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Research Article

Evaluation of Electromagnetic Field Pollution Level in Gaziantep City with Geographic Information Systems

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Abstract

The advancement of technology has led to the widespread use of electronic devices, such as cell phones, which generate electromagnetic fields. Factors like population growth and social needs have contributed to the widespread use of these devices. In parallel with this situation, there has been a significant increase in the number of base stations, high-voltage lines, and TV antenna receivers that provide communication. This study evaluated the electromagnetic field pollution levels in Gaziantep using Geographic Information Systems (GIS). 662 base stations were identified in Gaziantep, the city under study. The Open Signal Map application was used to identify the base stations, and GPS was used to pinpoint their locations. Measurements were conducted using the Lutron EMF 839 device, following the 6-minute rule recommended by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). The measurement results were analyzed using the interpolation method in ArcGIS 10.8 software, which estimates values between known data points to determine the electromagnetic field levels in the city. The analysis revealed higher electromagnetic field levels in areas with concentrated base stations than in other areas. Additionally, there was a significant decrease in electromagnetic field values from the center to the periphery. A comparison of the electromagnetic field values in Gaziantep with the ICNIRP and Türkiye's national limit values revealed that they were below the specified limit.

Keywords: Electromagnetic Field, Electromagnetic Field Map, GIS, Gaziantep

Introduction

As technologies like broadcasting and mobile communication systems advance, people encounter radio frequency (RF) and increased exposure to electromagnetic fields (Cansız et al., 2018; Baliatsas, 2012; Schüz and Mann, 1999). Various electronic devices we use daily, such as smartphones and microwaves, emit electromagnetic fields. Electromagnetic field pollution in our surroundings escalates daily due to technological progress (Cansız and Kurt, 2012:103). Electric charges in the environment give rise to magnetic fields (Polat, 2017:11). An electromagnetic field is a collection of waves vibrating at a particular frequency with specific spacing between them (Uygunol, 2009:9). Hence, numerous everyday technological devices, such as cell phones and microwave ovens, emit substantial electromagnetic fields. Devices like base stations, TV transmitters, radio transmitters, microwave ovens, and cell phones contribute to pollution by generating electromagnetic fields (Cansız and Kurt, 2012:103). The electromagnetic field from 30 kHz to 300 GHz is considered high-frequency. High-frequency electromagnetic waves create pollution based on base stations (Karadağ et al., 2014:239-240). Particularly in 3G, 4G, and 5G communication systems, which feature new and advanced high-frequency networks, electromagnetic waves pose significant concerns in living spaces (Lindbohm et al., 1992; Feychting and Ahlbom, 1994). At the beginning of these concerns, although the new generation 3G and 4G base stations have lower output power compared to previous generations, factors such as user-induced, long duration of use, etc., have led to an increase in the effect of waves on living things (Person et al., 2012). Electromagnetic fields can be described as the spread of electromagnetic radiation. Non-ionizing electromagnetic radiation is the energy released through waves or particles (Karadağ et al., 2014:314). The speed of electromagnetic waves caused by electricity and magnetism creates an electromagnetic spectrum at varying wavelengths (Erdin, 1978:157). The electromagnetic spectrum (Ulaby, 2001) classifies electromagnetics based on frequency and intensity.

Electromagnetic fields interact by exerting force on electric charges or ions in the same environment. Since there are biochemical environments and ions in the bodies of living things, electromagnetic fields emitted by cell phones, base stations, electricity transmission and distribution lines, wireless communication tools, and all kinds of electrical and electronic devices and equipment have effects on the human body and other living things (Çerezci, 2012:13). Implications from electromagnetic radiation pollution exposure are in both urban and rural areas which influence human health before conception, during pregnancy, childhood, adolescence and up to adult life (Kelishadi et al., 2013). For this reason, the science of measuring, evaluating and monitoring the exposure levels of electromagnetic field pollution while also qualifying the deterministic effects of such frequencies on human health has become more crucial to the public (Thulu et. al, 2023). The American Academy of Sciences epidemiological studies have revealed that there is an increase in cancer cases in children living in houses near high-voltage lines. Researchers have determined that children residing near high-voltage lines face a 1.5 times

higher cancer risk compared to those in other areas (Seyhan, 2010:160). This situation creates considerable concern among the public about the potential health risks of prolonged exposure to electromagnetic waves emitted from radio base stations in working and living environments. This has led to the need for continuous monitoring and prediction of electromagnetic waves (Giliberti et al., 2009:56).

