, E. (2007). Neurobehavioral effects among inhabitants around mobile phone base stations. *Neurotoxicology*, 28(2). <https://doi.org/10.1016/j.neuro.2006.07.012>
- Altpeter, D. E. (2000). *Salzburg Resolution on Mobile Telecommunication Base Stations*. <https://www.robindestoits.org/attachment/74227/>
- Assoumou Obiang, P., Bang Ntamack, J. A., Minkobame Zaga Minko, U. P., Ntsame Mezui, J. E., & Meye, J. F. (2020). Prise en charge chirurgicale des cancers du sein au Centre Hospitalier Universitaire d'Angondjé, à Libreville au Gabon. *Bulletin Médical d'Owendo*, 18(48), 16-20.
- Basu, S., Chanda, A., Gogoi, P., & Bhattacharyya, S. (2021). Organochlorine pesticides and heavy metals in the zooplankton, fishes, and shrimps of tropical shallow tidal creeks and the associated human health risk. *Marine Pollution Bulletin*, 165, 112170. <https://doi.org/10.1016/j.marpolbul.2021.112170>
- Beka Beka, A., & Ada Nzoughe épouse Obounou, C. (2021). Processus d'urbanisation et habitat au Gabon: Diagnostic et résilience des populations du « Grand Libreville ». *Regardsuds, Nous publions un volume par an (Numéro Spécial)*. <https://regardsuds.org/processus-durbanisation-et-habitat-au-gabon-diagnostic-et-resilience-des-populations-du-grand-libreville-2/>
- BioInitiative. (2007). *De graves inquiétudes de Santé Publique sont soulevées à propos de l'exposition aux champs électromagnétiques (CEMs) des lignes à haute tension et des téléphones cellulaires*. <http://www.next-up.org/pdf/BioInitiativePressVFr.pdf>
- Bivigou Ilima, G. R. (2020). *Cultures maraîchères et cartographie du risque de contamination des eaux superficielles à Libreville: Cas du 1er arrondissement* [Mémoire de Master]. Université Oamr Bongo.
- Carpenter, D. O. (2013). Human disease resulting from exposure to electromagnetic fields. *Reviews on Environmental Health*, 28(4),

- 159-172. <https://doi.org/10.1515/reveh-2013-0016>
- Chaza, C. (2017). *Pollution des sols et des eaux souterraines par les pesticides dans la région d'Akkar au nord du Liban : Evaluation des risques sanitaires*. [Thèse de doctorat]. Université Libanaise - Université de Lille, Sciences et technologies.
- Direction Générale de la Statistique (DGS). (2015). *Résultats globaux du Recensement Général de la Population et des Logements de 2013 du Gabon (RGPL2013)*.
- Eger, H., Hagen, K. U., Lucas, B., Vogel, P., & Voit, H. (2004). The Influence of Being Physically Near to a Cell Phone Transmission Mast on the Incidence of Cancer. *Umwelt Medizin Gesellschaft*, 17(4).
- Gómez-Perretta, C., Navarro, E. A., Segura, J., & Portolés, M. (2013). Subjective symptoms related to GSM radiation from mobile phone base stations: A cross-sectional study. *BMJ Open*, 3(12), e003836. <https://doi.org/10.1136/bmjopen-2013-003836>
- Hirata, A., Diao, Y., Onishi, T., Sasaki, K., Ahn, S., Colombi, D., De Santis, V., Laakso, I., Giaccone, L., Joseph, W., Rashed, E. A., Kainz, W., & Chen, J. (2021). Assessment of Human Exposure to Electromagnetic Fields: Review and Future Directions. *IEEE Transactions on Electromagnetic Compatibility*, 63(5), 1619-1630. *IEEE Transactions on Electromagnetic Compatibility*. <https://doi.org/10.1109/TEMPC.2021.3109249>
- International Commission on the Biological Effects of Electromagnetic Fields (ICBE-EMF), Belyaev, I., Blackman, C., Chamberlin, K., DeSalles, A., Dasdag, S., Fernández, C., Hardell, L., Héroux, P., Kelley, E., Kesari, K., Maisch, D., Mallery-Blythe, E., Melnick, R. L., Miller, A., Moskowitz, J. M., Sun, W., & Yakymenko, I. (2022). Scientific evidence invalidates health assumptions underlying the FCC and ICNIRP exposure limit determinations for radiofrequency radiation: Implications for 5G. *Environmental Health*, 21(1), 92. <https://doi.org/10.1186/s12940-022-00900-9>
- Ivanga, M., Engohan-Aloghe, C., Koumakpayi, I. H., Meye, J. F., & Belembaogo, E. (2021). Situation du cancer du Col Utérin au Gabon : Une revue de la littérature. *Bulletin Médical d'Owendo*, 19(50), 23-27.
