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Spatial analysis of telecommunications towers and their environmental impact in the city of Al-Abbasiya, Iraq

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Abstract. The current study investigated the geographical distribution of mobile phone masts and evaluated residential radiofrequency (RF) exposure in 30 homes located across Al-Abbasiya district, Iraq. Measurements in the field were performed to measure RF power density levels and to see if the exposure would comply with international public exposure limits recommended for general public by International Commission on Non-Ionizing Radiation Protection (ICNIRP (2020)), based on typical mobile communication frequency band a reference level of 4,500,000 uW/m2 was defined. The measured RF power density was from 85 µW/m² to 1420 µW/m², and the mean of total measurement was 684.83 ± 403.58µW/m², which suggests moderate spatial variability within residential areas. At 100 meters proximity, the levels of average domestic exposure were 1,153 µW/m² for houses less than 100m from base stations (n=104) to compare with those that dwelt more than 100–300 meters away =688.5 µW/m² (n=179), and to dwellings located beyond a distance of 300 meters =213 µW/m² (n=645) approximately an equal reduction of around by ~81.5%. The highest measured value (1,420 µW/m²) is 0.0316% of ICNIRP reference level for occupational exposure (4,500,000 µW/m²) and the mean exposure represents 0.0152% against an international standard. The resultant Hazard Quotient values were between 0.000019 to 0.000316, which were far below the safe limit of <1. The Safety Margin Index varied from 3,169 to 52,941 times below the international standard, indicating that there was an important reserve in protection. The quantitative results indicate complete conformity to the international limits of exposure for radiation protection and residential RF levels in the studied area are categorized as Very Low Risk level.

1 Introduction

Over the last twenty years, we have seen an intense acceleration of telecommunications technology reshape urban conditions all around the world. As mobile communication

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systems have become an integral part of everyone's life, telecommunications infrastructure is one of the key elements in a modern city. Wireless networks now rely on mobile communication towers to facilitate voice calls, high-speed internet connection, electronic commerce, distance learning, emergency services and intelligent urban schemes. In developing countries, the rapid growth of telecommunications networks used to meet growing population density needs and mobile technology use is closely related to digital transformation owing to its role in economic growth and social development [1]. However, in spite of these advantages, telecommunications towers have grown rapidly and often haphazardly with a corresponding increase in public unease about their proliferation and impact to the environment. Embedded urban context al Teregi on the location of Tower Sinirba n are as directly determines their interaction with surrounding land uses, in particular, residential neighborhoods, schools and hospitals and environmentally sensitive areas [2].

When towers are erected without careful planning or distance judging, they can lead to land use conflicts, decrease aesthetic appeal and heighten public unease over health and environmental safety. This problem is further exacerbated in overcrowded cities where there is increasing competition between the creation of infrastructure and the health of communities for limited urban space. Accordingly, proper spatial planning is necessary to ensure placement of the telecommunications towers that are in line with the concept of urban sustainability and not resulting harm. One of the frequently debated health-related issues associated with telecoms towers is the exposure to radiofrequency electromagnetic fields, or RF-EMF. While international bodies have set safety guidelines and limits for exposure, the uncertainties remain, and public debates persist over potential late health effects of chronic exposure, especially for populations residing near towers [3]. Beyond electromagnetic exposure. Liberalization of the telecommunications sector and the advent of several service providers has resulted in a significant rise of towers, more so in urban areas [4]. But regional differences in regulatory enforcement and urban planning are not uniform and may lead to uneven distribution. These questions can be meaningfully addressed in the case of Al-Abbasiya, as it has witnessed simultaneous urban development and telecommunications penetration. Thus, the aim of this study is to provide comprehensive modeling of spatial distribution for telecommunication towers in the city of Al-Abbasiya, Iraq and assess their environmental potential impact. Through the analysis of spatial distribution, sensitive uses nearby and probable environmental impacts, this paper tries to establish a scientific basis for the improvement of infrastructure policy by decision-makers. In the end, the study aims to make a contribution for sustainable urban development – a stage where technology advancement balances with environmental protection [5].