The International Research Agency has classified the electromagnetic fields generated by cell phones for research purposes. Electromagnetic fields have significant carcinogenic effects on humans (Rodriguez et al., 2012:1536). In 1996, the World Health Organization initiated the Electromagnetic Field Project (EMF) in response to the increasing cases of diseases such as cancer, Alzheimer's, Parkinson's, and Multiple Sclerosis (MS), which correlated with the growing presence of artificial and natural electromagnetic field sources globally (Seyhan, 2010:160). The project aims to evaluate the impact of exposure to static and changing electric and magnetic fields within the 0-300 GHz frequency range on health and the environment. Within the scope of this project,

- Possible health effects of EMF exposure and ensuring coordination at the international level are important considerations,
- Develop internationally acceptable standards for EMF exposure,
- Creating a perception of risk against EMF,
- Advise national authorities, other institutions, the public, and workers on the hazards arising from EMF exposure and the necessary mitigation measures,

are among the main objectives (WHO).

Table 1. Türkiye National 900 MHz and 1800 MHz Limit Values

Frequency	**900 MHz**				**1800 MHz**			
Environment Condition	Single Device Limit Value	Single Device Limit Value	Total Limit Value	Total Limit Value	Single Device Limit Value	Single Device Limit Value	Total Limit Value	Total Limit Value
Electric Field Intensity	10,23 V/m	10.230.000 $\mu W/m^2$	41,25 V/m	41.250.000 $\mu W/m^2$	14,47 V/m	14.470.000 $\mu W/m^2$	58,34 V/m	58.340.000 $\mu W/m^2$

Source: Regulation on the Determination, Control and Supervision of Exposure Limit Values of Electromagnetic Field Intensity from Electronic Communication Devices according to International Standards, 2011.

The EMF project involves 55 participating countries and international organizations. Türkiye has become one of the member countries of the World Health Organization's EMF project, taking into account its main objectives. Istanbul, Ankara, and Izmir have established continuous electromagnetic field measurement stations.

Each country has established its limit values to minimize the harmful effects of electromagnetic radiation and protect people from its hazards. The World Health Organization (WHO) and the internationally recognized International Commission on Non-ionizing Radiation Protection (ICNIRP) have set these limit values based on a 24-hour exposure period, to ensure continuous protection from electromagnetic radiation (Erezci, 2012:17). The Information and Communication Technologies Authority (BTK) in Türkiye has determined the limit values for electromagnetic radiation in the 900 MHz and 1800 MHz frequency bands through regulations. In our country, the accepted limit value for electromagnetic radiation exposure from a single device in the 900 MHz frequency band is 10.23 V/m, with a total limit of 41.25 V/m. In the 1800 MHz frequency band, the limit value for electromagnetic radiation exposure from a single device is 14.47 V/m, with a total limit of 58.34 V/m (Table 1).

This study aimed to identify the areas in Gaziantep city and its immediate surroundings where modern technology's electromagnetic wave level is both dense and sparse. In order to determine the changes in electromagnetic fields, day and night measurements were carried out. Electromagnetic fields were determined using a mobile measurement device, and electromagnetic field pollution maps were prepared by evaluating the measurement results.

Limits and Area Of Study

This study aimed to identify the areas in Gaziantep City that exhibit high and low levels of GSM-based electromagnetic field pollution. The study area is the city center of Gaziantep province, situated in the Middle Euphrates Region of Southeastern Anatolia, bordered by Şanlıurfa, Adıyaman, Kahramanmaraş, Osmaniye, and Kilis provinces, as well as Syria. Gaziantep province consists of Araban, Yavuzeli, Nurdağı, İslâhiye, Şahinbey, Şehitkamil, Oğuzeli, Nizip, and Karkamış districts. The study area comprises the city center of Şahinbey and Şehitkamil districts (Figure 1). In the study area, 662 base stations were identified (Figure 2). The city has a wide distribution of GSM base stations. There is a decrease in GSM base stations from the city center to the periphery (Figure 1).

Material and Method

This study examines the electromagnetic field values emitted by GSM-based base stations for research.

