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Using Geographical Information System for Electromagnetic Fields Environmental Pollution Mapping (Applied Study in Baghdad City)

Jawad Abdulkadhim Alaboudi , Mohamad T. Hamza, Alaa M. Hammadi and Adnan H. Afaj

Environment and water Directorate, Ministry of Science and Technology.

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ABSTRACT

The development of new technology increases the exposure level to non-ionizing EMF radiations. Recent development of spatial data management in the framework of GIS has created a new trend of environmental mapping. In this work, maps for different EMF sources have been developed for the Baghdad city using Arc Map GIS version 10, the utilization of such spatial analysis maps is very important for future planning and EMF exposure assessment studies. Statistical analysis for measurement data was made using IBM SPSS Version 20. The maximum contribution of EMF exposure was referred to FM radio stations and GSM mobile base station due to high power transmitters and large number of base stations, maximum EMF strength caused by FM radio stations was 10.2 (V/m) and the average exposure level 3.578 (V/m). High-level exposure values unveil the necessity of imposing new recommendations and limits concerning stations site selection and reducing exposure levels in residential areas as low as possible.

Introduction

People are exposed to many sources of non-ionizing radio frequency (RF) electromagnetic fields (EMF) including radio and TV transmitters, telecommunications links, and satellite communications as well as mobile phones and their supporting transmitters base stations. There is a great concern expressed about possible health effects associated with exposure to such non-ionizing EMF radiations. International guidelines have been issued to protect professional workers and the public from short-term high level EMF exposure (1, 2, 3, 4 and 5).

To avoid the excessive exposure in a certain area, environmental geographical maps for EMF exposure level and distribution to be known. During the last years employment of GIS extended from topographical surveys to environmental applications, GIS has been created in order to show some thematic maps, which represent the distribution of EMF pollution (6).

The using of GIS for the evaluation of EMF effects from Iraqi 132KV electrical transmission system was introduced in 2011 (7). Samples of 132KV high voltage transmission lines are selected for calculation of magnetic and electric field levels and compared with ICNIRP (International Commission on Non-Ionizing Radiation Protection) standard limits. GIS maps are introduced for visually highlight the unsafe zones in proximity of lines.

Materials and Method

Fields measurements have been implemented in the Iraqi capital city (Baghdad) which was selected as a sample of the study area. The study area was converted into a virtual mesh by subdividing into smaller square areas, the mesh density varied according to the required accuracy as more dense required when high gradient EMF exposure level is expected. The measurements are implemented in the interception points of the mesh lines to produce a regular distribution of data.

EMF field strength measurements are made using a calibrated spectrum analyzer type (SPECTRAN HF-6065) with (hyper LOG) measuring antenna type (AARONIA 7060). Geographical locations in decimal degree are measured using Garmin GPS type (GPS62st), the required statistical analysis for measurements is implemented using IBM SPSS Version 20.

The inverse distance weighted (IDW) interpolation spatial tool has been used for EMF exposure level calculation in unknown areas. IDW is the process of estimating an unknown value by using values that are already known.IDW method is widely used in GIS atmosphere analysis applications, the reason behind that is less distortion with high accuracy maps obtained when enough measuring points are available (8).

Data analysis

The EMF radiation exposure metrics have been considered as: the electric-field strength E (V/m), the power density S (W/m^2), furthermore, exposure ratios (ER) and average contributions(AC) and maximum contributions(MC) are defined. The exposure ratio ER of an EMF radiation exposure is defined as the ratio between the maximum measured electric field value for the considered exposure type over the total locations and the corresponding ICNIRP reference level (L_E):

$$ER = 100 * \frac{\max_{i=1..N}(Ei)}{L_E} (\%) \quad (1)$$

With the maximum value over N locations when considering all data, Ei (V/m) is the field strength of an EMF radiation exposure type at location i, respectively, L_E the corresponding ICNIRP reference levels for electric-field strength in (V/m), a ratio smaller than 100 % means that ICNIRP reference levels are satisfied. The exposure ratio can also be defined with respect to power densities (ERs).

