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Assessment of electromagnetic radiation on human brain at different regions in Al-Najaf city, Iraq

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Abstract
This work points to the study of the effects of Electromagnetic Radiation (Electric and magnetic fields) on human health (Brain) in fifteen different locations divided into three sections: north, middle, and south in Al-Najaf City, Iraq. The practical readings for each location were done using a JD-3001 Geiger counter, a type of dosimeter detector, a portable device from Dongguan Jinlide Electronic Technology Co., Ltd, China.

Two times readings were taken morning and evening. So, the total reading was thirty readings grouped into two groups and continued for two months from September to November 2023. The data were transferred to the computer and stimulated with different programs Microsoft Excel, Geographic Information System (GIS), and Statistical Program for Social Science (SPSS), Then compared with the acceptable limit recommended by ICNIRP, IEEE, and ITU.

The results show that according to the readings of electric and magnetic fields, the minimum values were in Al-Mkrama and Al-Madena for both morning and evening periods. Also, readings of electric and magnetic fields in the evening show that the maximum values were in Al-Ansar and Al-Judayda for the morning readings, and for the evening readings Al-Nidaa and Al-Ameer.

For the power density, the minimum readings in the morning and evening were Al-Makrama and Al-Madena respectively, the main reason is that Power density is related to electric and magnetic fields which means the results conform with each other. On the other hand, the maximum readings of Power density are Al-Nasor and Al-Ameer.

The values of Specific Absorption Radiation (Related to the human brain) at (σ = 0.3300 and σ = 0.0042) were the minimum values in the morning in Al-Makrama and the highest value was in Al-Ansaar. For the evening readings, the minimum value was in Al-Madena and the highest value was in Al-Ameer. The values of Power Density and Specific Absorption Radiation conform with each other, by the correlation relation between them. This means there is a significant relation at $p < 0.05$.

The differences and variance in reading values are related to many reasons some places have an opening place with less distortion of different types of electromagnetic radiation, and some are old that people there do not use a lot of electronic communications or some are old places with many schools and a large number of old buildings. In comparison, others are near the airport and the tawers of communications.

Finally, All values of the Electric field, Magnetic field, Power Density, and Specific Absorption Radiation are low the acceptable recommendation values of 1 mwatt/m^2 and 2 watt/Kg respectively, recommended by ICNIRP, and did not pose any harm to the human body's health.

Keywords: Electromagnetic radiation, specific absorption radiation, power density, human health, Najaf city

Introduction
Concerns regarding the detrimental effects of non-ionizing radiation on human and public health resulting from exposure to electromagnetic fields emitted by certain power, electrical, and wireless devices that are frequently found in homes, workplaces, schools, and communities have been expressed in a number of scientific publications (Mohammadreza Aghaei *et al*. 2012) [1]. Electromagnetic field (EMF) radiation, which is produced when energy-containing photons travel across space. Radiation may be classified into several categories depending on how much energy is present. Ionizing radiation and non-ionizing radiation (NIR) are the two categories into which electromagnetic field radiations fall. Ionizing radiations have enough energy to break the bond between electrons in atoms or molecules, forming ions in the process. X-rays and UV radiation are two types of ionizing radiation (Shashank Vijay 2017) [2].

A sort of energy that radiates or emits energy away from its source is known as non-ionizing radiation. Energy comes in a variety of forms, each having unique physical characteristics that may be quantified and expressed in wavelengths and frequencies. There are three different wave frequencies: high, medium, and low (Mann and Röschke 2004) [3].

The majority of studies on the detrimental effects of non-ionizing radiation on health have focused on three main categories of anthropogenic non-ionizing radiation, which are as follows: First, power lines, electrical appliances, and electronic devices emit very low frequency electromagnetic radiation (EMR) (Mohammed *et al*. 2013) [4]. The second is electrical pollution, which arises from the operation of some electronic devices (like energy-efficient appliances, variable speed motors, plasma televisions, etc.) that can produce frequency signals in the 3-150 kHz range, which then travel through and radiate from the wiring in impacted houses and other structures (A. Sanyal and 2002) [5]. Third, wireless telecommunications equipment including cell towers, wireless phones, antennas, and broadcast transmission towers emit microwaves and radiofrequency waves (Leung *et al*. 2011) [6].

Previous studies have shown that the harmful effects of EMR include humans, animals, plants, and the entire ecosystem (Ziegelberger, Gunde 2020) [7] (Tsai and Hamblin 2017) [8] (Shivanagouda Mudigoudra, Kiran Ragi, Mahesh Kadennavar, Naveen Danashetty, Prashant Sajjanar, Arun Y Patil, Sridhar M 2020) [9] (Pournoori, Delavari H., and Madah 2023) [10] (Pooja Jangid, Umesh Rai and 2022) [11] (Manana Kachakhidze 2023) [12]. It is also clear that many international organizations concerned with environmental affairs and developed countries consider electromagnetic radiation as a type of environmental pollution (EP). Therefore, it established specifications and enacted laws to limit its harmful effects on humans health. The recenct study focuse on assessment of electromagnetic radiation in different regions in Al-Najaf City, Iraq.