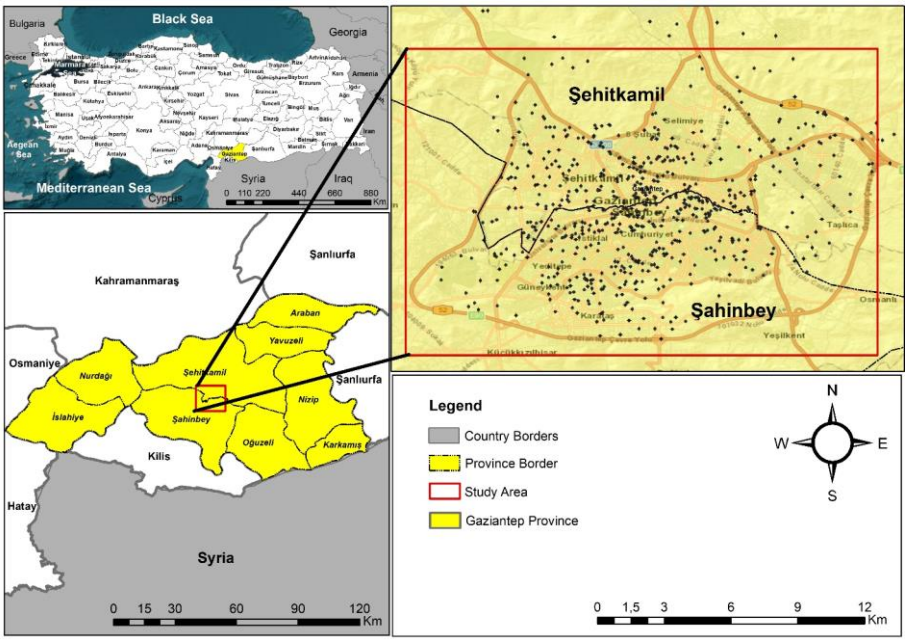

Fig. 1. Location Map of the Study Area

Fig. 2. Base Stations

The Open Signal Map application determined the spatial distribution of GSM-based base stations in Gaziantep city. The Open Signal Map application includes point data of GSM-based base stations worldwide and in Türkiye, as well as their coordinates and a spatial distribution map (Figure 3). A Lutron EMF-839 100 KHz–3 GHz electromagnetic field meter was used to measure the electromagnetic field pollution emitted by GSM-based base stations in Gaziantep (Figure 3). The Lutron EMF-839 electromagnetic field meter has a wide measurement range, measuring radio-frequency electromagnetic fields between 100 kHz and 3 GHz. Measurements with the electromagnetic field meter were conducted at 37 randomly chosen locations within and around the base stations in Gaziantep to assess the field strength. The measurements were conducted over a period in April 2024. Measurements were evaluated for a minimum of 6 minutes at each point. The measurement results were transferred to ArcGIS 10.8 software for spatial analysis and visualization.

The transferred measurement results were processed using the Inverse Distance Weighting (IDW) method, an interpolation figure type. The inverse distance weighting method, a common interpolation technique, calculates values at unknown points based on the distances from known points, emphasizing closer points' influence. The inverse distance weighting method compares a known point with nearby unknown points to estimate values based on their proximity, aiming to find an average value. The inverse distance-weighted method suggests that the correlation and similarity between neighboring values are proportional to their proximity. This relationship can be mathematically represented as a function of the inverse distance between a known point and its neighboring points to estimate values (Canales et al., 2022).

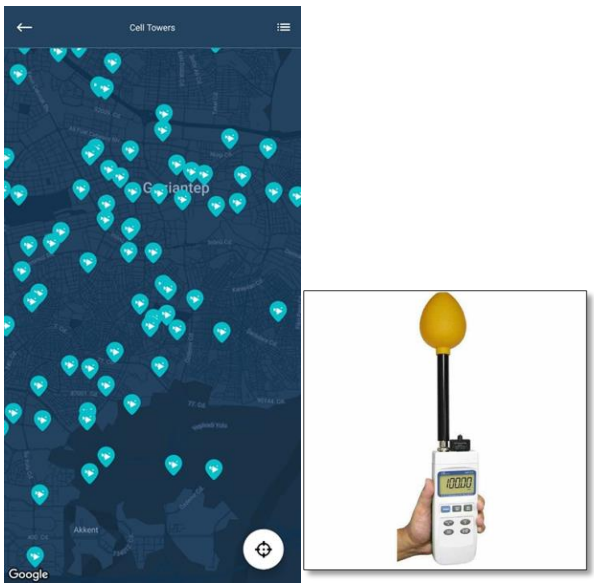

Fig. 3. Example of Base Station Distribution in Open Signal Map Application and Electromagnetic Field Meter

Findings

This study analyzes the spatial distribution of electromagnetic field pollution in Gaziantep city, examining its causes and consequences. The study assessed the level of electromagnetic field pollution by comparing areas with high and low concentrations of GSM base stations in the city.

