Journal of Applied Sciences, Information and Computing
Volume 7, Issue 1, April - May 2026
School of Mathematics and Computing, Kampala International University

ISSN: 3007-8903 https://doi.org/10.59568/JASIC-2026-7-1-18

Review of radio frequency field exposure effects of people living near mobile base stations in Uganda

Tuhame William, Michael Adelani Adewusi
[1,2]School of Mathematics and Computing, Kampala International University,
[1]william.tuhame@kiu.ac.ug, [2]michael.adewusi@kiu.ac.ug

Abstract
Concerns regarding the possible health effects of radiofrequency (RF) field exposure have been raised in recent years due to the expansion of telecommunications infrastructure, such as wireless communication antennas and mobile phone base stations, especially for those who live close to these installations. The purpose of this work is to examine the body of research on the effects of radiofrequency field exposure on Ugandans who live close to mobile base stations. Specifically, the paper examined the health-related implications of RF exposure, considering both environmental and biological impacts. Drawing on current studies from various regions worldwide, the review assessed the level of RF exposure among individuals in different regional settings within Uganda. Furthermore, the paper explored RF effect reduction mechanisms and provide recommendations for mitigating potential risks. By raising awareness of these issues and offering practical recommendations, this paper seeks to inform public discourse and guide future planning and deployment of telecommunication networks in Uganda.

Keywords: Base station, Health Effects, Electromagnetic Fields, Radiofrequency.

1 Introduction
Global connections and communication have changed dramatically in recent years due to the widespread use of mobile communication devices. In Uganda, mobile phone penetration has increased significantly from 23% in 2010 to over 70% by 2021 (UCC, 2021). As a result, mobile base station installations are widespread. In addition to enabling increased connectivity, these developments have sparked worries about the possible negative health impacts of being exposed to the radio frequency (RF) electromagnetic fields (EMFs) that these stations create.

Research has shown that radiofrequency exposure can have a range of biological impacts, and discussions over the possible dangers of prolonged exposure are still going on (Lloyd et al., 2020). Numerous physiological and psychological problems, such as headaches, sleep difficulties, and cognitive impairments, have been linked to radiofrequency radiation in different places, according to research (Baan et al., 2011; Hardell & Carlberg, 2015). However, there is still a lack of research specifically focused on Uganda, which leaves a gap in our knowledge of how these factors affect local populations.

The purpose of this study is to compile the body of research on the consequences of radiofrequency field exposure, with an emphasis on Ugandan people that live close to mobile base stations. It will critically examine the socioeconomic effects of mobile telecommunications in the nation as well as

the relevant scientific data. As a result, this assessment will help advance a more thorough comprehension of the possible health hazards linked to radiofrequency exposure in Uganda and offer suggestions for further study and legislative measures.

1.1 Background on RF Exposure

As a type of non-ionizing radiation, radiofrequency radiation lacks the energy necessary to ionize atoms or molecules or free securely bound electrons. The frequency range of RF fields, which is usually between 3 kHz and 300 GHz, is what defines them instead. According to ICNIRP (2020), mobile base stations mostly function in the frequency ranges designated for cellular communication, which are typically 700 MHz to 2.7 GHz. Because of the cumulative exposure from several sources, such as cell phones, Wi-Fi, and other wireless devices, concerns have been raised over safety standards and health impacts. Exposure from a cell tower is contingent upon the type of antennas, their quantity, their actual usage, and the time of day, according to ICNIRP (2020).The public's extensive usage of cell phones is to blame for the environment's "Electro pollution" and has turned into a health issue (Nageswari, 2015).

1.2 Base Station Deployment status in Uganda

Over the past ten years, Uganda has seen a sharp rise in the deployment of mobile base stations due to the country's expanding need for mobile communication services (Kamulegeya et al. 2017). With an estimated 3,200 active mobile base stations spread throughout urban and rural areas as of 2023, Uganda has witnessed notable developments in its telecommunications infrastructure (UCC, 2023). In order to increase connectivity and encourage digital inclusiveness, both public and private sector initiatives have helped to promote this expansion. Mobile phone penetration has been steadily rising, according to the Uganda Communications Commission (UCC), reaching almost 77% by 2022 (UCC, 2022).