Materials and Methods

Area of Study

Najaf is a city with a population of 1,500,522 people (According to 2017 statistics). Its geographical area is 28,824 square kilometers, and it lies within a longitude of 44º19' E and the latitude of 31º59’ N and is 70 meters above the mean sea level (K. Abdulkareem 2018) [13]. The city of Najaf is one of the most important administrative centers in the holy city of Najaf. To its north lies the city of Al-Haydariyah at a distance of (40 km), and from its east is the city of Kufa, at a distance of (10 km), and adjacent to it from the southeast is located the city of Al-Manazira at a distance of (25 km), while the course of the Euphrates River lies on its western side (Hussein *et al*. 2020) [14], as shown in figure (1).

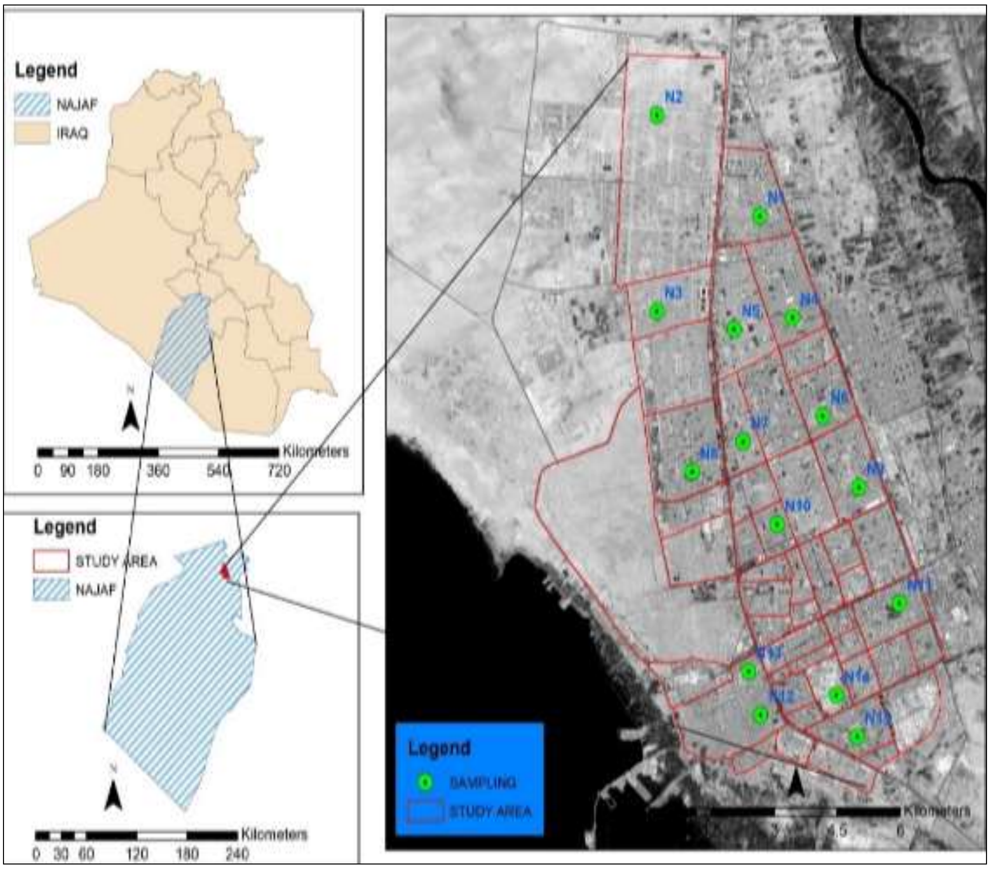

Fig 1: Najaf City Area

Collection of Readings

Thiry recorded readings were collected to be studied in this research, fifteen were recorded in the morning and the other fifteen were in the evening for the same location for Najaf city using a dosimeter detector named JD-3001 Geiger counter, during September and November 2023, then took the average readings for each location (day and night) to estimate the electromagnetic radiation. The data in Table (1.1) is stimulated with GIS and SPSS programs to show the variations of electromagnetic radiation for the area under study.

Table 1: Names of locations with sample codes and coordinates.

Sample Name	Location Name	Coordinates	
N1	Al-Makrama	32°03'18.8"N	44°19'33.9"E
N2	Abo-Talib	32°01'33.8"N	44°18'55.6"E
N3	Al-Nidaa	32°03'24.0"N	44°18'22.6"E
N4	Al-Nasor	32°01'33.8"N	44°18'55.6"E
N5	AL-Saad	32°00'06.1"N	44°20'27.0"E
N6	AL-Ameer	32°00'21.4"N	44°21'31.8"E
N7	AL-Mualemeen	31°59'36.5"N	44°20'24.7"E
N8	AL-Wafaa	32°03'21.1"N	44°20'36.9"E
N9	AL-Zahraa	31°59'55.5"N	44°21'53.5"E
N10	AL-Quduss	32°00'06.4"N	44°22'22.2"E
N11	AL-Ansaar	31°59'01.4"N	44°21'34.4"E
N12	AL-Judayda	31°59'25.4"N	44°20'01.2"E
N13	AL-Madena	31°59'38.2"N	44°18'54.6"E
N14	AL-Hanon	31°59'04.1"N	44°20'26.1"E
N15	AL-Shorta	31°58'53.3"N	44°19'49.2"E

Detection System: There are several types of detectors such as a gaseous detector, solid-state nuclear track detectors, semiconductor detectors, etc. The factor that determines the most suitable type of detector depends on the type of sample and auxiliary equipment in the laboratory. In this study, a modern dosimeter detector called a Geiger counter was used with specific properties.