The Open Signal Map application identified 662 GSM base stations in the Gaziantep city center. These base stations are scattered all over the city. The density of base stations decreases from the city center to the periphery. In the 900 MHz frequency band, the lowest value is 63.214 µW/m2, and the highest is 1.598.750 µW/m2. In the 1800 MHz frequency band, the lowest value is 74.985 µW/m2,

and the highest is 1.785.480 μW/m2. Considering that the 900–2200 MHz frequency bands are generally used by cell phones, it is seen that the electromagnetic field level is higher in the measurement areas numbered 21, 22, 23, 25, 27, 28, and 29 compared to other areas (Table 2). The elevated electromagnetic pollution levels in these areas result from the high usage of cell phones due to the dense human population. Additionally, the proximity of base stations in these areas further increases the pollution levels. The pollution levels decrease as the number of base stations reduces from the city center to the outskirts (Figures 5-6). Although the areas with high electromagnetic field levels are consistent in the 900 MHz and 1800 MHz frequency bands, the intensity varies. The lowest 900–1800 MHz frequency level was measured at points 8 and 37. For the 900 MHz frequency, 63.214 μW/m2 was detected at the eighth measurement point and 63.569 μW/m2 at the 37th measurement point. In the 1800 MHz frequency band, 74.985 μW/m2 was detected at the 36th measurement point and 75.898 μW/m2 at the seventh measurement point (Figures 6–7). The detected electromagnetic field values fall within the ICTA's limit values range. The high electromagnetic field values in certain areas were attributed to the heavy utilization of GSM bands during the measurements. It can be said that using high data flow bands such as 3 G and 4.5 G may also be practical. Due to the dynamic nature of GSM frequency bands, the values may fluctuate throughout the day based on usage intensity. While the level is high during periods of high usage, the level is low during periods of low usage. The intensity of use of the GSM base station directly influences this level. As a result of the measurements made in the study area, they were compared with the limit values set by ICNIRP and Türkiye in the 900 MHz and 1800 MHz frequency bands, and it was determined that the levels were generally below the human exposure limits. Nevertheless, this study specifically evaluated GSM base stations and their immediate vicinity. Other sources of electromagnetic radiation besides base stations include high-voltage lines, transformers, radio television, and wireless transmitters. However, the study only measured the surroundings of GSM base stations and found them within the exposure limit.

Table 2. Measurement Points of the study area, 900 MHz and 1800 MHz

Measurement Point	900 MHz	1800 MHz
1	101.259	136.985
2	95.354	125.412
3	75.985	101.254
4	79.054	125.412
5	89.746	95.898
6	65.985	79.598
7	87.659	102.658
8	63.214	75.898
9	102.365	145.874
10	102.658	145.894
11	153.296	179.854
12	143.224	168.798
13	175.985	198.547
14	181.325	201.549
15	201.369	235.412
16	109.854	149.858
17	354.698	365.984
18	1.235.040	1.359.860
19	1.504.590	1.654.540
20	1.458.740	1.589.850
21	1.102.560	1.159.880
22	1.307.990	1.456.590
23	459.650	498.565
24	985.465	1.032.540
25	1.447.850	1.569.850
26	1.598.750	1.785.480
27	1.032.260	1.069.860
28	896.547	909.854
29	789.854	856.985
30	245.874	265.874
31	159.874	175.985