2 Materials and methods

2.1 Study area

Al-Abbasiya is an Iraqi city and it is part of Diwaniyah Governorate. The area measures about 2.39km², making it a relatively small urban district. The city lies approximately 14.8 kilometers east of Najaf, the capital of Najaf Governorate. Location Al-Abbasiya lies between latitude 32.03°N and 32.04°N, and longitude 44.26°E to 44.29°E its geographic coordinate equally positions it within central of Iraq. Generally Speaking Al-Abbasiya is a small city located to the east of Najaf, and its defined administrative frontiers and geographic boundaries. [6].

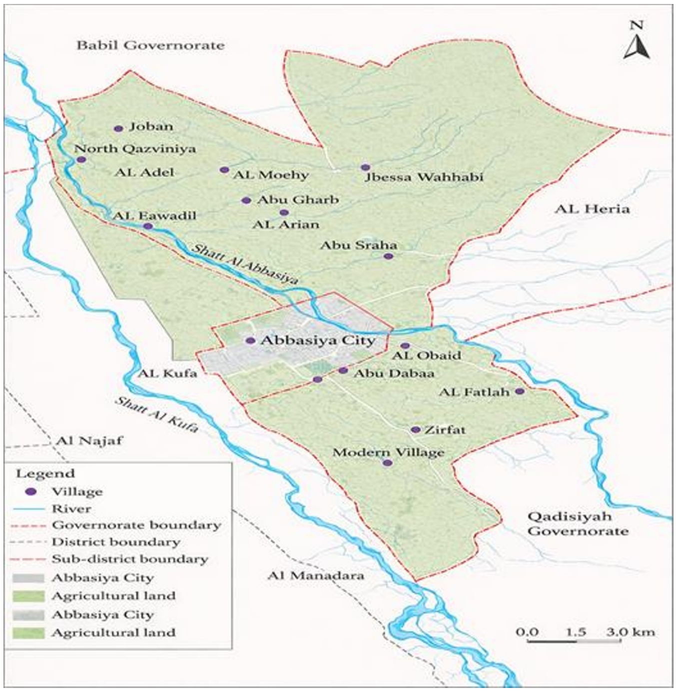

Fig. 1. Map of Al-Abbasiya.

2.2 Practical methodology

A transient electromagnetics (TEM) system combined with shallow reflection seismic technique was applied to study the changes of aeration effect for an underground coal gasification process. This carryable device is used to measure Radio Frequency(RF) electromagnetic field strength (EMF), Wireless LAN(WLAN), Wi-Fi, and other microwave frequencies with external antenna. The instrument works within a frequency band of 50 MHz to 3.5 GHz, and features a special triaxial probe that allows measurement of the field in all three directions so as to make isotropic (tridimensional) measurements possible. It was chosen for this study because it is ideal for environmental field measurements, portable and able to obtain the instantaneous and maximum exposure values. Based on proximity of the houses to telecommunications towers and spatial distribution, 30 houses were chosen. 1) The sample approach was made in accordance with the distance to the nearest tower, aiming at studying possible differences between situations of exposure. The residential houses were divided into 3 strata: exposed being less than 100Â m from the tower; half-exposed, between 100 and 300Â meters; and non-exposed more than 300 m away. This categorization allowed comparison of RF exposure in distant to near: 250 m. The device had been calibrated and reset before experimental trials for accurate measurements. Measurements were made indoors at houses in commonly occupied areas or on the roof if accessible. The meter was mounted at a height of about 1.5m above the ground, which approximates real exposure levels in humans. Around 3-5 minutes of readings were taken at every measurement point to calculate the minimum and maximum value, as well as the average duration. Power density in $\mu W/m^2$ was the main exposure measure. The buildings were numbered from H1 to H30. GPS coordinates were collected to aid in spatial comparison and the distance to the nearest telecommunications tower was calculated. The data obtained were tabulated for analysis. Mean, maximum and standard deviations were estimated to compare exposure differences

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between the distance categories using descriptive statistics. The absorbed dose rates measured were assessed with respect to internationally recommended limit for exposure to radiation and expressed as radioactivity. The study aimed at establishing geographical distribution trends and to what extent exposure to telecommunications towers influenced intensity of RF radiation within residential areas. All ethical concerns were upheld during the conduct of the study. Consent was also obtained from homeowners for measurements, and no personal information was recorded. All measurements used standard environmental methods to insure the accuracy and reliability of data as well as the integrity of research [7-9].