As seen in figure 1.1 below, mobile network providers have installed a sizable number of mobile base stations in urban areas, particularly atop tall buildings, and others near people in public spaces like schools, hospitals, marketplaces, and residential neighborhoods without adhering to ITU regulations.

Figure 1. Base Station deployed next residential areas in Makindye Division Kampala (Field,2024)

1.3 Purpose and Scope of Review

The purpose of this review is to compile the most recent information on how populations residing close to mobile base stations are affected by RF field exposure. This study analyzed the data on health risks associated with radiofrequency exposure, identify gaps in the current research, and investigate the implications for public policy and community health by looking at recent studies and public health assessments.

1.4 Aim of the study

i. To examine health-related implications of RF exposure on Human
ii. To assess the level of RF exposure among individuals in different regional settings within Uganda
iii. To explore RF effect reduction mechanisms to save human life

iv. To provide recommendations for mitigating potential risks to the public

2 Related Literature Review

Numerous nations have carried out some research in this area. Experts claim that mobile phones and BTS create electromagnetic fields (EMFs) that are harmful to people, animals, birds, and other living things. Short-term health problems caused by this kind of radiation are referred to by some experts as "microwave sickness" or "radiofrequency syndrome," and they include symptoms including headache, fatigue, irritability, irregular sleep patterns, and others. (Delhi et al, 2014).

2.1 Health Related Implications of RF exposure on Human

2.1.1 Impact on Brain

According to Ameen (2014), radiation penetration in the head exposes endothelial cells that line the brain's tiny blood vessels to mobile phone radiation, which can harm the blood-brain barrier, a crucial safety barrier that prevents dangerous substances from entering the brain because endothelial cells become stressed after an hour of exposure to the mobile phone radiation limit (2 watts per kilogram of tissue). Additionally, endothelial cells' protein structure changes, so toxins can enter the brain and cause cancer tumors and heart attacks.

The National Institutes of Health (2011) discovered that exposure to cell phone radiation for 50 minutes altered brain activity in the areas of the brain nearest to the phone's antenna in a research including 47 participants. Other related Studies also found persons who use cell phone more often have more headaches, can change brain waves during sleep and impact sleep (Hepburn et al. 2018). A number of published studies, including this one from Yale University, have shown that exposure to wireless radiation can impair brain growth and reduce brain cell counts. Pregnant mothers who used their phones more frequently had children who were more likely to have behavioral issues, according to studies **(**Sathia et al, 2019).

2.1.2 Impact on Reproductive Health

Both male and female reproductive organs are exposed to significant levels of radiofrequency radiation when cell phones are in the pockets of pants. The testicular barrier is thought to be more responsive than most other membranes in the human body (Cokgor et al, 2020).Researchers at major research centers throughout the world have often found that cell phone radiation affects sperm. Studies have found that RF radiation can lead to decreased sperm quality, including lower sperm motility and viability. For instance, Agarwal et al. (2016) demonstrated that sperm exposed to RF radiation experienced increased oxidative stress, leading to cellular damage and apoptosis. In females, RF exposure has been associated with potential impacts on ovarian function, raising questions about long-term fertility (Tsurita et al., 2018).

2.1.3 Tumor Formation and Cancer Risk

Long-term mobile phone use may be linked to a higher risk of developing several tumor forms, especially brain tumors, according to some research. It may be more susceptible to glioma and acoustic neuroma, according to research by Hardell and Sage (2017).

2.1.4 Cognitive Function and Memory

Several studies have explored the effects of cell phone radiation on cognitive function and memory. Evidence suggests that RF exposure may impair cognitive abilities, particularly in children and adolescents, whose brains are still developing. A study by Röösli et al. (2013) found that children who frequently used mobile phones exhibited poorer memory performance compared to those with limited exposure. Similarly, findings from Volkow et al. (2011) indicated that acute exposure to cell phone radiation altered glucose metabolism in the brain, suggesting a potential impact on brain activity and cognitive function. These results raise concerns about the long-term implications of daily cell phone use on cognitive development (Völk, S., et al. 2015).

2.1.5 Sleep Disturbances

Exposure to RF radiation from cell phones and base stations may also contribute to sleep disturbances. Research has shown that individuals who use mobile phones close to bedtime often report poor sleep quality and increased daytime sleepiness. A study by Kramarenko et al. (2017) found that RF exposure can disrupt circadian rhythms, leading to

difficulties in falling asleep and maintaining restful sleep. Poor sleep quality is linked to a range of health issues, including obesity, cardiovascular disease, and mental health disorders. As mobile devices become integral to daily life, the potential for RF radiation to interfere with sleep patterns highlights the need for awareness and strategies to minimize exposure, particularly during nighttime hours (Wood, M., et al. 2023).

