A Detailed Assessment of Electromagnetic Radiation Impact from Cell Towers on Residents Living in Cape Coast, Ghana

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ABSTRACT

This study investigates the relationship between the proximity of individuals to cell towers and their exposure to Electromagnetic Radiation (EMR), using data from 150 respondents in Cape Coast, Ghana. Through correlation matrix analysis and polynomial regression, we explored how distance to cell towers affects EMR exposure levels. Our findings reveal a non-linear relationship, aligning with the inverse square law, and suggest significant implications for urban planning and public health policy.

Keywords

Cell Towers, Electromagnetic Radiation (EMR), polynomial regression, urban planning, policy.

1. INTRODUCTION

Ghana got connected to the internet in August 1995. Since then, the country has gone through a lot of technological advancement. As of January 2023, Ghana registered approximately 23 million internet users, growing from 22.6 million reported in the year before [1]. In fact, in Ghana, an inconspicuous yet potent transformation is taking place. This has caused the skyline to be increasingly punctuated by network masts and cell towers. This indeed is a real symbol of technological advancement and connectivity. But beneath the surface of this digital transformation, there are worries about the possible health risks that the local population may experience from these buildings. Even though cell towers are important for economic growth and communication, their widespread installation has generated discussion regarding the potential negative health impacts of the electromagnetic radiation (EMR) they release into the atmosphere. This paper aims to examine the complex problem of network masts in Ghana and strike a compromise between public health safety and technical growth. Numerous researches around the globe have emphasized how vital it is to comprehend the effects of EMR exposure. Like in many developing nations, Ghana's fast telecommunication infrastructure development has not been supported by thorough study of the implications for the environment and human health.

For example, electromagnetic radiation from cell towers is a new type of environmental pollution that raises worries about its effects on wildlife, vegetation, and human health [2]. Furthermore, Yahya [3] drew attention to the unsightly and possible electromagnetic field (EMF) risks connected to cell towers in cities, and she recommended camouflaging strategies to lessen these effects. Jog & Paranjape [4] also stressed the necessity of taking preventative action to guarantee a shift towards green communication, such as monitoring cell tower radiation levels and putting hardware solutions like mesh enclosures into place. It becomes essential to wisely handle these problems in the context of Ghana, where adoption of mobile technology is critical to the country's progress. By putting findings from international research into the specific socioeconomic and environmental context of Ghana, this paper seeks to provide light on the health risks linked with network masts. With this investigation, we hope to add to a better-informed conversation on Ghana's sustainable technological development, making sure that the country's digitalization process protects the welfare of its citizens.

2. RELATED WORKS

The introduction of cellular technology has transformed communication and promoted economic growth and global connectedness. However, the spread of cell towers and network masts—which are essential to this digital evolution—has raised questions about possible health risks related to electromagnetic radiation (EMR).

This literature review critically investigates the body of research on the health effects of cell towers, with a particular focus on studies pertinent to Ghana and comparisons with findings worldwide.

There is growing recognition that cell tower electromagnetic radiation poses a health concern and is one type of environmental pollution. A thorough investigation was carried out by Kaur and Dhami [2] to evaluate the EMR exposure levels from cell phone masts. Their findings indicated that radiation exposure is positively correlated with proximity to cell towers, with shorter distances from the towers showing significantly higher radiation levels. The study emphasized how crucial it is to take into account cell towers' direction and distance while assessing the safety of the surrounding surroundings.

Cell towers not only pose health risks but also frequently cause visual pollution, especially in urban areas. Yahya [3] discussed the negative impact of cell towers on urban aesthetics and proposed the use of camouflaged cell towers to mitigate this issue. The study made the case that by carefully positioning these disguised towers in open spaces away from heavily populated regions, camouflaged cell towers might potentially lower EMF dangers in addition to improving the aesthetic attractiveness of urban areas.

In order to address the issues of cell tower radiation, preventative action is necessary. Jog and Paranjape [4] investigated a number of approaches for quantifying and

reducing the emissions that cell towers radiate. As part of their project, they had to audit the levels of radiofrequency emissions and install hardware solutions, including mesh enclosures, to reduce radiation. The study made a strong argument for environmentally friendly communication, highlighting the necessity of a well-rounded strategy that protects public health and welfare while satisfying the public's increasing desire for cellular communication services.