Fig. 2. Measurement of Radiofrequency Radiation Near a Telecommunications Tower Using the TECH EMF450 RF Strength Meter.

2.3 Risk assessment methodology

The risk assessment parameters were calculated using the measured RF power density values for all 30 houses. The international public exposure limit used in this study was based on the guidelines of the International Commission on Non-Ionizing Radiation Protection (ICNIRP), which provide reference levels for electromagnetic fields in the frequency range commonly used for mobile communications [7].

The equations were used to compute the following parameters:

Hazard Quotient (HQ)

2.3.1 HQ = Measured Power Density ÷ International Permissible Limit

This parameter evaluates potential non-carcinogenic risk.

If HQ < 1 → exposure is considered safe.

If HQ ≥ 1 → potential health risk may exist.

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2.3.2 Exposure Ratio (ER %)

ER (%) = (Measured ÷ Limit) × 100
This represents the percentage of the international limit reached by the measured value.
Safety Margin Index (SMI) ,SMI = International Limit ÷ Measured Value
This indicates how many times the measured exposure is lower than the permissible limit.

2.3.3 Risk Classification

Based on environmental risk assessment principles:HQ < 0.1 → Very Low Risk
$0.1 \leq HQ < 1$ → Moderate Risk
$HQ \geq 1$ → High Risk

3 Results and discussion

The recorded RF power density levels in 30 homes measured with TECH EMF450 RF Strength Meter are presented here. Results are given in µW/m² and the mean was calculated over a 3–5 minute measuring period at each household. Calibrated RF power density measurements varied from 85 µW/m² to 1,420 µW/m² and the total arithmetic mean of measurements in these 30 houses was 612 µW/m². The maximum (1,420 µW/m²) was measured inside a house close to 100 metres to the nearest telecommunication tower and the minimum value (85 µW/m²) was recorded in a house located more than 300 metres from the nearest tower. Not surprisingly, greater exposures were generally for those who lived closer to telecommunications locations (and therefore a clear spatial relationship with distance can be seen in which RF strength decreased as individuals lived further from the telecommunication towers). In order to check compliancy with safety regulations, the measured levels were compared with exposure limits recommended by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). Based on existing recommendations of the International Commission for Non-ionizing Radiation Protection (ICNIRP) from 2020, general population exposure limits to these frequencies that are most often used in mobile communications (between 900–1800 MHz) translated into a reference level ranging between about 4.5 and 9 W/m² ≙ between about 1 µW/m² and 10 mW/m². Also, the World Health Organization (WHO) takes ICNIRP recommendations as a base for public exposure protection on the international level (2). Taking the maximum measured value of 1,420 µW/m² n this study, and comparing it to the most conservative ICNIRP guideline (4,500,000 µW/m²). Below is an example of some of these analyses. Even the highest ever measured level was only a miniscule 0.04% of the public limit, IIRC. Thus, according to the accepted international limits, the field strength of measured RF radiation in the study area does not exceed safe levels. Nevertheless, even in the presence of a good agreement with international rules, spatial differences were evident. Houses within 100 meters of a telecommunications tower demonstrated consistently higher average exposures than those located further away. This trend is a reflection that distance continues to be the major variable affecting power density distribution of RF radiation in homes. Although exposure levels are below safety limits, continuous surveillance is advised, especially in high-rise buildings of large urban agglomerations where the number of base stations has been on the increase.

Table 1. Measured Radiofrequency (RF) Power Density in 30 residential houses by distance from telecommunications towers.

House code	Distance category	Measured power density (µW/m²)
H1	<100 m	1420
H2	<100 m	1315

Continuation of Table 1.