2.1.6 Increased Risk of Cancer

Several studies have suggested an association between long-term exposure to cell phone radiation and an increased risk of certain tumors, particularly brain tumors such as gliomas and acoustic neuromas. A comprehensive review by Hardell and Sage (2017) highlighted that individuals with extensive mobile phone use had a higher incidence of these types of tumors. Additionally, the International Agency for Research on Cancer (IARC) has classified RF radiation as possibly carcinogenic to humans (Group 2B), further emphasizing the need for ongoing research into the long-term health effects of exposure. Young women who kept their phones in their bras for years have been diagnosed by doctors with developing strange tumors right beneath where the phone antennas are located. In addition to having no genetic predisposition to the disease, these women had no history of breast cancer, and the form of cancer they had was uncommon. These days, a lot of breast surgeons advise against wearing cell phones in bras (Wong, T., et al., 2018).

2.1.7 Behavioral Issues

Increased exposure to RF radiation has been linked to behavioral problems, particularly in children. Research indicates that children with higher cell phone usage may exhibit symptoms associated with Attention Deficit Hyperactivity Disorder (Benjamins et al., 2018). Furthermore, animal studies have demonstrated that RF radiation can lead to changes in behavior, such as increased hyperactivity and anxiety-like behaviors (Lerchl et al., 2015). These findings emphasize the need for caution in cell phone usage, especially among younger populations.

2.1.8 Psychological Effects

The psychological effects of cell phone and base station radiation exposure are an emerging area of concern. Studies have suggested that increased RF exposure may be associated with symptoms of anxiety and depression. A review by Grit et al. (2019) indicated that heavy mobile phone users reported higher levels of psychological distress compared to those with limited use. Additionally, chronic exposure to RF radiation may exacerbate stress responses, impacting mental well-being. Given the growing reliance on mobile technology for communication and social interaction, understanding the psychological implications of RF exposure is crucial, particularly in vulnerable populations, such as adolescents and young adults.

2.2 Suggested RF Effect Reduction Mechanisms to Save Human Life

The hierarchy of exposure reduction in occupational hygiene comprises personal protective equipment, engineering controls, administrative controls, and substitution. Similar tactics include distancing and limiting use, modifying the technology and design of RF-emitting equipment, avoiding use, and investigating shielding options in order to lessen RF exposure to the general population.

Enhancing Base Station Coverage Design and Placement. Mobile phone base station siting and design are two of the best strategies to minimize radio frequency exposure. Studies have shown that adequate base station coverage can significantly lower average RF exposure for users (Brennan et al., 2015). Continuous monitoring and adjusting of base station outputs based on real-time traffic and environmental factors can further enhance efficiency and safety. Improving base station coverage can significantly lower RF exposure levels. When mobile devices connect to well-distributed and efficient base stations, they require less power to maintain a stable connection, resulting in lower RF emissions (El-Fattah, et al. 2022). A study by Gruber et al. (2018) demonstrated that areas with robust network coverage saw a marked decrease in the RF output from devices.

Substitution. Using landline corded phones helps reduce radiofrequency exposure from cell phones or cordless phones, but communication flexibility is

lost. Wireless local area networks (WLANs) and WiFi can be replaced by direct cable connections, however the overall reduction in radio frequency (RF) is negligible (Joseph et al., 2010).

Another viable method of lowering RF exposure is the development of low-radiation mobile technologies. It has been demonstrated that newer technologies like Long Term Evolution (LTE), Universal Mobile Telecommunications System (UMTS), and Code Division Multiple Access (CDMA) use less power than more established ones like Global System for Mobile Communications (GSM). For instance, CDMA and UMTS transmit less frequently at maximum power, thus minimizing overall exposure (Gati et al., 2009). When using a mobile phone, RF exposure can be reduced by having good base station coverage since adaptive or power regulation lowers the output power to the lowest required for signal fidelity (Wong et al. 2018).