Geiger counter: JD-3001 Geiger counter is a type of dosimeter detector. It's a portable device from Dongguan Jinlide Electronic Technology Co., Ltd, China. The operating system of the device for temperature: (0 °C - 50 °C), humidity: (RH 10% - RH 80%). The most important property of the device is that switching between nuclear radiation and electromagnetic radiation. In addition, the two types of radiations could be calculated at the same time according to the adjustment of the device, also the time adjusted for five minutes as shown in figure (2).

Fig 2: JD - 3001 Geiger counter

The nuclear response time is three seconds, dose rate response: is < ± 20% (1 µSv/h - 99.99 mSv /h), and energy response: is < ± 30% (48 Kev - 1.3Mev). For electromagnetic radiation, the precision: (electric field: 1V/m; magnetic field: 0.01µT), the alarm threshold value: (electric field: 50 V/m; magnetic field: 0.3µT), the range: (electric field: 1V/m - 1999 V/m; magnetic field: 0.01µT-999.99µT). The power supply is built in a 3.7V lithium battery and it can be charged with cable or to the laptop device. It can detect electromagnetic waves emitted by general electrical appliances, such as computers, televisions, mobile phones, microwave ovens, and other commonly used electrical appliances. Anti-interference ability, capable of reliable operation in complex electromagnetic environments. Also, the device is provided with a cable to transfer data from the device to the computer as Excel data.

Mathematical Equations

To study the effect of electromagnetic radiation on human health two important parameters must be included which are power density (PD), and specific absorption radiation (SAR) these two parameters focus on the effect of electromagnetic radiation on the brain, that computed according to an international recommended values of 2 watt/Kg and BL of 0.001 (Dhami 2011, Union 2021) [15, 16], as follows (Admawi 2021) [17]:

$$S = E \times H = \frac{E^2}{377} \quad (1)$$

$$SAR = \frac{\sigma |E|^2}{\rho_b} \quad (2)$$

Where

S = PD (mW/m^2).

E = Elctric field strength (V/m).

H = Magnetic field strength (A/m).

SAR = Specific Annual Radiation.

σ = conductivity of the human brain tissue $\frac{1}{omh \ x \ m}$.

ρ_b = Mass density of human brain tissue (kg/m^3).

Results

The current research focused on calculating PD and SAR by knowing the values of electric and magnetic fields to find the effect on the human brain, then copared these values with the biological limit (BL) and ICNIRP. Also, it uses GIS technical program and SPSS for mapping and drawing electromagnetic radiations and related parameters for all samples under studyAn important statistical calculation were found by using SPSS program (for both readings day and night) such as: Mean, Median, Mode, Standard Deviation, Variance, Range, Minimum, Maximum, Sum. This is connected with correlations between all variables which are: temperature, humidity, electric field and magnetic field.

Calculate of Electric and Magnetic Field

The values of the electric and magnetic field were taken directly from the JD-3001 Geiger counter and for all thirty readings (day and night), as shown in table (2) and table (3), as a set to find PD, SAR, and BL for each location under study, then compared with international values by (ICNIRP). Also, maps with GIS programs are drawn for electric and magnetic fields for the area under study as shown in figures (3) and (4).

Table 2: Electric and magnetic fields of samples in the morning.

Sample Name	Temperature (C)	Humidity (%)	Electric Field (v/m)	Magnetic Field (uT)
N1	31.2	32.8	28.25	2.49
N2	35.6	27.1	35.25	3.35
N3	40.0	23.7	38.25	3.45
N4	32.5	28.2	34.75	3.28
N5	35.6	25.2	36.25	3.60
N6	33.6	28.3	33.75	3.30
N7	36.4	24.5	37	3.39
N8	37.9	23.6	38	3.40
N9	32.7	35.8	34.5	3.05
N10	35.4	30.6	37.5	3.48
N11	39.6	28.1	39	3.69
N12	31.5	32.6	30.75	3.98
N13	32.5	30.0	38	3.38
N14	33.0	31.0	36.25	3.45
N15	32.9	30.0	38	3.23
Mean	34.7	28.8	35.70	3.37

Table 3: Electric and magnetic fields of samples in the evening.

