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Evaluation Study of Radio Frequency Radiation Effects from Cell Phone Towers on Human Health

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Abstract—The presence of a large number of cell phone towers on the roofs of buildings inside cities raises several questions about whether the radiated electromagnetic frequency (EMF) and power spectrum density (PSD) affect the population even if the towers were installed based on the exiting conditions and standards in the cities. This paper aims to answer all these ambiguous questions by measuring the emitted EMF from the local towers built in a small city of Al-Kut in Iraq. This study was set to investigate the health impact of EMF radiation from the cell phone towers and determine how this EMF effects on the human immunity to diseases. The practical measurements were obtained using the EMF meter and the global positioning system (GPS) and employing the geographical information system (GIS). In this paper, two study groups were selected. The first one lived in the area with three installed towers at distance of 50–100 m between them. The second group resided in the area where towers were installed outside its borders at distances of more than 500 m. The results show that the first group suffers from a health problem much more than the second one. In addition, a high percentage of residences were the most educated, but the less knowledgeable people about EMF radiation impacts at long-term exposure, a fact that can be attributed to the academic curriculum deficiency. Therefore, the study has recommended integrating environmental concepts in the governmental institutions and organizations for all mature persons, irrespective of their academic qualification, to increase people's awareness about this topic.

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1. INTRODUCTION

Wireless networks have been used extensively during the last decade, and their technologies are progressively changing from one generation to another offering better services. These new technologies have witnessed significant interest in all sectors of society even in the educational sector over the last few years [1]–[3]. These kinds of networks emit radiofrequency radiation which is suspected to affect humans negatively.

The radio waves propagate in space transmitting the radio and television signals. The nature of these systems depends on certain bands of the electromagnetic spectrum. The fact is that the emission of the electromagnetic waves is absorbed by human body and the absorbed energy causes some health problems depending on the strength of that emission [4]–[7].

Over fifty years ago, there had been numerous studies to prove the effects of these waves on human beings. Despite the tremendous advantages provided by mobile phones, and all the promises of emerging high-quality services, there are still some barriers which are related to the technical limitations and the absence of high accuracy for determining the exact location of users in need [8], [9]. This situation prompted researchers to highlight this issue, especially since the increase in the number of towers within residential areas is continuing.

Table 1. Radiated power from RF sources

RF source	Operating frequency, MHz	Power transmission
AM/FM tower	0.54–108	1–300 kW
TV tower	48–814	10–500 W
Mobile phone	900–1800	1–2 W
Cell-phone tower	800–2450	20 W
Wi-Fi	2400–2500	> 100 mW

The outcomes of the research indicated the need to take into account several aspects, namely that the cell phone towers are not harmful as long as their waves are radiated under the limit allowed by the international organizations [4]. This is in contrast to the other research, which indicated that this radiation could affect human beings under the long term exposure, although it emits under the limit of exposure and that required some researches to continue studying the effects for several years. Moreover, what has been shown in some recent scientific research proved that these limits are relatively high for causing any damage to the population in the short term exposure and that these towers should be placed outside the boundaries of residential areas [10].

In 2012, a group of 29 experts from America, Sweden, Austria, Canada, Greece, India, Italy and the Slovak Republic have submitted a report regarding the re-assessment of those regulations to ensure a strong scientific public strategy for electromagnetic radiation. That team who came up with the idea that the limits of the Federal Communications Commission (FCC) are very high as compared with the existing practical limits, which does not provide a good protection especially the biological effects of exposure to these electromagnetic waves under the long term use [11]. Their results based on a 67 study which dealt with the presence of biological effects under the common limits [12].

The telecommunications sector in Iraq is one of the fastest-growing sectors that can be seen since 2004. Until now, the usage of IT by universities, colleges, and schools for imparting training programs is gradually increasing [13]. This sector is based on laws and standards issued by the Iraqi Ministry of Communications (IMC) and the Communications and Media Commission (CMC) [14].

Despite the existence of these standards, some violations can be observed within the Iraqi cities. The towers can be seen inside the city on the roofs of houses, government institutions and universities, etc. Such situation has caused the population to be confused about what these waves are and what their impact is in the long term. Some previous articles showed that the effect of long term exposure could be the reason behind the serious increase of breast cancer [15].

This study is aimed at determining the level of radiation and its effects on human body immunity among the Al-Kut towns regarding EMF cell phone tower effects, identifying the required measurements to suggest a recommendation for Iraqi authorities, comparing the results with the international standards, and investigating possible solutions for the topic awareness among residences regarding the access to the role of our institution and organization for public community health.