Use of Air-Tube Headsets and Radiation Shields. The use of accessories such as air-tube headsets and RF radiation shields can also play a critical role in reducing exposure. Research has indicated that using air-tube headsets can significantly decrease exposure during calls. Additionally, the development and utilization of RF shields for phones can reduce the amount of radiation emitted while still allowing for effective communication.

Administrative controls. According to Peyman et al. (2011), exposures are maximum in the vicinity of RF-emitting equipment, such as the 16–33 cm range for WLAN access points and wireless routers and several centimeters for the majority of mobile phones, depending on the size of the antenna. Exposures become negligible in the far field because the power density there drops proportionately to the cube of the distance between the emitter and the receiver. With regard to mobile phones, distance can be achieved by texting while holding the phone away from the body or head, using headphones, or using the speaker phone.

Usage Time Management. Limiting the duration of mobile phone use is another critical strategy. Prolonged exposure increases the cumulative dose of RF radiation. The World Health Organization (WHO) suggests that users should be mindful of their talking time and utilize text messaging as an alternative whenever possible (WHO, 2019).

Promoting Airplane Mode. Encouraging the use of airplane mode when mobile devices are not in use can drastically reduce RF emissions. Airplane mode disables the device's wireless functions, including cellular, Wi-Fi, and Bluetooth signals, thereby eliminating unnecessary RF exposure. A study by Noonan et al. (2019) showed that users who frequently switched their devices to airplane mode reported lower levels of headaches and fatigue.

Incorporation of Health Risk Assessments in Technology Deployment. Lastly, health risk assessments should be an integral part of the deployment process for new wireless technologies and infrastructures. Before new networks are established, comprehensive assessments can evaluate their potential impact on public health. This proactive approach allows stakeholders to identify risks early and implement appropriate mitigation strategies. Continuous monitoring of health outcomes associated with RF exposure from new technologies is essential for ensuring ongoing public safety (Mauseth et al., 2016).

3.0 Methodology

3.1Research Design

The study utilized a systematic review methodology design which involved a structured approach to gathering and synthesizing relevant literature. This method ensured transparency, minimized bias, and provided a comprehensive overview of existing knowledge on the topic.

3.2 Search Strategy

To obtain relevant data, the study used Literature Search Strategy where by Electronic databases such as PubMed, Scopus, IEEE Xplore, and Google Scholar were searched systematically based on Keywords. Each database provided access to a wealth of peer-reviewed articles, conference papers, and technical reports that are critical for a thorough review of the existing literature on this topic for the past 13 years ranging from 2000 to 2023.

3.3 Data Collection and Selection

Data was extracted using a standardized form to capture study details, methods, RF exposure metrics, health outcomes reported, and mitigation strategies discussed. By using this exacting

approach, the review made sure that the chosen studies were high-caliber, pertinent, and offered insightful information about the negative health impacts of radiofrequency exposure from mobile base stations in Uganda.

3.4 Data Synthesis

Synthesized data was analyzed thematically according to the research objectives, identifying patterns, key findings, and discrepancies across studies.

4.0 Results and Discussion

Research often indicates that low levels of RF exposure, such as those from common devices, are unlikely to cause significant health problems. Most studies suggest that the risks are minimal and that the evidence does not support a strong link to serious health conditions like cancer or neurological disorders. The study reported that the odds ratio (OR) for brain tumors was approximately 1.0 for the majority of mobile phone users, indicating no significant increase in risk for the general population. However, for the highest tertile of cumulative RF exposure, the OR for gliomas was 1.40 (95% CI: 1.0–1.97) for brain tumors in the highest category of mobile phone use (≥30 minutes/day) compared to non-users, suggesting a potential increased risk for long-term, high-level users. The results were statistically significant only for those with the highest exposure levels (Interphone Study Group, 2011).

Related with the effect on the sleep, one of study found that RF exposure did not significantly alter sleep patterns or quality. However, some participants reported minor disruptions, with statistically insignificant differences in sleep latency and duration when comparing high vs. low RF exposure groups (Röösli et al., 2012). For example, the study by Thomas et al. (2008) included in the review reported a mean difference of 1.2 minutes in sleep latency between high and low RF exposure groups, which was not statistically significant. The overall conclusion was that RF exposure did not show a consistent, substantial impact on sleep (Röösli et al., 2012).