Sample Name	Temperature (C)	Humidity (%)	Electric Field (v/m)	Magnetic Field (uT)
N1	33.3	29.2	35	2.92
N2	33	30.4	35.5	3.30
N3	32.9	30.1	35	3.37
N4	33	37.9	34.5	3.00
N5	29.5	47.3	27.25	2.36
N6	33.2	38.7	38.25	3.27
N7	28.4	51.1	26.5	2.47
N8	31.3	42.5	31.75	2.69
N9	31.7	54.6	32.25	3.32
N10	30.9	52.8	29.25	2.60
N11	29.3	46.8	25.75	2.19
N12	26.5	44.5	26.25	2.08
N13	26.6	44.5	24.5	1.81
N14	26.4	43.3	25.25	1.86
N15	28.8	47.1	30.25	2.32
Mean	30.3	42.7	30.48	2.64

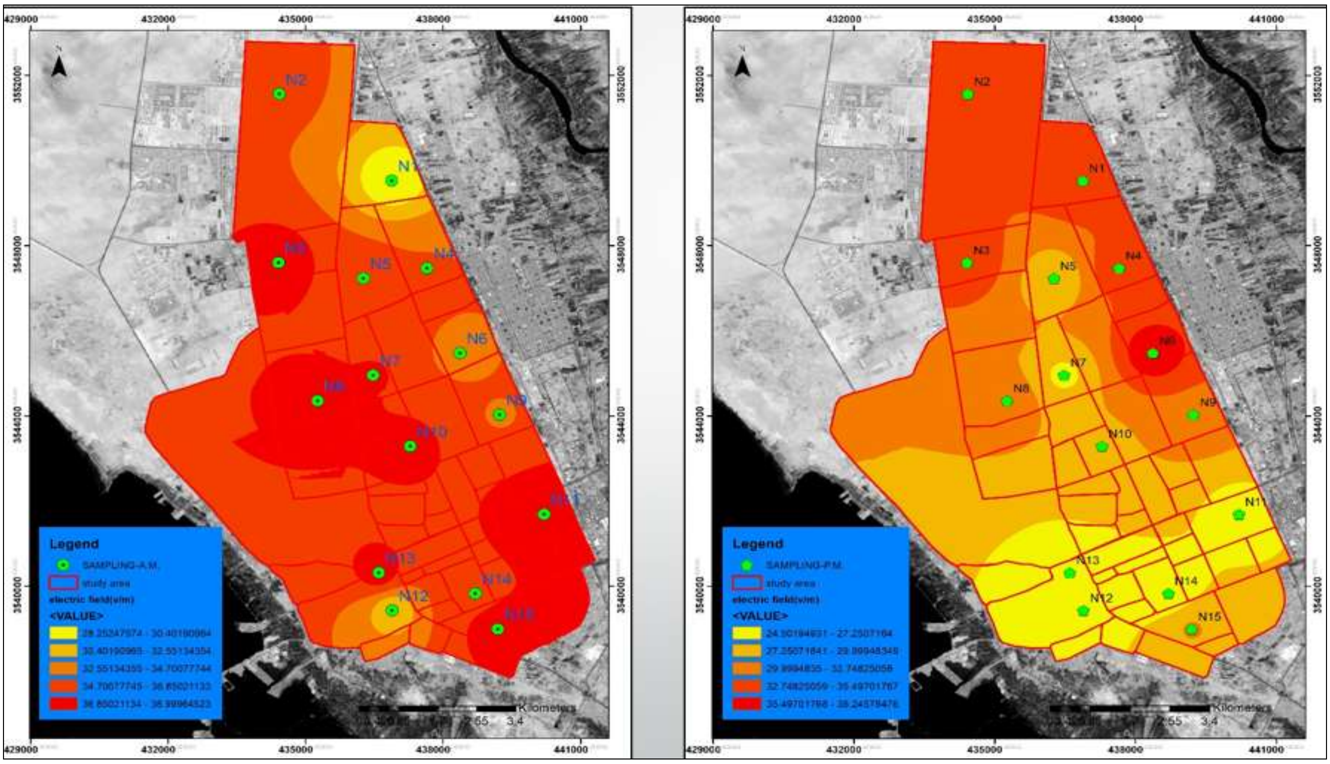

Fig 3: GIS Maps for an Electric Field in the Morning and evening

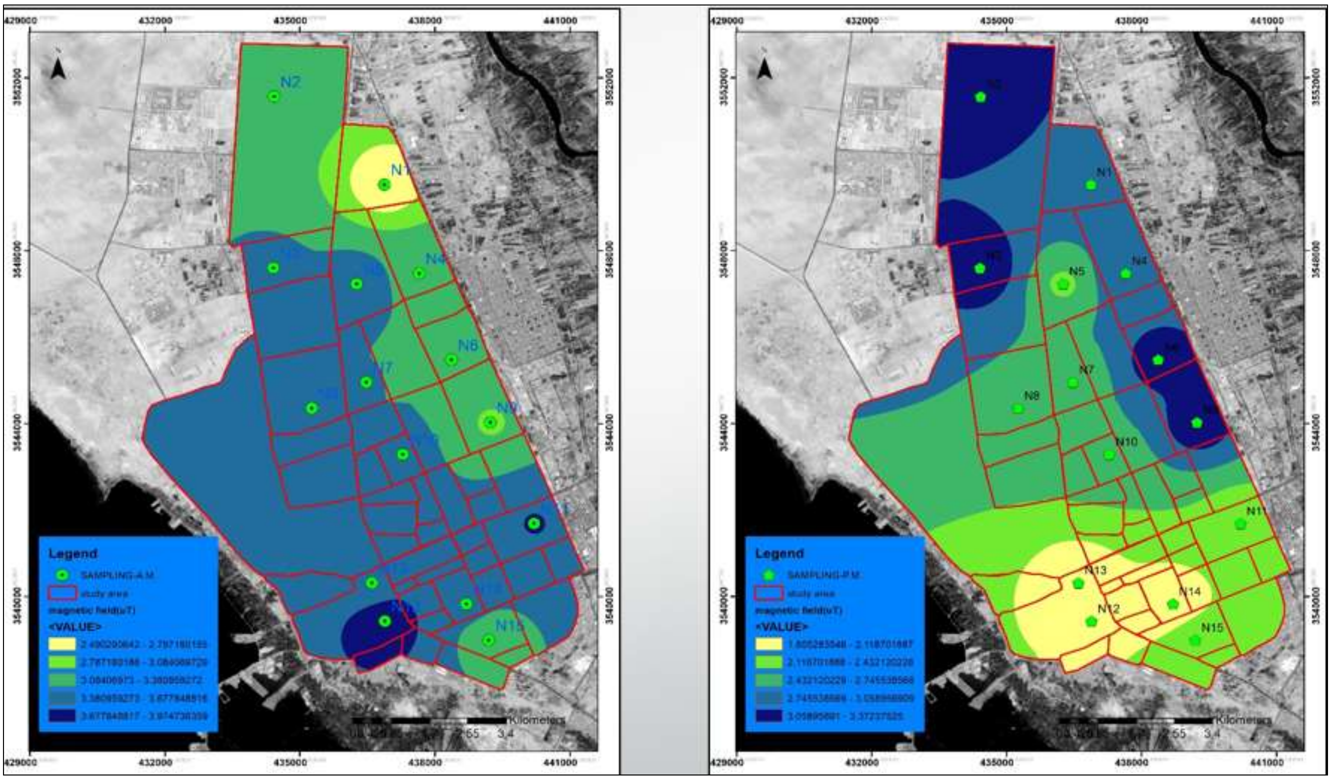

Fig 4: GIS Maps for Magnetic Field in the Morning and evening

Calculate of Power Density (PD)

The values of power density are found by using equation (1), as mentioned in chapter two, these values are for both electric and magnetic fields, as shown in table (4) below to find the maximum and minimum values and then compared with international health institutions (Union 2021) [16].

Calculate Specific Annual Radiation (SAR)

The values of Specific Annual Radiation (SAR) is found by using equation (2), these values are for both of day and night, as shown in tables (5) and table (6) below to find the maximum and minimum values and then compared with international health institutions (ICNIRP 2022, Matthes *et al*. 1998) [18, 19].

Table 4: Values of PD in morning and Evening.

Sample Name	PD (mwatt/m^2) at Morning	PD (mwatt/m^2) at Evening
N1	0.070	0.102
N2	0.118	0.117
N3	0.132	0.118
N4	0.114	0.104
N5	0.131	0.064
N6	0.111	0.125
N7	0.125	0.066
N8	0.129	0.085
N9	0.105	0.107
N10	0.130	0.076
N11	0.144	0.056
N12	0.122	0.054
N13	0.129	0.044
N14	0.125	0.047
N15	0.123	0.070

Table 5: Values of SAR for (EEG) at Morning.

Sample name	SAR (EEG) watt/Kg at 0.3300	SAR (EEG) watt/Kg at 0.0042