2. RADIATED POWER SPECTRUM DENSITY

It is well known that humans are exposed to electromagnetic waves continuously from the nature as a primary source. The radio frequency spectrum includes a set of bands of frequencies that are used in wireless communication for transmitting and receiving information [16]. The amount of energy passing through a unit area per unit time is referred to as the power spectrum density (PSD).

The PSD radiation of a transmitting isotropic antenna is designed to radiate uniformly in all directions. PSD can be calculated at a distance D using the following formula:

$$\mathrm{PSD} = \frac{P_t G_t}{4\pi D^2}, \tag{1}$$

Table 2. Maximum permissible exposure level for different standards [19]

Organization	Country	Year	PSD, W/m^2	
			900 MHz	1800 MHz
HUNGARY	Hungary	1986	0.1	0.1
NRPB	United Kingdom	1993	33	100
CENELEC	Europe	1995	4.5	9
ICNIRP*	Germany	1998	4.5	9
AS/NSZ	Australia	1998	2	2
SALZBURG	Austria	1998	0.001	0.001
ITALY	Italy	1998	1	1
NISV	Switzerland	1999	0.04	0.1
FCC	USA	1999	6	12

* Iraq follows ICNIRP standard.

where P_t refers to the power of transmitting antenna [W], G_t refers to the gain of transmitting antenna [dB], and D refers to the distance between T_x and R_x [m].

The RF spectrum is considered as a non-ionizing radiation since it does not have enough energy to damage the chemical bonding of atoms and molecules [17]. However, the biological system of the human is getting affected due to the deep penetration of such waves under the long-term exposure. Table 1 presents the typical values of radiated power depending on the radio frequency source [18].

3. SAFETY STANDARDS AND REGULATIONS

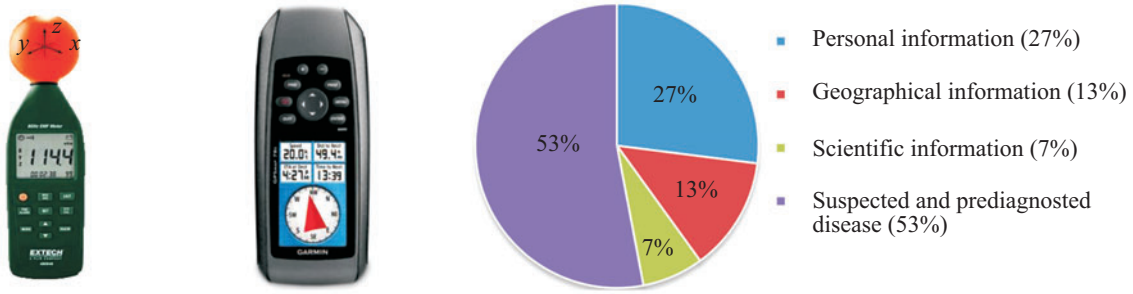
There are many International standards adopted by the governments of different countries. The main reason for adopting these standards was to regulate the EMF antenna radiation and protecting residences living next to cell phone towers. The International Commission on Non-Ionizing Radiation Protection (ICNIRP) issued the most effective standard, which is adopted by a wide number of countries all over the world [19]. In the USA, the Federal communications commission (FCC) has set many quantitative parameters to control EMF radiation for service providers aimed at reducing the exposure level. Table 2 shows the permissible exposure levels in many countries for human health protection.

It is known that many studies have found that all these radiation levels surrounding the residences have values below the permissible FCC limits [20]. This study came up with an idea to check if these numbers affect the residences under the long term exposure. It is focused on the current remarkable situation, which includes a dramatic increase in health issues among people who live near those transceiver towers.

4. STUDY INSTRUMENTS

The first part of the study measurements was carried out using the field strength meter, which was an RF 8 GHz EMF meter (Fig. 1(a)), and the GPS Garmin (Fig. 1(b)). This meter is sensitive enough to EMF and useful when used to measure the strength of the electric field and give the position of the maximum field that means the direction of effective communication tower.

Figure 1(b) represents the device that gives all the information about the position of the tower and provides all details about the direction and other features. To begin with, this EMF meter was developed for monitoring and measuring EMF field strength, Wi-Fi, microwave leakage, and base station antenna radiation of cell phone towers. The output measurements of this meter were designed to optimize a range of frequencies 0.9–8 GHz within a three-axis radio channel.



(a) (b) (c)

Fig. 1. Electromagnetic field meter (a), GPS Garmin (b), chart diagram explanation of overall survey (type of questions) (c).