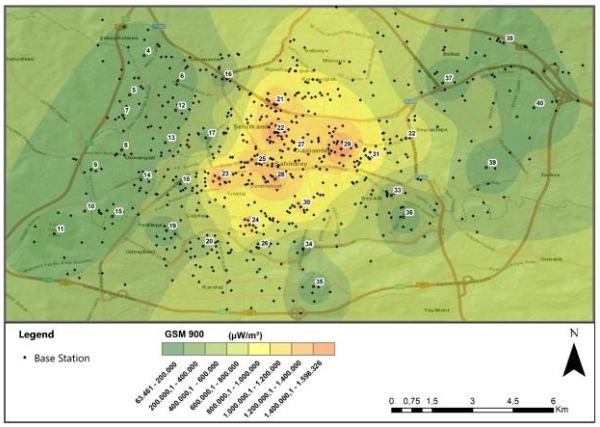

Fig. 5. GSM 900 MHz Frequency Electromagnetic Field Map of the Study Area

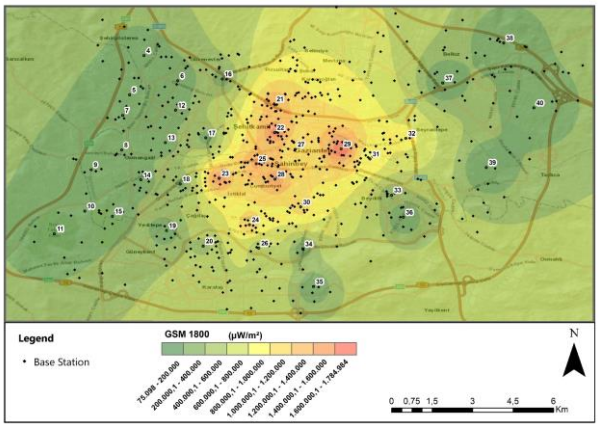

Fig. 6. GSM 1800 MHz Frequency Electromagnetic Field Map of the Study Area

Conclusion and Discussion

The study identified the electromagnetic field pollution from GSM-based base stations in Gaziantep city. Measurements were taken in April 2024 at GSM base stations and the areas directly surrounding them. The measurements were evaluated and analyzed by calculating the 6-minute average determined by ICNIRP.

The highest electromagnetic field level was detected at the 26th measurement point in Gaziantep city's 900–1800 MHz frequency band. At the 26th measurement point, the levels were 1.785.480 µW/m2 at 900 MHz frequency and 1.598.750 µW/m2 at 1800 MHz frequency. The 8th and 37th measurement points recorded the lowest electromagnetic field values in the study area. 63.214 µW/m2 at the 8th measurement point and 74.985 µW/m2 at the 37th measurement point. Seven of the 662 GSM base stations emit higher electromagnetic levels than those in other areas. Especially these 7 GSM base stations are located closer to each other, and there are more base stations around them.

Uygunol and Durduran (2010) evaluate studies similar to this one and conclude that the location selection and design of base stations play a significant role in determining the electromagnetic pollution of Konya City. They recommend further reduction of the determined limit values to safeguard human health. The electromagnetic pollution rate was not dangerous in the electromagnetic field pollution measurement conducted by Dilek and Şahin (2021) at Recep Tayyip Erdoğan University Central Campus. However, a regional evaluation revealed that the intensity of instant use in some areas led to high levels of electromagnetic field pollution. A study by Ünsal et al. (2015) looked at the electromagnetic field radiation map of the Evliya Çelebi campus of Dumlupınar University. They found that the electromagnetic field values were below the ICTA's limit values and did not pose any health risks. The electromagnetic field levels around us in Diyarbakır change constantly, and the measured electromagnetic field values may change from one measurement to the next. This was found in a study by Cansız and Kurt (2012) that used the Drivet test method to map electromagnetic field pollution. It has been determined that devices emitting electromagnetic waves, such as TV and radio transmitters, can increase electromagnetic pollution in the living environment.

Electromagnetic devices emit electromagnetic radiation that is highly harmful to human health. Reducing electromagnetic field levels in areas with high population density is critical. Despite the electromagnetic field level in Gaziantep being below the ICTA's limit values, specific areas still exhibit relatively high levels. Base stations in areas with high electromagnetic field values should have their frequency values checked. Dynamic mapping of electromagnetic pollution and identification of base stations causing pollution are essential. GSM base stations, electric voltage lines, TV, and antenna transmitters, among others, should also be considered due to their potential contribution to electromagnetic pollution. It is essential to strengthen the coverage of transmission lines emitting electromagnetic radiation to improve signal quality and reduce the number of stations to minimize electromagnetic pollution. 1800 MHz and 900 MHz wavelengths are different, with the 900 MHz wavelength being longer due to its lower frequency band. The wavelength is longer for 900 MHz due to its lower frequency band. Therefore, frequencies with longer wavelengths pose a higher health risk. Hence, it is recommended to use base stations with a frequency band of 1800 MHz and above instead of 900 MHz base stations.

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