The public's perception of the health concerns posed by cell towers is a significant factor in the development of regulatory and policy frameworks. When Hutter et al. [5] looked into the worries of locals who lived close to cell towers, they found that these people believed that cell towers and mobile phones posed greater health dangers than they did for a control group of students. The study emphasized that in order to allay irrational fears and promote better informed public debate, open communication and active public participation in decision-making processes are essential.

Research conducted in Nigeria [6] revealed a direct correlation between the length of time spent exposed to mast radiation and its impact on health, with headaches being one among the symptoms. A descriptive cross-sectional survey was used to evaluate the health risks that the exposed community faced from non-ionizing radiation from telecom masts. The respondent's hazard profile and sociodemographic pattern were recorded. The majority of responders (60.8%), according to the data, were young people between the ages of 20 and 30. According to the risk profile, most people (62%) reported a variety of symptoms, with headaches being the most common (51.6%), in line with previous research. High voltage cable and telecom mast have a substantial synergistic link on the health effect (p value < 0.05). Additionally, it was demonstrated that the hazard effect is directly related to the proximity and duration of exposure to mast radiation, with a p value < 0.05. Therefore, this study shows that mast radiation exposure has health effects, and reducing it will significantly enhance healthy living.

The detrimental effects of non-ionizing radiation from mobile towers were brought to light in a review by Skandhan [7]. According to their research, ultraviolet, gamma, and X-ray radiation is expanding. Mobile towers emit hazardous radiation, while non-ionizing gadget radiation comes from devices including laptops, tablets, smart TVs, and phones. Non-ionizing radiation also includes visible light, microwaves, and FM radio waves.

There are differences in signal intensity due to the uneven spatial deployment of telecom masts in Ghana, especially in the Greater Accra Metropolitan Area [8]. According to the study, growing customer numbers raises sustainability concerns about the accessibility, availability of telecommunication masts, environmental health, and management hazards among the area's major industrial actors.

Another issue is regulatory compliance with mast siting; non-compliance could jeopardize sustainability initiatives [9]. The study evaluates the degree of adherence to the rules governing the location of telecom towers in the Kumasi Metropolis. Using a comparative case study research methodology, interviews were conducted with 83 respondents. The study's findings demonstrated that the mast height guideline was completely followed. On the other hand, there was a significant amount of non-compliance with the 20-meter safety zone. Additionally, there have been violations of the telecom companies' obligation to guarantee co-location of their masts in the study areas. In conclusion, the attempt to make Kumasi viable may be jeopardized by the lack of adherence to the rules.

According to Ebekozien [10], Environmental, health, and physical variables affect residents' perceptions of and willingness to live near masts. The study looked at what influences people's perceptions of and willingness to live near telecom masts and offered some remedies to allay people' worries about potential health risks. The results of this report will help policymakers and other stakeholders make better decisions on how residents perceive their living conditions in mast areas, which is one of the study's implications. To address potential health risks and inhabitants' concerns, it was suggested that the government establish a regulatory body with a mandate for non-ionizing radiation protection.

It has been highlighted that additional exposure evaluation and epidemiological research are necessary to reduce health risks related to mast radiation [11]. This research conducted a comparative analysis of a few chosen epidemiological studies conducted worldwide, wherein health complaints reported by individuals residing in close proximity to mobile base stations were found to be correlated with the measured power density. According to the work, Common symptoms like headache, fatigue, irritability, sleep disorders, and nausea can be associated with exposures ranging from 20 W/m2 to 13.2 W/m2 at distances less than 350 m.

3. METHODOLOGY

3.1 Study Design

This cross-sectional study aimed to evaluate the perceptions and health concerns of Cape Coast residents in relation to their proximity to cell towers. The research objectives were to assess self-reported health conditions, fears related to electromagnetic radiation (EMR) exposure, and aesthetic concerns regarding cell towers within urban landscapes.