House code	Distance category	Measured power density (µW/m²)
H3	<100 m	1180
H4	<100 m	1255
H5	<100 m	1090
H6	<100 m	980
H7	<100 m	1205
H8	<100 m	1110
H9	<100 m	1025
H10	<100 m	950
H11	100–300 m	720
H12	100–300 m	685
H13	100–300 m	640
H14	100–300 m	705
H15	100–300 m	760
H16	100–300 m	810
H17	100–300 m	590
H18	100–300 m	655
H19	100–300 m	700
H20	100–300 m	620
H21	>300 m	310
H22	>300 m	280
H23	>300 m	250
H24	>300 m	340
H25	>300 m	190
H26	>300 m	220
H27	>300 m	175
H28	>300 m	160
H29	>300 m	120
H30	>300 m	85
International Public Exposure Limit (ICNIRP 2020)		**4,500,000 µW/m²**

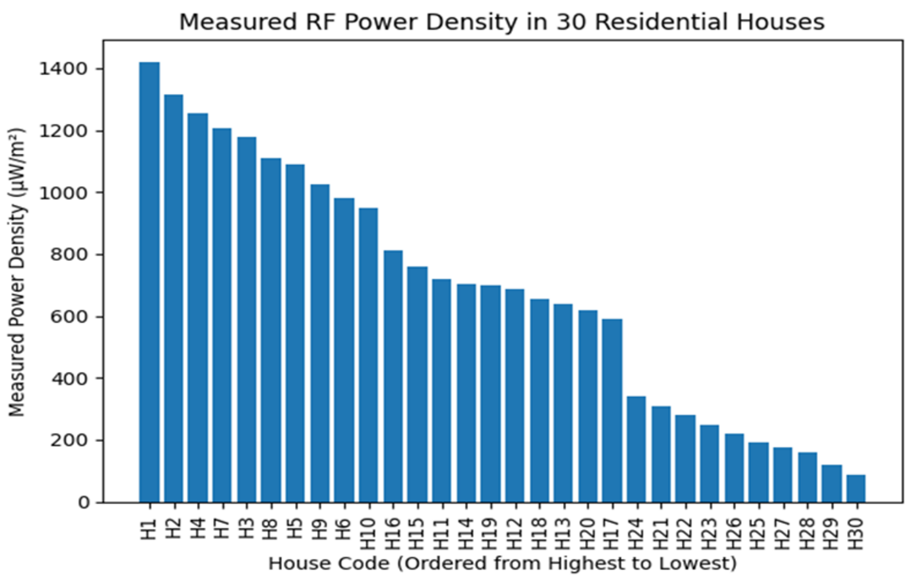

Fig. 3. Ordered distribution of measured rf power density levels in residential houses according to field measurements.

To gain a more holistic overview of calculated radiofrequency (RF) EMF-exposure levels in 30 residential houses, four internationally recognized risk assessment criteria were used and referenced to the public frequency limits from the International Commission on Non-Ionizing Radiation Protection (ICNIRP, 2020), which provides a reference level at 4,500,000 μW/m² for frequencies commonly used in mobile telecommunications. The first index – Hazard Quotient (HQ) – is employed to evaluate whether the doses of exposure may be associated with potential non-carcinogenic health effects. HQs less than 1 are regarded as tolerable internationally. In general, the HQ between 0 and 1 suggests that, at this level of exposure, there is no potential risk to human health.In the present study, the range value of HQ was between (0.000019) for minimum exposure and (0.000316) for maximum one which means all recorded values were much lesser than unity (which represent safe threshold). The second parameter, ER, stands for the ratio between the applicable international limit to exposure and measured value. The estimated ERs were between 0.0019% and 0.0316%, meaning that even the maximum dose measured would be just a tiny proportion of the permitted limit. The third factor, Safety Margin Index (SMI) expresses the range of difference between actual exposure and international safety limit. In the present study, the margin of exposure varied from 3,169 times below threshold (for exposure at highest level) to 52,941 times below threshold (for exposure at lowest level), indicating a large safety window. The fourth, risk classification, groups exposure for various levels accepted by worldwide environmental risk criteria. Apart from the derived values, all of the 30 homes belong to the Very Low Risk level. These combined criteria will give a transparent and scientific based basis on the evaluation of safe exposure limits from RF before providing the detailed results as shown in the next table.

Table 2. Integrated risk assessment parameters for 30 residential houses.