N1	0.2532	0.0032
N2	0.3943	0.0050
N3	0.4642	0.0059
N4	0.3832	0.0049
N5	0.4170	0.0053
N6	0.3614	0.0046
N7	0.4344	0.0055
N8	0.4582	0.0058
N9	0.3777	0.0048
N10	0.4462	0.0057
N11	0.4826	0.0061
N12	0.3000	0.0038
N13	0.4582	0.0058
N14	0.4170	0.0053
N15	0.4582	0.0058

Table 6: Values of SAR for (EEG) at Evening.

Sample name	SAR (EEG) watt/Kg at 0.3300	SAR (EEG) watt/Kg at 0.0042
N1	0.3887	0.0049
N2	0.3999	0.0051
N3	0.3887	0.0049
N4	0.3777	0.0048
N5	0.2356	0.0030
N6	0.4642	0.0059
N7	0.2228	0.0028
N8	0.3199	0.0041
N9	0.3300	0.0042
N10	0.2715	0.0035
N11	0.2104	0.0027
N12	0.2186	0.0028
N13	0.1905	0.0024
N14	0.2023	0.0026
N15	0.2904	0.0037

Discussion

In this study, the values for all variables which are: Temperature, humidity, Electric field, Magnetic field, Power Density, and Specific Annual Radiation were used to find their values and study the relation between them, then compared with the acceptable limit recommended by ICNIRP. In the same time all values were drawn and described by SPSS, version 28.0.

For electric and magnetic fields, from tables (2) and (3), the electric field in the morning the minimum value is 28.25 v/m which is N1 in (Al-Makrama) and the maximum value is 39 v/m in N11 for (Al-Ansaar), while in the evening the minimum value is 24.5 v/m which is N13 in (Al-Madena) and the maximum value is 38.25 v/m in N6 at (Al-Ameer). At the same time, for the magnetic field in the morning, the minimum value is 2.49µT in N1 for (Al-Makrama) and the maximum value is 3.98µT in N12 at (Al-Judayda), on the other hand for the magnetic field in the evening the minimum value is 1.81µT at N13 in (Al-Madena) and the maximum value is 3.37µT at N3 in (Al-Nidaa). Figure (5) shows the histogram distribution of Electric and Magnetic Fields at day and night for all areas under study.