3.2 Survey Development and Data Collection

A comprehensive questionnaire was developed to capture a wide range of variables, including demographic information, health status, specific health concerns potentially linked to cell tower exposure, subjective assessments of EMR exposure, proximity to the nearest cell tower, levels of fear regarding EMR exposure, self-assessed knowledge about the effects of cell towers, and aesthetic concerns regarding the presence of cell towers in urban settings. The target population comprised adults aged 18 years and above residing in Cape Coast. A stratified random sampling technique was employed to ensure representative participation across various demographics (age, gender, and socioeconomic status) and geographical locations within the city. The stratification aimed to capture diverse perspectives related to different proximities to cell towers.

Data were collected through Google forms online and this survey allowed for broader reach and convenience for participants. Data collection efforts were conducted over a three-month period to ensure adequate coverage of the target population.

4. RESULT AND ANALYSIS

The collected data were analyzed through both descriptive and inferential statistics. Descriptive analysis provided an overview of the sample's demographics, health status, and initial findings related to their distance from cell towers, anxiety levels, and aesthetic concerns. The dataset consists of 150 entries, with each entry containing 16 variables, detailing the impact of cell tower proximity on participants' health, their perceptions of

electromagnetic radiation (EMR) exposure, and effects on the aesthetics of urban environments. Key variables reflecting community sentiment and urban planning issues related to cell towers, such as Aesthetic Concern Rating, Community Engagement Score, Availability of Alternative Tower Designs, Visibility of Cell Towers, and Perceived Design Quality of Towers, were selected for further analysis. Subsequently, Pearson correlation coefficients were computed for these selected variables to measure the strength and direction of linear relationships between them. The Pearson correlation coefficient ranges from -1 to 1, where values near 1 indicate a strong positive correlation, values near -1 indicate a strong negative correlation, and values around 0 indicate no linear relationship.

Table1. Descriptive Statistics of Respondent Perceptions and Cell Tower Proximity measures

central tendencies	EMR Exposure Level (mW/cmÄ²)	Aesthetic Concern Rating	Visibility of Cell Towers	Perceived Tower Design Quality	Distance to Nearest Landmark (meters)	Community Engagement Score	Presence of Alternative Tower Designs
count	150	150	150	150	150	150	150
mean	0.322267	5.466667	0.64	5.706667	641.3333	5.106667	0.286667
std	0.290166	3.038161	0.481608	2.862736	320.0643	2.857104	0.453719
min	0.05	1	0	1	100	1	0
25%	0.08	3	0	3	300	2.25	0
50%	0.27	5	1	6	500	5	0
75%	0.4375	8	1	8	1000	7	1
max	1.19	10	1	10	1000	10	1

Table 1. Correlation Matrix of cell tower impact and community engagement indicators

coefficient matrix					
variables	Aesthetic Concern Rating	Community Engagement Score	Presence of Alternative Tower Designs	Visibility of Cell Towers	Perceived Tower Design Quality
Aesthetic Concern Rating	1.00000	-0.06995	0.03376	-0.00826	0.03282
Community Engagement Score	-0.06995	1.00000	0.15228	-0.08897	-0.07738
Presence of Alternative Tower Designs	0.03376	0.15228	1.00000	-0.10811	-0.01233
Visibility of Cell Towers	-0.00826	-0.08897	-0.10811	1.00000	-0.06250
Perceived Tower Design Quality	0.03282	-0.07738	-0.01233	-0.06250	1.00000