Tele:

E-mail address: jawadkadhim66@yahoo.com

$$ER_S = 100 * \frac{\max_{i=1\ldots N}(S_i)}{L_S} \%$$ (2)

With the maximum value over N locations, Si (W/m^2) the power density of EMF radiation exposure level at location i, and LS the corresponding ICNIRP reference levels in (W/m^2).

The percentage of average contribution (AC) and maximum contribution (MC) of power density for each EMF source to the total power density value are defined as the average and maximum of the ratio of the power density of each source and the total exposure:

$$AC = 100 * \underset{i=1\ldots N}{Av.}\left(\frac{S_{source,i}}{S_{tot}}\right) \%$$ (3)

$$MC = 100 * \underset{i=1\ldots N}{Max}\left(\frac{S_{source,i}}{S_{tot}}\right) \%$$ (4)

AC and MC represents average and maximum contribution over each EMF source type, S*source,i*(W/m^2) the power density of an EMF source at a location i, and S*tot* (W/m^2) is the total power density for all EMF sources at location i.

The total exposure ratio ER*tot* is defined as the maximum cumulative ratio between total electric field values in an environment (we have one urban residential environment in this study) and the corresponding ICNIRP reference levels (1).

$$ER_{tot} = 100 * \max_{i=1\ldots N}\left(\sqrt{\sum_j \frac{E_{j,i}^2}{L_j^2}}\right) \%$$ (5)

With the maximum value over N locations per environment, E*j,i*(V/m) the total field strength EMF radiation exposure level (total field strength at each GPS location), jis exposure type present at the location i and L*j* the corresponding ICNIRP reference level. ER*tot* is thus the maximum cumulative ratio for multiple exposure type (9).

Results and Discussions

The data analysis algorithm was applied by using formulae in equations 1 to 4, the results are shown in table 1. Equation 5 reveals to a maximum cumulative ratio equal to 37.85, the maximum contribution of EMF radiation exposure in Baghdad refer to relatively high power FM radio transmitters to and due to the large number of GSM900 mobile phone base stations distributed throughout measurements area, hence, the total contribution is a function of the transmitted power and the total number of transmitters in the study area (10).

The GIS algorithm shown was applied to the measurement results of MOST (Ministry of Science and Technology) location as a sample for selected secondary zones which simulates the application of the same algorithm to any civilian or industrial areas.

The GSM900 EMF exposure in MOST shown in figure 1, the high level exposure area represents the location of recently installed GSM900 base station above technical affairs office, this area around 22500 m^2, this area should be signed with hotspot exposure zone alarm warning milestones.

All precautionary measures must be taken into account in high level exposure zones to reduce the possible adverse health and environmental impacts (11, 12).

The other relatively high level exposure areas represent the effect of EMF reflections due to artificial obstacles such as buildings, water tanks, and other metal objects. The UHF and VHF TV local ground stations EMF exposure was shown in figures 2 and 3, the EMF exposure from VHF TV stations were seven times greater than EMF exposure caused by UHF TV