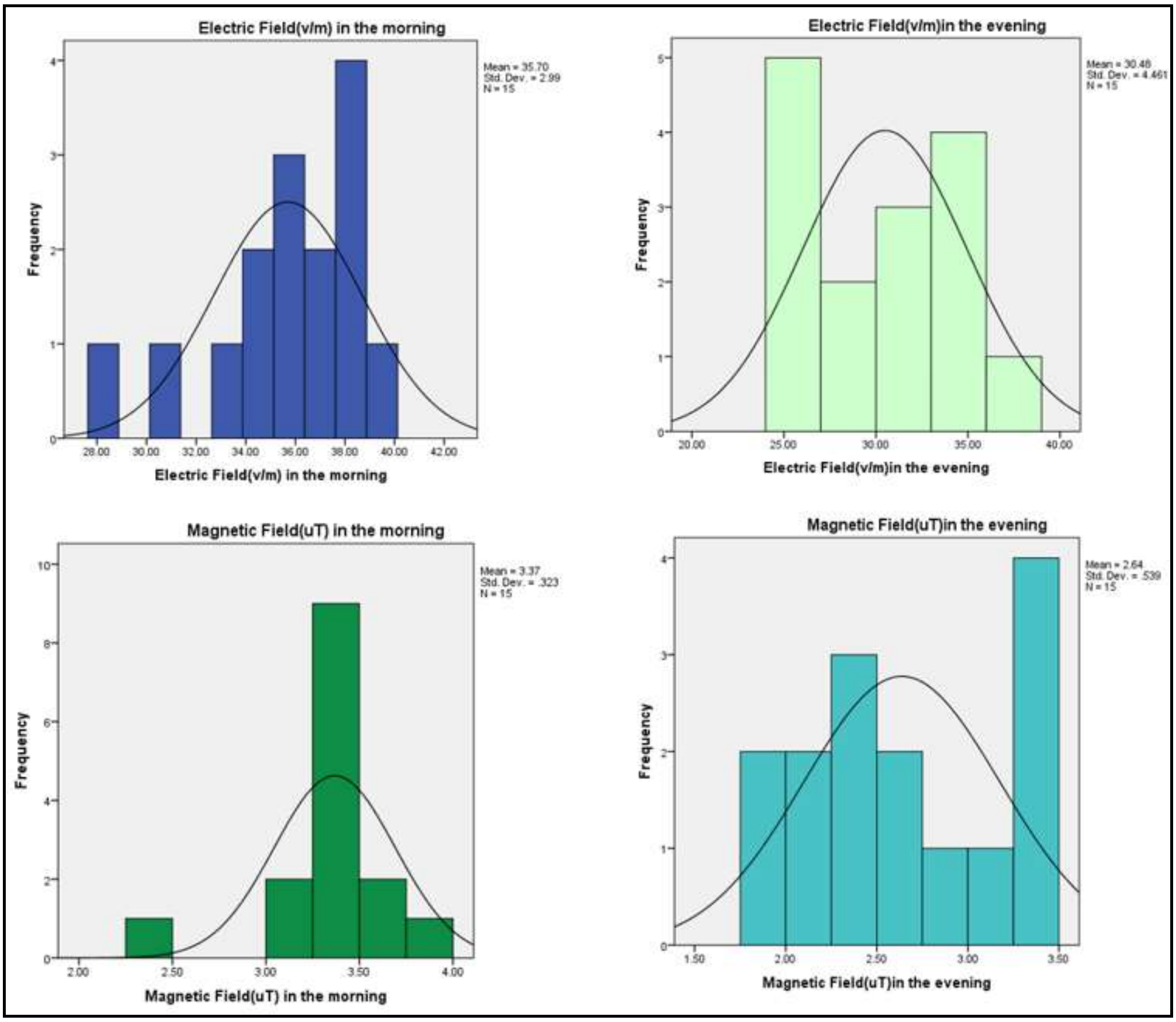

Fig 5: Histogram distribution of Electric field and Magnetic Field at day and night.

In the same time, from table (4) the minimum value of PD in the morning is 0.070 mwatt/m^2 which is N1 in (Al-Makrama), while the maximum val0.114 mwatt/m^2 which is N4 in (Al-Nasor).on the other hand, for evening readings the minimum and maximum values are 0.044 mwatt/m^2 and 0.125 mwatt/m^2 and which are N13 and N6 in (Al-Madena) and (Al-Ameer) respectively. Figure (6) shows the histogram distribution of Power Density in the morning and evening.