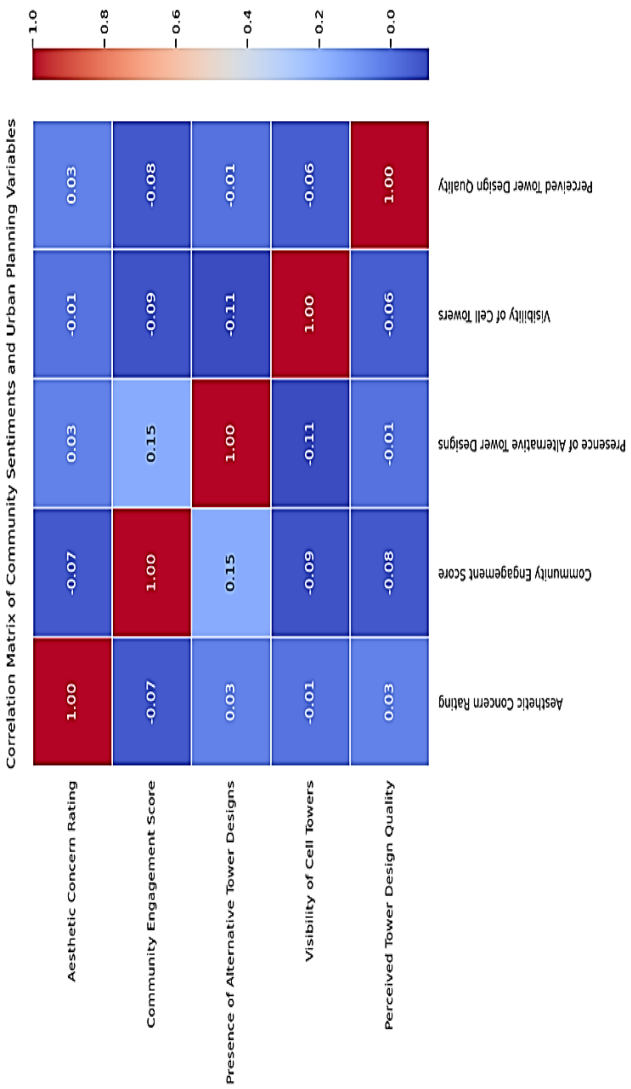

Figure 1. Heatmap image of the correlation matrix of cell towers and community engagement variables

The descriptive statistics for the dataset in Table 1 reveal that respondents experience an average EMR exposure level of 0.32 mW/cm² with some variability, as evidenced by a standard deviation of 0.29. Aesthetic concerns about cell towers have a moderate mean rating of 5.47, but with a fairly wide range of opinions. Cell towers are generally less visible to respondents (mean visibility rating of 0.64), and the perceived quality of tower design is also moderate (mean of 5.71). The average distance to the nearest landmark is 641 meters, suggesting that landmarks are not in close proximity to the respondents, and community engagement scores average at 5.11, indicating a moderate level of community interaction with a wide spread in responses. Finally, alternative tower designs are relatively uncommon among respondents, with a low average presence reported. Overall, the statistics indicate a moderate perception of and engagement with cell tower-related issues, with significant variability in several aspects.

The correlation matrix analysis seen from Table 2 and figure 1 offers a refined view of the interplay between community sentiments and urban planning decisions regarding cell tower installations. Notably, the Aesthetic Concern Rating displays very low correlation coefficients with all other variables, indicating a minimal connection between aesthetic worries about cell towers and factors such as community engagement scores, the introduction of alternative tower designs, the visibility of cell towers, or the overall perception of tower design quality within this dataset. Moreover, the Community Engagement Score is slightly positively correlated with the presence of alternative tower designs ($r = 0.15$), suggesting that a higher degree of community involvement might be weakly linked with efforts to diminish visual impacts through innovative designs. Despite this, the strength of this relationship remains subdued. Additionally, the Presence of Alternative Tower Designs exhibits a minor positive correlation with community engagement scores yet is found to be negatively correlated with the visibility of cell towers ($r = -0.11$), implying that alternative designs could be somewhat effective in reducing tower visibility, though this association is faint. The Visibility of Cell Towers itself shows negligible correlations with other variables, suggesting that the visibility of cell towers from a respondent's location scarcely affects community sentiments or perceptions of design quality. Similarly, the Perceived Tower Design Quality has very low to negligible correlations with community engagement efforts, the presence of alternative designs, or the visibility of towers ($r = -0.11$), underscoring that respondents' views on how seamlessly towers blend with the urban environment are largely unaffected by these factors.

Overall, the correlations among these variables are relatively weak, indicating that community sentiments regarding the aesthetics of cell towers, as captured by this dataset, are not strongly influenced by the measured factors of community engagement, alternative design efforts, or visibility of towers. This could suggest that community sentiments about cell tower aesthetics are influenced by other factors not captured in this dataset or that the relationships are more complex and not linearly correlated.