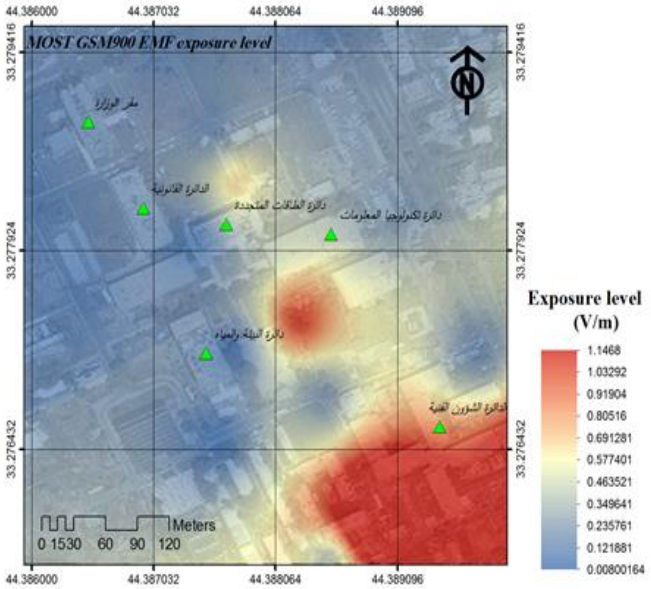

Figure 1. GSM900 EMF exposure level in MOST location.

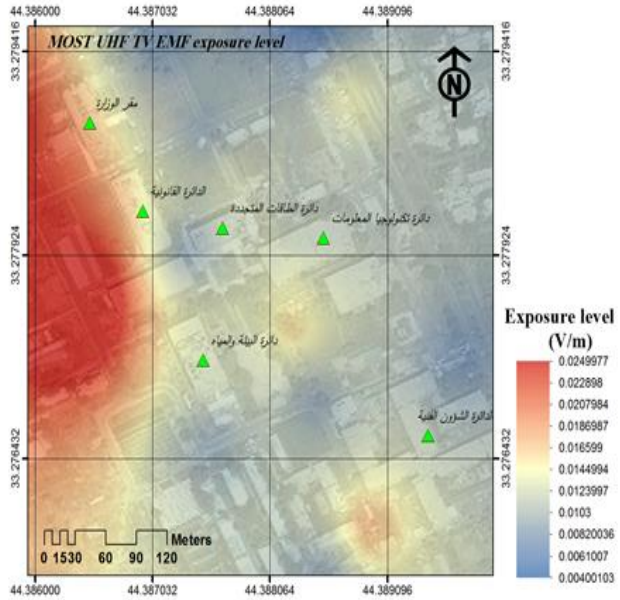

Figure 2. UHF TV stations EMF exposure level in Most.

Table 1. Measurements data analysis results.

EMF source	E_{min}, V/m	E_{max}, V/m	L_E, V/m	E_{av}, V/m	ER, %	ERs, %	AC, %	MC, %
GSM900	0.008	1.147	41.3	0.323	2.77	0.077	36.15	99.81
GSM1800	0.001	1.253	58.3	0.492	2.15	0.046	35.45	83.47
Wi-Fi	0.001	0.096	61	0.013	0.16	2.47e-4	2.39	34.37
AM radio	0.0001	0.15	43	0.015	0.35	0.0012	4.58	77.55
FM radio	0.003	10.6	28	3.578	37.8	14.3	76.75	100
VHF TV	0.001	0.504	27.5	0.063	1.83	0.0336	4.94	28.1
UHF TV	0.001	1.15	41	0.097	2.8	0.078	14.82	94.82

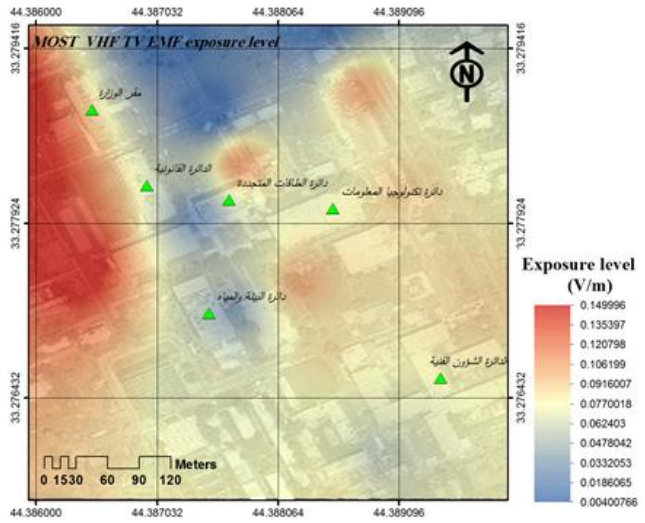

Figure 3. VHF TV stations EMF exposure level in MOST.