On the study which examined the effect of short-term RF exposure on cognitive performance in young adults related with exposed to RF from a mobile phone showed a decrease in memory performance, with a 6.4% reduction in short-term memory recall compared to a control group with no RF exposure (Loyd et al., 2011). While another study done on a population of 400 adolescents found no significant differences in cognitive test scores between high and low RF exposure groups as it did not find conclusive evidence of cognitive impairment due to RF exposure. The results showed that the mean cognitive scores of those with higher RF exposure were virtually identical to those with lower exposure, with a p-value greater than 0.05 for all cognitive tests, indicating no significant effect (Völk et al., 2015).

The quantitative analysis showed a reduction in sperm motility by 8-10% and a decrease in sperm viability by about 10% with high RF exposure. However, these effects were considered small, and the clinical significance of these findings remains debated. The review concluded that while there are some indications of a potential impact, the results are not conclusive enough to establish a clear causal relationship (Agarwal et al., 2016).

Quantitative studies on RF exposure have yielded mixed results. While some evidence suggests a potential increase in cancer risk and minor effects on reproductive health with high levels of exposure, most studies find minimal or no significant health effects for the general population, especially at levels below current safety limits. Finally, at Low RF exposure, there are Minimal risks with no significant increase in health risks, with relative risk estimates often close to 1.0. With Moderate Exposure, there is a slightly increased risk for certain conditions, with relative risks typically in the range of 1.1 to 1.2 for cancers among workers and minor symptoms with chronic exposure. And with high Exposure, there is increased risk for thermal injuries and potential long-term health effects, with specific absorption rates (SAR) used to measure safety limits (Agarwal et al., 2016).

5. Conclusion and Recommendations

5.1 Conclusion

With majority of base stations existence in public premises especially nearby peoples residential areas, almost all people both Educated and Uneducated in Uganda are still not aware about their

effects on both human life and environment which puts their life on very high risk to both short run and long run healthy effects. However much the network providers try to put notices nearby the base stations sites notifying the public about the high frequency on the premise, they still build them in areas surrounded by people's homes without considering their effects. Hence there is need of government involvement to create public awareness and put in place some strong regulations and other measures on such deployment.

The level of RF exposure among individuals in different regional settings within Uganda varies significantly due to factors such as population density, telecommunication infrastructure, mobile phone usage patterns, proximity to transmission towers, regulatory standards, and ongoing research on health implications. Urban areas typically exhibit higher RF exposure levels compared to rural regions, influenced by the concentration of telecommunication infrastructure and wireless technologies. Efforts to monitor and regulate RF exposure levels are essential to safeguard public health, although challenges remain in ensuring comprehensive compliance and addressing community concerns. Continued research and collaboration are crucial in advancing understanding and mitigating potential risks associated with RF radiation in Uganda's diverse regional settings.

Quantitative studies on RF exposure have yielded mixed results. While some evidence suggests a potential increase in cancer risk and minor effects on reproductive health with high levels of exposure, most studies find minimal or no significant health effects for the general population, especially at levels below current safety limits. These findings emphasize the need for ongoing research to further clarify the long-term effects of RF exposure on health.

Finally, at Low RF exposure, there are Minimal risks with no significant increase in health risks, with relative risk estimates often close to 1.0. With Moderate Exposure, there is a slightly increased risk for certain conditions, with relative risks typically in the range of 1.1 to 1.2 for cancers among workers and minor symptoms with chronic exposure. And with high Exposure, there is increased risk for thermal injuries and potential long-term health effects, with specific absorption rates (SAR) used to measure safety limits.

5.2 Recommendations

In Uganda, the growing number of mobile base stations has sparked worries about possible health consequences from electromagnetic field (EMF) exposure. While current scientific consensus indicates that the levels of radiation emitted by these stations are typically below international safety guidelines, public anxiety remains prevalent. Based on the review of literature regarding the effects of radio frequency (RF) exposure on individuals living near mobile base stations in Uganda, the following recommendations are proposed:

1. There is need to always Conduct Comprehensive Research and Monitoring. This can be done by Initiating longitudinal health studies focusing on communities living near mobile base stations. This should include regular health check-ups and surveys to monitor potential health impacts over time.
2. The government should carry out Public Education and Awareness Campaigns on EMF exposure, its sources, and the current scientific understanding of its health effects. This can be done by use of multiple platforms such as radio, social media, and community meetings. And develop materials that debunk common myths and misinformation about mobile base stations and EMF exposure.
3. To conform to international safety standards established by agencies such as the International Commission on Non-Ionizing Radiation Protection (ICNIRP), the National Regulatory Framework and Standards must be reviewed.
4. In order to build trust and transparency and create a responsive framework to address these issues, community engagement and consultation should always take place prior to the installation of new mobile base stations.
5. To identify and evaluate the possible effects of EMF exposure on weaker groups, including elderly people, pregnant women, and children. There is need to establish buffer zones around mobile base stations, especially in areas

densely populated by vulnerable groups, to mitigate potential risks.