To explore the connection between levels of electromagnetic radiation (EMR) exposure and proximity to cell towers, we utilized the variables "EMR Exposure Level (mW/cm²)" and "Exact Distance to Nearest Mast (meters)" from the dataset. This examination aimed to illustrate how EMR exposure levels vary with changing distances from cell towers, an essential factor in evaluating potential health implications and establishing safety guidelines. Given electromagnetic radiation's properties, an inverse relationship was anticipated: the farther away one is from the source (in this case, the cell tower), the lower the exposure level is expected to be. This expected pattern aligns with the inverse square law of physics, which suggests that the strength of an electromagnetic field (EMF) emitted by a point source diminishes proportionally to the square of the distance from that source.

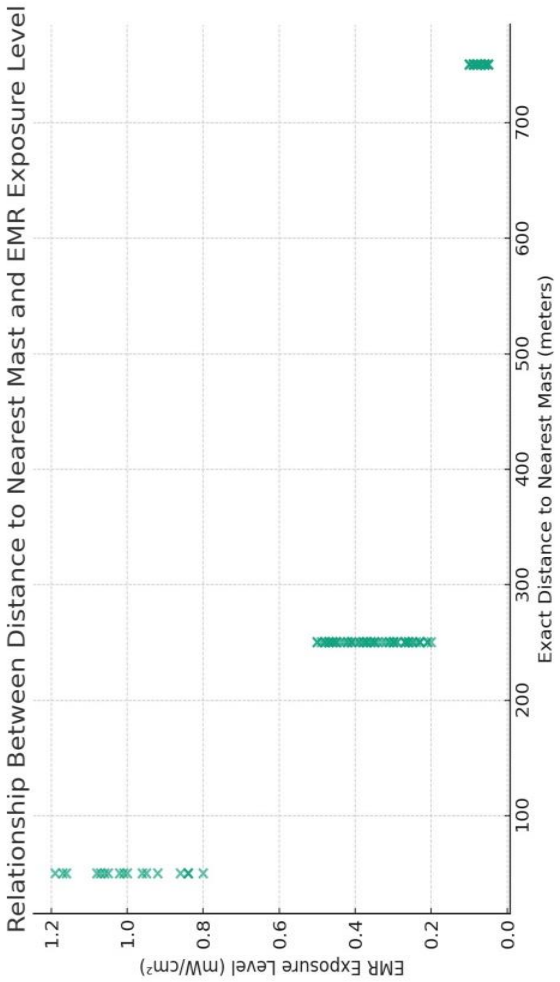

Figure 2. Scatter plot displaying the relationship between EMR exposure level and the exact distance to the nearest mast

The scatter plot in figure 2 illustrates the relationship between EMR (Electromagnetic Radiation) exposure levels (measured in mW/cm²) and the exact distance to the nearest mast (measured in meters) for the respondents in the dataset. The plot provides a visual representation of how EMR exposure levels change with distance from cell towers. From the scatter plot, we observe a distribution that suggests a decrease in EMR exposure levels as the distance to the cell tower increases, aligning with the expectation based on the inverse square law of electromagnetic radiation. This pattern is crucial for understanding the potential health risks associated with proximity to cell towers and can inform guidelines and regulations regarding tower placement and design to minimize exposure and to further quantify this relationship and assess its statistical significance, a regression analysis was performed, allowing us to model the exact nature of the decrease in exposure levels with distance. This provided more detailed insights into how much exposure levels drop off as one moves away from cell towers, which is valuable for urban planning, public health policy, and community awareness efforts.