stations due to the direct line of sight between MOST geographical location and Al-Hurra TV station broadcasting transmitters tower which is located above Sheraton hotel building, both VHF and UHF EMF exposure levels are lower than GSM900 EMF exposure level in MOST location. The EMF exposure level assessment in Baghdad city has been produced by different radiation sources as a sample for large area EMF exposure assessment. FM radio stations EMF exposure level map for Baghdad is shown in figure 4, the figure showed there are four hotspot of high level exposure areas: two located in the eastern part of Baghdad representing a number of FM radio station located relatively close to gather, the other two hotspots are located in the western part of Baghdad with the same interpretation of the two previous hotspots. Figure 5showed the UHF TV broadcasting exposure level in Baghdad in a form of EMF cloud over the city center. Figure 6 showed the VHF TV broadcasting EMF exposure level in Baghdad, the exposure level reveals to the effect of Al-Hurra and Al-Salam TV broadcasting stations as they are two main VHF EMF sources. The statistical analysis of FM station is shown in table 2,figures 7 and 8, the average exposure level was 3.578 V/m, this value unveils the necessity of imposing new recommendations and exposure standard limits concerning the site selection of such stations and reducing the exposure level in residential areas as low as possible.

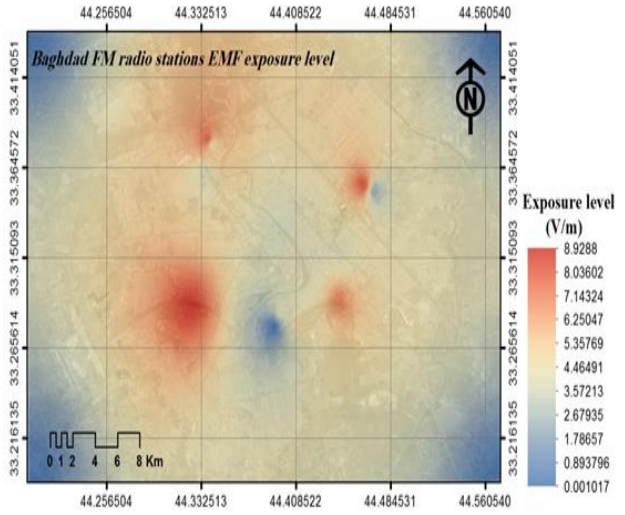

Figure 4. FM radio stations EMF exposure level in Baghdad.

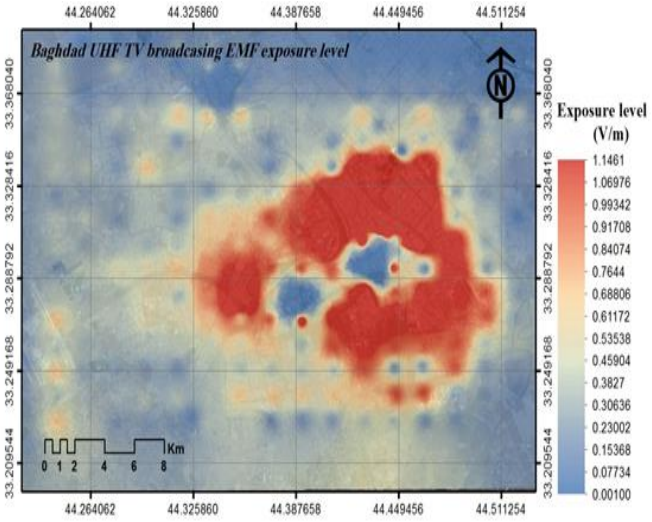

Figure 5.UHF TV broadcasting EMF exposure level in Baghdad.