According to the existing requirement, readings were obtained only for measuring the power density of 900 and 1800 MHz frequencies. In the GPS section, GPS Garmin was used to locate the cell phone tower positions on the ground through the calculation of the *x*-*y* coordinates (Fig. 1(b)) [21], [22].

The second part of the investigation was based on a primary survey using a questionnaire and that was based on the most common health problems that were revealed in the previous studies. Personal information and multiple-choice questions were asked in the survey. In total, it included 14 questions. The questions covered four aspects of cell phone tower radiation effects including personal information, general background about the topic, suitability of existing towers, and pre-diagnosed health issues (Fig. 1(c)). Three of the questions were set to acquire some personal information, such as gender, age, and academic qualification. Four questions were dedicated to the background knowledge about the existing impacts of towers on humans, and the rest focused on the possible health problems that were previously diagnosed. The evaluation questionnaire of people's health was accomplished for each person through a direct interview by two trained researchers.

5. STUDY GROUP

The questionnaire was distributed in 2018 between two groups of residences at Al-Kut city. The first group was located in a town called Hay Al-Gadeer, which included three cell phone towers near one another with less than a hundred meters apart within the area of about 15600 m^2. The second study group was limited to the area almost empty from cell phone towers within the area of 1700 m^2, which is called Al-Kafaat. The first zone was considered as a local area hosting the largest number of towers among the areas in Al-Kut city.

The study groups involved all the enrolled adults ($N = 158$) with people of both sexes aged in the range of 15–85 years old. The questionnaire was distributed during four weeks, and each group took two weeks to complete the survey. The questionnaire was answered by residences during holding sessions to guarantee that the residents have relied on their ultimate knowledge and pre-diagnosed health problems to answer the survey. The whole study continued for six months from October 1, 2018 to April 2019, which included the writing of the proposal, visiting the areas, collecting data, reviewing the literature and then starting the writing and analyzing data.

Figure 2 shows the overall distributed towers in Al-Kut city according to the last report submitted by the Iraq ministry of environment in 2018. Figure 2 shows the region that is taken for group 1 and group 2 and it represents the region of questionnaire and measuring the effects of radiation on the human livings in this region.

6. STATISTICAL ANALYSIS

The data has been distributed and collected on the residences and analyzed to reveal the side effects of cell phone tower radiation. This data can be applied to several statistical indicators to assess and evaluate the model [23], [24]. In any case, in this study, the statistical analysis was achieved with the help of SPSS (Statistical Package for Social Science) and MS Excel 2016 for means comparisons [25].

Results were expressed as a percentage of SD (standard deviation). The resultant values were also analyzed based on descriptive statistics and inferential statistics. The descriptive statistics included the measurement of frequencies and percentages. The inferential statistics represents the chi-square test used to find the association between the two groups and the related variables.

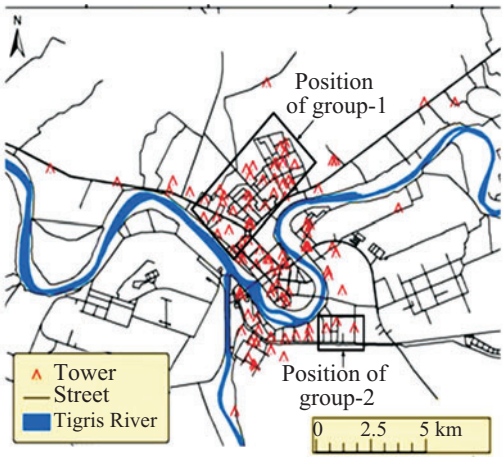


Fig. 2. Distribution of cell phone towers in Al-Kut city.

Table 3. Distribution of study population according to demographic characteristics

Variable		Group-1		Group-2	
		No.	%	No.	%
Gender	Male	41	51.9	49	62.0
	Female	38	48.10	30	38.0
Age	< 30	43	54.4	36	45.6
	30–50	28	35.4	31	39.2
	≥50	8	10.1	12	15.2
Education level	Illiterate	1	1.3	3	3.8
	Primary	16	20.3	14	17.7
	Secondary	23	29.1	24	30.4
	Institute and higher	39	49.4	38	48.1

Data was entered and analyzed by SPSS of version 24. P-value < 0.05 was considered significant. Relative risk (RR) and 95% CI (confidence intervals): RR has been calculated for variables as the ratio of the risk of group-1 who were exposed to the risk that group-2 was not exposed to. The relative risk was calculated from the 2×2 table to determine the presence or absence of association between health problems and any of the variables.