6. The government should always encourage mobile network operators to invest in and deploy technologies that minimize EMF emissions, such as small cell technology and advanced antennas. Promote the development of mobile infrastructure that combines multiple services (e.g., telecommunications, broadcasting) to reduce the number of base stations needed.

6. References

[1] Agarwal, A., Singh, A., Hamada, A., & Kesari, K. (2016). Cell phones and male infertility: A review of recent innovations in technology and consequences. *International Journal of Impotence Research, 28*(3), 129–136.

[2] Ameen, J. J. (2014, March). Reduction of Cell Phone Electromagnetic Radiation Effect on Human Body. *International Journal of Sciences* .

[3] Baan, R., Grosse, Y., Lauby-Secretan, B., et al. (2011). *Carcinogenicity of radiofrequency electromagnetic fields.* The Lancet Oncology, 12(7), 624-626.

[4] Benjamins, J. A., et al. (2018). "Cell phone use and attention deficit hyperactivity disorder in children: Evidence from the national health and nutrition examination survey." *Environmental Research*, 163, 136-143. DOI: 10.1016/j.envres.2018.01.003.

[5] Brennan, P., Deltour, I., Vecchia, P., & Mann, S. (2015). Mobile phone base stations and exposure levels: A systematic analysis. *Bioelectromagnetics, 36*(1), 38–45.

[6] Cokgor, E. U., et al. (2020). "Effects of radiofrequency electromagnetic field exposure on reproductive health: A systematic review." *Environmental Health Perspectives*, 128(6), 1-12. DOI: 10.1289/EHP6197.

[7] El-Fattah, M. A., Abou El-Naga, R., & Mahfouz, A. (2022). *Health effects of radiofrequency radiation exposure among residents near mobile base stations.* Journal of Environmental Health Science & Engineering, 20, 123-130.

[8] Gati, A., Hadjem, A., Wong, M. F., & Wiart, J. (2009). Exposure induced by WCDMA mobile phones in operating networks. *IEEE Transactions on Wireless Communications, 8*(12), 5723–5727.

[9] Grit, K., et al. (2019). "Psychological distress and mobile phone use: A systematic review." *International Journal of Environmental Research and Public Health*, 16(6), 1019. DOI: 10.3390/ijerph16061019.

[10] Gruber, G., Schmid, G., & Überbacher, R. (2018). Network coverage and radiofrequency exposure: Investigating the relationship in urban environments. *Radiation Protection Dosimetry, 181*(1), 35–42.

[11] Hardell, L., & Carlberg, M. (2015). *Mobile phone use and the risk for brain tumours: A case-control study.* International Journal of Oncology, 47(1), 60-64.

[12] Hepburn, C. M., Radford, M., Curry, J., & Walsh, J. J. (2018). *The effects of mobile phone use on sleep patterns and headaches: A review of recent studies*. Journal of Sleep Research, 27(3), 215-222.

[13] ICNIRP. (2020). 'Guidelines for Limiting Exposure to Electromagnetic Fields (100 kHz to 300

[14] GHz). International Commission on Non-Ionizing Radiation Protection', Health physics. *Health Phys* , pp. 483–524.

[15] ICNIRP. (2020). "Guidelines for limiting exposure to electromagnetic fields (100 kHz to 300 GHz)." *Health Physics*, 118(5), 483-524. Link

Interphone Study Group. (2011). Brain tumour risk in relation to mobile telephone use: Results of the INTERPHONE international case-control study. *International Journal of Epidemiology, 39*(3), 675–694.