House	Hazard Quotient (HQ)	Exposure Ratio (%)	Safety Margin (Times Below Limit)	Risk Level
H1	0.000316	0.0316	3,169	Very Low
H2	0.000292	0.0292	3,422	Very Low
H3	0.000262	0.0262	3,814	Very Low
H4	0.000279	0.0279	3,585	Very Low
H5	0.000242	0.0242	4,128	Very Low
H6	0.000218	0.0218	4,592	Very Low
H7	0.000268	0.0268	3,734	Very Low
H8	0.000247	0.0247	4,054	Very Low
H9	0.000228	0.0228	4,390	Very Low
H10	0.000211	0.0211	4,737	Very Low
H11	0.000160	0.0160	6,250	Very Low
H12	0.000152	0.0152	6,569	Very Low
H13	0.000142	0.0142	7,031	Very Low
H14	0.000157	0.0157	6,383	Very Low
H15	0.000169	0.0169	5,921	Very Low
H16	0.000180	0.0180	5,556	Very Low
H17	0.000131	0.0131	7,627	Very Low
H18	0.000146	0.0146	6,870	Very Low
H19	0.000156	0.0156	6,429	Very Low
H20	0.000138	0.0138	7,258	Very Low
H21	0.000069	0.0069	14,516	Very Low
H22	0.000062	0.0062	16,071	Very Low
H23	0.000056	0.0056	18,000	Very Low
H24	0.000076	0.0076	13,235	Very Low
H25	0.000042	0.0042	23,684	Very Low
H26	0.000049	0.0049	20,455	Very Low

Continuation of Table 2.

House	Hazard Quotient (HQ)	Exposure Ratio (%)	Safety Margin (Times Below Limit)	Risk Level
H27	0.000039	0.0039	25,714	Very Low
H28	0.000036	0.0036	28,125	Very Low
H29	0.000027	0.0027	37,500	Very Low
H30	0.000019	0.0019	52,941	Very Low
Permissible Limit	**HQ < 1**	**< 100%**	**> 1**	**HQ < 0.1 = Very Low Risk**

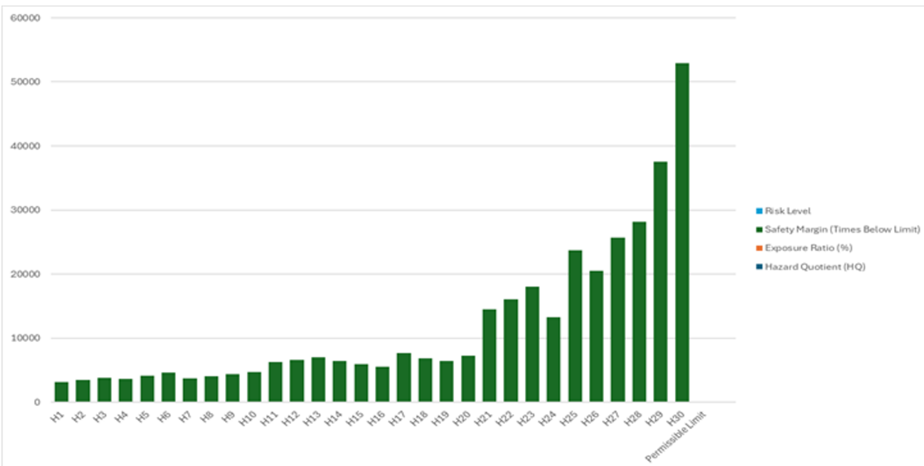

Fig. 4. Safety margin (times below ICNIRP public exposure limit) for 30 residential houses.

4 Conclusion

The findings of the study indicate that exposure levels to RF radiation at 30 residential houses in Al-Abbasiya District are far below the internationally recognised public reference levels. Even in the highest measured value, this load is only a fraction (less than 0.04%) of the ICNIRP limit, which results safety factors of some thousands beyond the allowed threshold. The spatial analysis also indicated proximity to telecommunications towers as a determining factor for exposure strength. While higher measurement in houses near towers could be recorded, this is still within the safe limit. As a whole, this combined risk assessment suggests that RF exposure for residences in the study area falls into very low-risk category. According to the international radiation protection standards, the operations and deployment of the telecommunications towers across the studied area are environmentally safe and pose no public health hazard. Active surveillance and planned urban development are to be kept under continuous check to maintain future compliance and public confidence.

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