7. RESULTS AND DISCUSSION

Demographic characteristics were recorded for 158 participates. The following are the descriptive results: Group-1 (participates living near base stations <100 m) consists of 79 participates (41 male and 38 female). The higher percentage of group-1 was in the age groups (<30 years) (54.4%). In this group, participants with institute or higher education levels represented 49.4%.

Group-2 (participates living away from base stations >500 m) consisted of 79 persons (49 male and 30 female). The 45.6% of group-2 was in the age groups (<30 years). In this group, participants with institute or higher education levels represented 48.1% (Table 3). This result is matched with Lalrinthara [26], who

Table 4. Distribution of participates according to health problems

Variable		Group-1		Group-2		RR	P-value
		No.	%	No.	%		
Abnormalities	Yes	73	92.4	20	25.32	3.65	—
	No	6	7.59	59	74.68		
Skin problem	Yes	61	77.2	10	12.7	6.10	0.0
	No	18	22.8	69	87.3		
Blood pressure issues	Yes	64	81.0	18	22.8	3.55	0.0
	No	15	19.0	61	77.2		
Hair loss issues	Yes	65	82.3	33	41.8	1.96	0.0
	No	14	17.7	46	58.2		
Sleeping difficulties	Yes	38	48.1	25	31.6	1.52	0.03
	No	41	51.9	54	68.4		
Tumors cases	Yes	19	24.1	0		—	0.0
	No	60	75.9	79	100		
Concentration difficulties	Yes	50	63.3	6	7.6	8.33	0.0
	No	29	36.7	73	92.4		
Fertility issues	Yes	40	50.6	8	10.1	5.0	0.0
	No	39	49.4	71	89.9		

found that male groups in their study showed the highest percentage (51.56%) for group-1 and (48.44%) for group-2.

Table 4 shows that the frequency and percentage of participates who reported health problems among the 158 participates and suffered from abnormalities were 73 (92.4%) of group-1 and 20 (25.32%) of group-2. It is worth to note that in group-1, the skin problem was reported by 77.2% of participants, and in group-2 this figure was 12.7%. These results did not agree with the Asian-Indian study, which indicated that the percent of skin problems was 20% [27].

It also showed that participates were currently suffering from blood pressure problems and hair loss was reported by 64 (81%) and 65 (82.3%), respectively, in group-1. In group-2, participates were currently suffering from the above problems were 18 (22.8%) and 33 (41.8%), respectively. Sleeping difficulties were reported by 38 (48.1%) participants in group-1. The current study showed lower results than those in [28], where it was stated that the percent of participates who suffered from sleeping difficulties was 72%. In addition, several studies highlighted the similarly of such associations and considered the mobile tower radiation exposure as an important factor behind sleeping difficulties [29], [30].

Besides, tumor cases were reported by 19 (24.1%). In this study, the results showed a significant association between mobile tower radiation exposure and tumors, which was statistically not significantly identified by another study where it is believed that the specified radiation does not have any impact on human tumors. More than a half of participates in both groups were suffering from memory and concentration difficulties and infertility. Comparable to the results found by the other study, we noticed that the radiation exposure was statistically not significant for infertility, while in that study, it was statistically significant [31]. The difference between the two groups with respect to all items was statistically significant ($RR > 1$, P-value < 0.05), except abnormalities.

Table 5. Distribution of health problems of participates in accordance with distance from towers

Health issues	Distance, m	Yes, %	No, %	RR	P-value
Abnormalities	<50	53.16	5.06	1.0652	0.662
	50–100	24.05	0	—	
	>100	15.19	2.53	—	
Skin problem	<50	50.63	7.6	1.7391	0.030
	50–100	17.72	6.33	1.4737	
	>100	8.86	8.86	—	
Blood pressure issues	<50	44.30	13.92	0.9684	0.249
	50–100	22.78	1.27	2.4828	
	>100	13.92	3.8	—	
Hair loss issues	<50	55.7	2.53	1.0301	0.000
	50–100	10.13	13.92	0.4534	
	>100	16.46	1.27	—	
Sleeping difficulties	<50	37.97	20.25	2.2826	0.001
	50–100	5.06	18.99	0.7368	
	>100	5.06	12.66	—	
Tumors cases	<50	17.72	40.51	0.8522	0.193
	50–100	0	24.05	—	
	>100	6.33	11.39	—	
Concentration difficulties	<50	39.24	18.99	1.8870	0.055
	50–100	17.72	6.33	2.0632	
	>100	6.33	11.39	—	
Fertility issues	<50	27.85	30.38	1.6739	0.032
	50–100	17.72	6.33	2.5789	
	>100	5.06	12.66	—	

In addition, the study showed that the highest frequency of health problems was in Zone-1 followed by Zone-2. There was a significant association between health problems (skin problem, hair loss issues, sleeping difficulties, and fertility issues) and distance to towers (P-value < 0.05). In regards to health problems (abnormalities, blood pressure issues, tumors cases, and memory and concentration difficulties), the obtained results are not statistically significant (P-value ≥ 0.05).