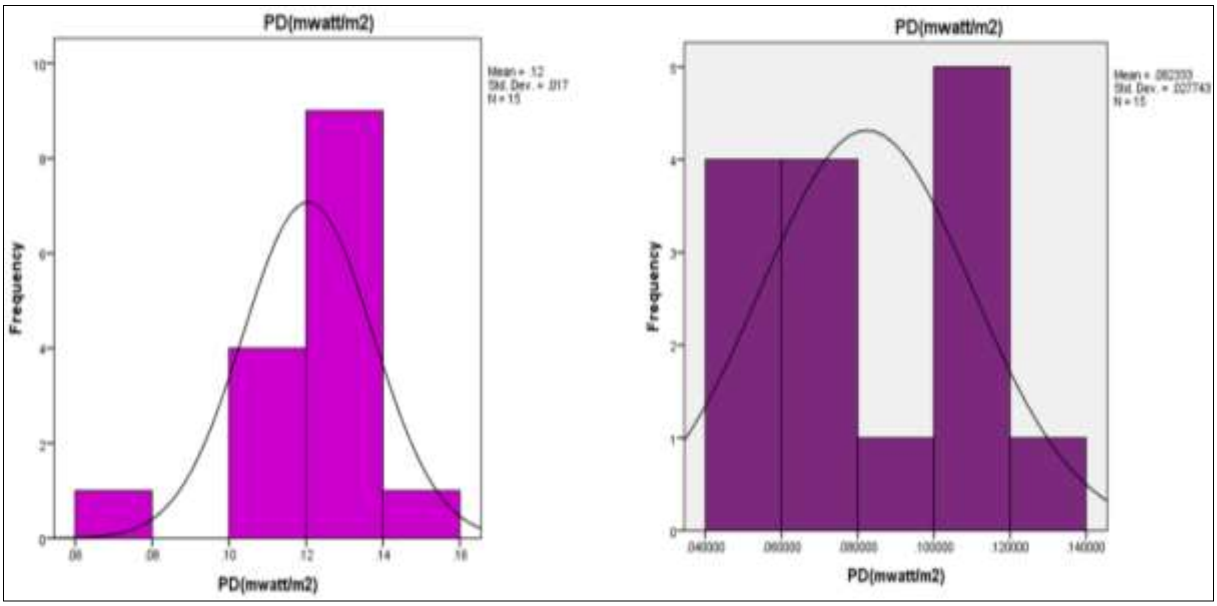

Fig 6: The histogram distribution of Power Density in the morning and evening

Also, according to tables (5) and (6), the minimum and maximum values of SAR for σ = 0.3300 in the morning are 0.2532 watt/Kg and 0.4862 watt/Kg for N1 and N11 which are (Al_Makrama) and (Al-Ansar) respectively. The value of SAR in the evening is 0.1905 watt/Kg and 0.4642 watt/Kg which is N13 and N6 in (Al-Madena) and (Al-Ameer) respectively. The minimum and maximum values of SAR for σ = 0.0042 in the morning are 0.0032 watt/Kg and 0.0061 watt/Kg for N1 and N11 which are (Al_Makrama) and (Al-Ansar) respectively. The value of SAR in the evening is 0.0024 watt/Kg and 0.0059 watt/Kg which are N13 and N6 in (Al-Madena) and (Al-Ameer) respectively. Figures (7) and (8) show a histogram distribution of Specific Annual Radiation with σ = 0.3300 and σ = 0.0042 in the morning and evening respectively.

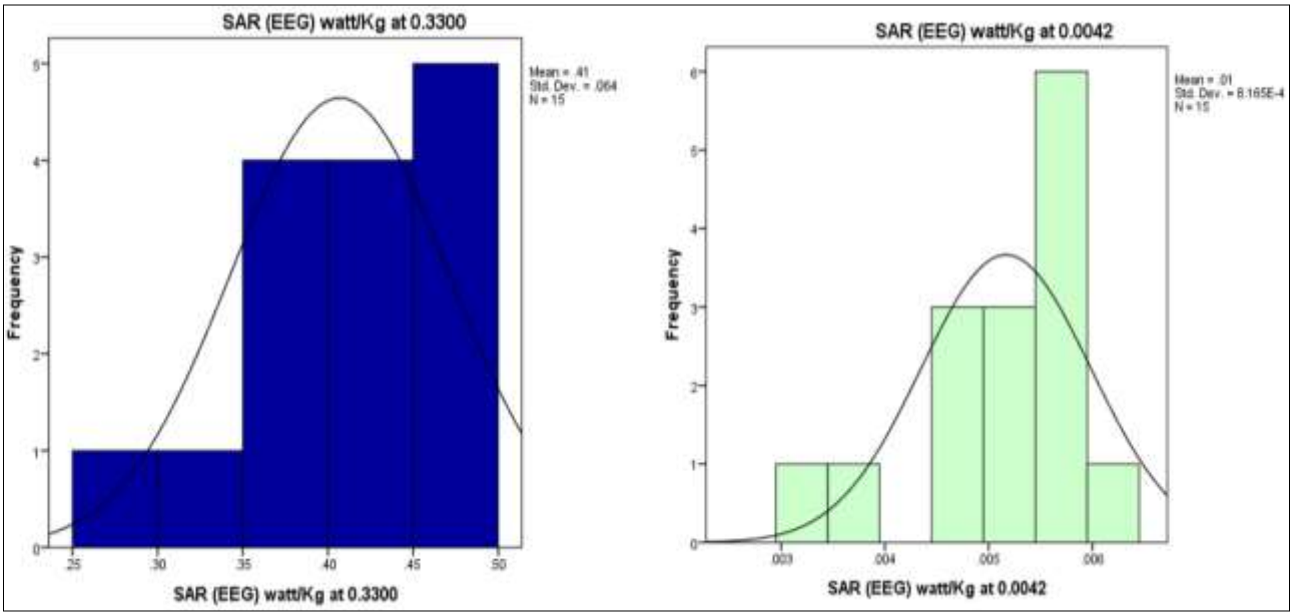

Fig 7: Histogram distributions of Specific Annual Radiation with σ = 0.3300 and σ = 0.0042 in the morning