- Jayaraju, N., Pramod Kumar, M., Sreenivasulu, G., Lakshmi Prasad, T., Lakshmana, B., Nagalaksmi, K., & Madakka, M. (2023). Mobile phone and base stations radiation and its effects on human health and environment: A review. *Sustainable Technology and Entrepreneurship*, 2(2), 100031. <https://doi.org/10.1016/j.stae.2022.100031>
- Khurana, V. G., Hardell, L., Everaert, J., Bortkiewicz, A., Carlberg, M., & Ahonen, M. (2010). Epidemiological Evidence for a Health Risk from Mobile Phone Base Stations. *International Journal of Occupational and Environmental Health*, 16(3), 263-267. <https://doi.org/10.1179/oeh.2010.16.3.263>
- Kundi, M., & Hutter, H.-P. (2009). Mobile phone base stations—Effects on wellbeing and health. *Pathophysiology*, 16(2-3), 123-135. <https://doi.org/10.1016/j.pathophys.2009.01.008>
- Maganga Moussavou, I. F., Itoudi Bignoumba, P. E., Saïbou, M., Mbounja, M., Eyi Nguema, A. G., Nsegue Mezui, A., Nzouto, P. D., Engoang, A. A., & Moussavou Kombila, J. B. (2021). Panorama des cancers digestifs au service d'hépatogastroentérologie du CHU de Libreville. *Bulletin Médical d'Owendo*, 54-57.
- Ministère de la Communication, de la Poste et de l'Economie Numérique (MCPEN). (2010). Arrêté n°025/MCPEN/CAB/2010 relatif à la

- réglementation de l'implantation des stations radioélectriques en République Gabonaise, 3.
- National Institutes of Health, & National Cancer Institute. (2022, mars 6). *Electromagnetic Fields and Cancer—NCI* (nciglobal, ncienterprise) [cgvArticle]. <https://www.cancer.gov/about-cancer/causes-prevention/risk/radiation/electromagnetic-fields-fact-sheet>
- Ndonghan Iyangui, N. N. (2016). Proximité des stations de base de téléphonie mobile et risques pour la santé à Libreville (Gabon). *Revue Canadienne de Géographie Tropicale*, 3(1), 37-48.
- OGAPEM. (2022). *Rapport d'activités 2018-2021* (p. 133). OGAPEM.
- Ramirez-Vazquez, R., Gonzalez-Rubio, J., Escobar, I., Rodriguez, C. del P. S., & Arribas, E. (2021). Personal Exposure Assessment to Wi-Fi Radiofrequency Electromagnetic Fields in Mexican Microenvironments. *International Journal of Environmental Research and Public Health*, 18(4). <https://doi.org/10.3390/ijerph18041857>
- Raphael Yende, G. (2016). *Analyse de l'usage des téléphones portables et leurs incidences d'ondes électromagnétiques sur la santé humaine en ville de Beni* [Thèse de doctorat]. CIUSTA-INTERNATIONAL.
- Regrain, C., Caudeville, J., de Seze, R., Guedda, M., Chobineh, A., de Doncker, P., Petrillo, L., Chiaramello, E., Parazzini, M., Joseph, W., Aerts, S., Huss, A., & Wiart, J. (2020). Design of an Integrated Platform for Mapping Residential Exposure to Rf-Emf Sources. *International Journal of Environmental Research and Public Health*, 17(15), 5339. <https://doi.org/10.3390/ijerph17155339>
- Roth, U., Selmane, L., & Faye, S. (2024). Measuring the EMF Exposure From Mobile Network Antennas: Experience From Luxembourg. *IEEE Access*, 12, 57688-57710. IEEE Access. <https://doi.org/10.1109/ACCESS.2024.3386432>
- Sagar, S., Adem, S. M., Struchen, B., Loughran, S. P., Brunjes, M. E., Arangua, L., Dalvie, M. A., Croft, R. J., Jerrett, M., Moskowitz, J. M., Kuo, T., & Rösli, M. (2018). Comparison of radiofrequency electromagnetic field exposure levels in different everyday microenvironments in an international context. *Environment International*, 114, 297-306. <https://doi.org/10.1016/j.envint.2018.02.036>
- Santini, R., Santini, P., Danze, J. M., Ruz, P. L., & Seigne, M. (2002). *Study of the health of people living in the vicinity of mobile phone base stations: I. Influences of distance and sex*.
- Thulu, F. G. D., Tembo, D., Nyirongo, R., Mzaza, P. J. C., Kamfosi, A., & Mawenda, U. C. (2023). Electromagnetic Frequency Pollution in Malawi: A Case of Electric Field and Magnetic Flux Density Pollution in Southern Africa. *International Journal of Environmental Research and Public Health*, 20(5), Article 5. <https://doi.org/10.3390/ijerph20054413>
- Viel, J. F., Clerc, S., Barrera, C., Rymzhanova, R., Moissonnier, M., Hours, M., & Cardis, E. (2009). Residential exposure to radiofrequency fields from mobile phone base stations, and broadcast transmitters: A population-based survey with personal meter. *Occupational and Environmental Medicine*, 66(8), 550-556. <https://doi.org/10.1136/oem.2008.044180>
- Wolf, R., & Wolf, D. (2004). Increased Incidence of Cancer Near a Cell-Phone Transmitter Station. *International Journal of Cancer Prevention*, 1(2), 123-128.