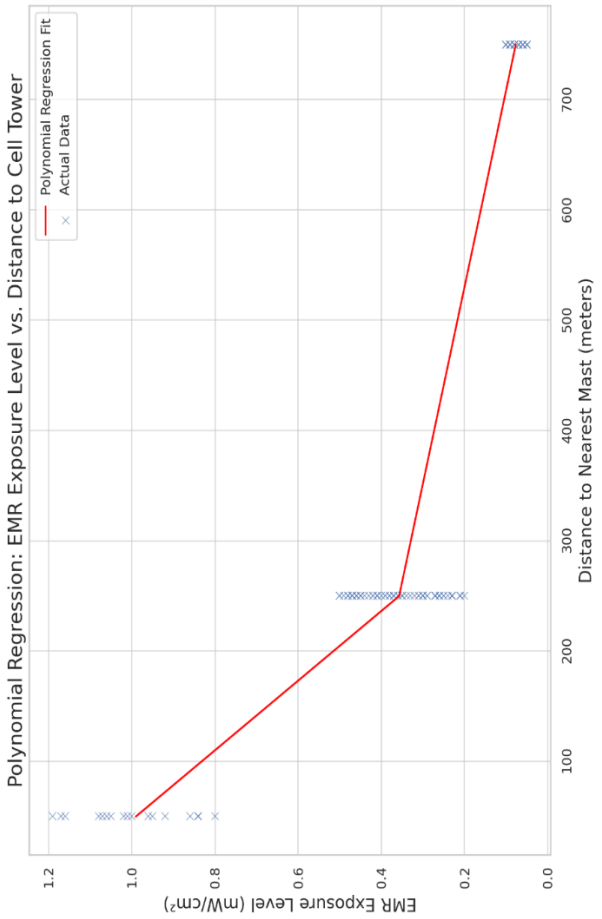

Figure 3. Scatter Plot with Polynomial Fit of EMR Exposure with the Distance from Cell Towers

The polynomial regression analysis exploring the relationship between electromagnetic radiation (EMR) exposure levels and proximity to cell towers revealed significant findings as shown in figure 3. The Mean Squared Error (MSE) was low at 0.0057, indicating a close fit of the model predictions to actual data. The R-squared value was high at 0.9316, showing the model could explain a significant portion of the variance in EMR exposure levels. The regression coefficients suggested a non-linear relationship, where EMR exposure decreases with increasing distance from cell towers, in line with the inverse square law. These results underscore the importance of considering distance in urban planning and public health strategies to minimize EMR exposure from cell towers.

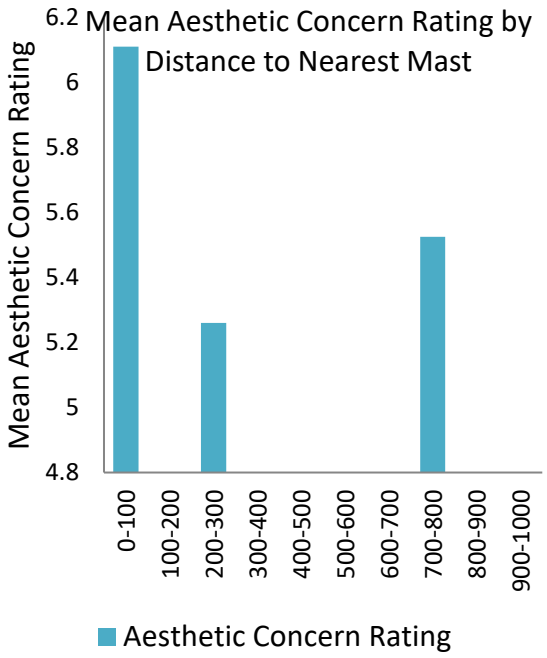

Figure 4. A graph displaying the mean aesthetic concern rating by distance to nearest mast

Figure 4 displays the mean aesthetic concern rating as it correlates to the distance from the nearest cell tower. A higher rating indicates greater concern. The graph suggests that concern is highest for those within close proximity (0-100 meters) to a mast and for those at a distance of 700-800 meters. The reasons for increased concern at these intervals might warrant further investigation to understand local context or specific conditions around the masts.

5. CONCLUSION

The investigation into cell tower proximity's effect on EMR exposure in Cape Coast has demonstrated a non-linear reduction in exposure correlating with increased distance, consistent with the inverse square law. This however, underscores the critical need for strategic planning in the placement of cell towers to protect public health. Community aesthetics concerns related to cell towers suggest underlying factors beyond what was measured, indicating opportunities for further study. The research highlights the necessity for longitudinal inquiry into the prolonged effects of EMR and for assessing the impact of regulatory practices. Advocating for stringent cell tower positioning regulations and proactive community participation, the study emphasizes that Ghana's technological expansion should not compromise the health and safety of her citizens.

6. ACKNOWLEDGMENTS

Our thanks to all hands that have contributed to the success of this work. We say Thank You.

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