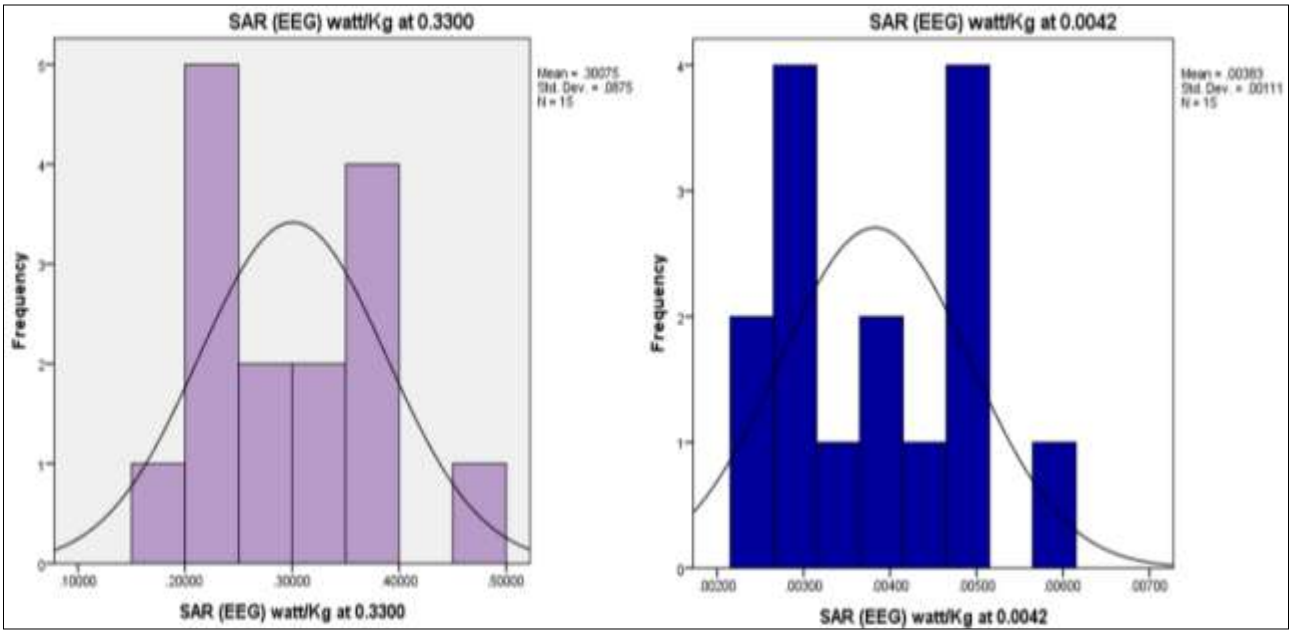

Fig 8: Histogram distributions of Specific Annual Radiation with σ = 0.3300 and σ = 0.0042 in the Evening

Conclusion

During the work of the current study, the following conclusions were reached:

1. According to the readings of electric and magnetic fields, the minimum values were in Al-Mkrama and Al-Madena for both morning and evening periods, this may be for the first place is an opening place with less distortion of different types of electromagnetic radiation and the second place is old that people there did not use a lot of electronic communications. All values were below the international limit.
2. Also, readings of electric and magnetic fields in the evening show that the maximum values were in Al-Ansar and Al-Judayda for the morning readings, and for the evening readings Al-Nidaa and Al-ameer, this may be related to many reasons such as the first place is near the airport and the tawers of communications, and the second place is an old place with many schools and a large number of old buildings. All values were below the international limits.

3. The relation between temperature and humidity with electric and magnetic fields shows that according to the tables and correlation relations, humidity had an effect on the electric field which means there is a significant relation at $p < 0.05$, but no effect on the magnetic field which means there is no significant relation at $p < 0.05$.
4. For the power density, the minimum readings in the morning and evening were Al-Makrama and Al-Madena respectively, the main reason is that PD is related to electric and magnetic fields which means the results are conforming with each other. On the other hand, the maximum readings of PD are Al-Nasor and Al-Ameer, this is because the first place is conforming with maximum readings of electric and magnetic fields, but the second place is the variance between areas and using different communication devices. All values of PD are low the acceptable recommendation values of 1 mwatt/m^2 by ICNIRP and ITU.
5. The values of SAR at ($\sigma = 0.3300$ and $\sigma = 0.0042$) were the minimum values in the morning in al-Makrama and the highest value was in Al-Ansaar, and for the evening readings, the minimum value was in Al-Madena, and the highest value in Al-Ameer.
6. The values of PD and SAR conform with each other, this could be proved by the readings value from the table and drawings, and by the correlation relation between them. This means there is a significant relation at $p < 0.05$.

Finally, all values were under recommaned limits and did not poss a harmful to the people.

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