[16] Joseph W, Frei P, Roösli M, Thuróczy G, Gajsek P, Trcek T, et al. (2010). *Comparison of personal radio frequency electromagnetic field exposure in different urban areas across Europe.*

[17] Kamulegeya, L. H., Mwanje, M. T., & Mwesigwa, A. (2017). Measured and perceived exposure of Kampala city dwellers to radio frequency electromagnetic fields from telecommunications base stations. *International Journal of Environmental Health Engineering, 6*(1), 8.

[18] Kramarenko, I., et al. (2017). "Effects of radiofrequency electromagnetic fields on sleep patterns and cognitive functions." *International Journal of Environmental Research and Public Health*, 14(4), 385. DOI: 10.3390/ijerph14040385.

[19] Lerchl, A., Klose, M., Grote, K., Fiedler, T., Reindl, J., & Spathmann, O. (2015). Tumor promotion by exposure to radiofrequency electromagnetic fields below exposure limits for humans. *Biochemical and Biophysical Research Communications, 459*(4), 585–590.

[20] Lloyd, A., Burch, J., & Kearney, J. (2020). *A review of the effects of radiofrequency electromagnetic fields on human health.* Environmental Research, 186, 109442.

[21] Mauseth, S., Cook, D., & Miller, A. (2016). Evaluating public health risks of radiofrequency exposure from new telecommunications technologies. *Environmental Research, 149*, 576–584.

[22] M. Bhawan, J. Lal Nehru Marg, N. Delhi. (2014). Effects of Electromagnetic Field Radiation from Mobile Towers and Handsets. *Telecom Regulator y Authority of India* , 25.

National Institutes of Health. (2011). *Electromagnetic fields and public health: Mobile phones*. Retrieved from https://www.nih.gov

[23] Noonan, C. W., Reif, J. S., Yost, M. G., & Touchstone, J. A. (2019). Cellular phone use and self-reported symptoms: A survey study on RF exposure effects. *Electromagnetic Biology and Medicine, 38*(3), 235–244.

[24] Peyman, A., Khalid, M., Calderon, C., Addison, D., Mee, T., & Maslanyj, M. (2011). Assessment of exposure to electromagnetic fields from wireless computer networks (Wi-Fi) in schools; results from a measurement study. *Health Physics, 100*(6), 594–612.

[25] Röösli, M., Aydin, D., Schreier, N., Loughran, S. P., & Röösli, M. (2012). Mobile phone base stations and sleep disturbances: A review. *Environmental Health Perspectives, 120*(10), 1360–1366.

[26] Röösli, M., Frei, P., Mohler, E., & Hug, K. (2013). Cognitive and behavioral effects of mobile phone radiation exposure in children and adolescents: A systematic review. *Environmental Research, 124*, 24–36.

[27] Sathia Raj, V., et al. (2019). "Impact of radiofrequency radiation on the behavioral responses of offspring in mice." *Bioelectromagnetics*, 40(5), 339-348. DOI: 10.1002/bem.22263.

[28] Thomas, S., Küting, T., Feldmann, J., & Pinger, A. (2008). Exposure to mobile phone electromagnetic fields and subjective symptoms: A double-blind study. *Psychosomatic Medicine, 70*(3), 345-348.

]29] Tsurita, G. D., et al. (2018). "Effects of mobile phone radiation on male fertility: A systematic review." *Andrology*, 6(6), 787-794. DOI: 10.1111/andr.12486.

Uganda Communications Commission (UCC). (2023). *Annual Sector Performance Report 2023*. Retrieved from UCC website

[30] Völk, S., et al. (2015). *The impact of radiofrequency electromagnetic fields on cognitive performance: results from a longitudinal study*. Neurotoxicology, 51, 114-123. DOI: 10.1016/j.neuro.2015.08.008.

[31] Volkow, N. D., et al. (2011). "Effects of cell phone radiofrequency signal exposure on brain glucose metabolism." *JAMA Internal Medicine*, 171(12), 1286-1287. DOI: 10.1001/archinternmed.2011.244.

[32] WHO. (2019). *Radiofrequency fields*. World Health Organization. Retrieved from WHO website.

[33]Wong, K. W., et al**.** (2018). "Radiofrequency exposure in mobile communications: The impact of network technology." *Bioelectromagnetics*, 39(3), 179-187. DOI: 10.1002/bem.22107.

[34] Wood, M., et al. (2023). *Long-term exposure to radiofrequency radiation: A systematic review*. *Environmental International*, 160, 107061.