An almost similar result was found in a study conducted in India on 64 adult persons. It showed that those living near base stations (<50 m) were having more health problems than those living away from base stations (>50 m) [32]. Same findings were obtained by N. A. Yekini et al. [33], from Nigeria on studying

Table 6. Average PSD levels at Zone-1

Points No.	Distance, m	PSD, μW/m^2	X-axis	Y-axis
1	1	132936.00	32.512104	45.840961
2	50	101819.00	32.512048	45.841229
3	100	20560.00	32.512228	45.841783
4	150	10480.00	32.512299	45.841668
5	200	8600.00	32.512361	45.841745

Table 7. Average PSD levels at Zone-2

Points No.	Distance, m	PSD, μW/m^2	X-axis	Y-axis
1	1	0.00233	32.982810	05.75047
2	50	0.00451	32.981231	05.75113
3	100	0.00186	32.981313	05.75170
4	150	0.00033	32.983691	05.75176

adverse health effects of mobile phone base stations during 2017. It was found that the radiation of base stations had adverse effects on human health where it could cause sleep disturbances, difficulty in concentrating the attention, memory loss, and skin problems [33]. Table 5 shows the most common side effects after exposure to those low-level RF waves, whether in the long term or short term.

The PSD values for Zone-1 and Zone-2 are displayed in Tables 6 and 7, respectively. That was concerning the distance from cell-phone towers and coordinates for Zone-1 and coordinates and measuring points for Zone-2. The median distance of Table 6 was chosen based on the typical range of residential areas to the cell-phone towers in medium-sized public cities. The X-axis and Y-axis, which are presented in Tables 6 and 7 mean latitude and longitude coordinates of the points, where PSD were measured.

Data analysis showed the lowest values of PSD at a distance of more than 400 m from the nearest base station. It can be noticed that the recorded PSD value is 132936 μW/m^2 at distance of 1 m, while 88 μW/m^2 at distance of 450 m away from the tower. On the other hand, Table 7 indicates many close readings for random points in Zone-2, which are not near cell-phone towers in that area, and that small difference is explained by to the network activity at that time.

8. CONCLUSIONS

In this study along with explaining some information about EMF waves, the effects of two different case studies have been presented and analyzed. The whole EMF measurements were beyond the limits of ICNIRP that is followed by Iraqi authorities.

In comparison, a public survey was held to get the idea behind low-level exposure and its harmful impact on the population. The results showed an increase in both short- and long-term health problems in general.

It can also be noticed from the safety standards discussed above that there is a contrast between these standards and acceptable limits adopted in different countries. In regard of this part, it is recommended that the service providers would keep the signal level below the lowest standard and using new technologies to improve the quality and reduce EMF antenna radiation.

In Al-Kut city, several initiatives can contribute to increasing the level of knowledge of our study by holding workshops, support events such as the World Health Day, and presenting seminars at institutes and universities or distributing a brochure. It is considered that education could be the most vital factor to spread the word and impact people's awareness of this kind of world pollution.

Finally, we can say that to solve the problem of adverse effects of the electrical field on human health it is necessary to facilitate the proscription of the towers from the concentration area of humans in order to reduce the chance of getting infected with disease that may destroy the life. Also, it is necessary to reduce the number of towers, which are used for mobile or communication services in the residence area in order to reduce the diseases.

In addition, there is another solution to reduce the effects of radiated energy by increasing the height of tower for antenna in order to reduce the concentration of the radiated energy and reduce these effects as much as possible. The other solution, which is more effective, is to use other types of frequencies or frequency bands that is less harmful for the human health. This solution will reduce the effects of electromagnetic field of communication towers, and the human health will be safer.

Finally, it can be said that there is a tradeoff between the quality of signal or the power transmitted from the tower and the chance of disease occurring in humans. This means that while reducing the power, the human receives a smaller amount of radiated power, and then the effect of this radiated power will be reduced and consequently lead to the reduction of human diseases.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

ADDITIONAL INFORMATION

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