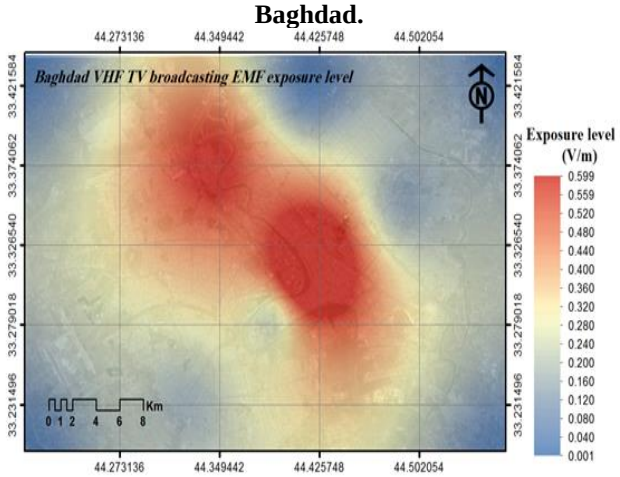

Figure 6.VHF TV broadcasting EMF exposure level in Baghdad.

Table 2. Statistical analysis of FM station exposure measurements (V/m).

Samples	714
Average	3.578518
Standard deviation	2.295239
Max.	10.6
Min.	0.003
Median	3.21
Skew	0.922524
Kurtosis	3.227956
Variance	5.268123

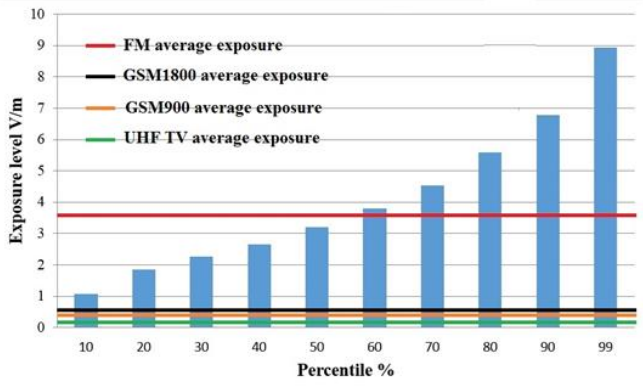

Figure 7. EMF FM radio stations exposure level measurements Percentile and avergae exposure level for different EMF sources.

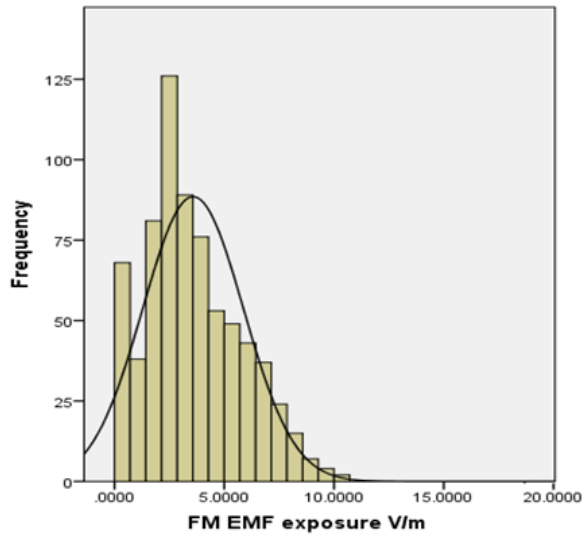

Figure 8. FM radio stations EMF exposure level measurements frequency distribution.

Conclusions and Recommendations

In this work a methodology procedures have been presented to determine EMF exposure distribution using geographical information system Arc Map GIS version 10.A range of typical EMF exposure maps has been introduced to investigate the exposure distributions, compare the contribution of the various RF sources, and check compliance with the ICNIRP guidelines for general public exposure. The results, procedures, and methodologies can be used by authorities and epidemiologists to estimate the exposure from EMF emitting sources and gain insight in which environments highest exposures occur and due to which sources. Moreover, the exposure variability that can be expected between different EMF sources is presented. Knowledge about these exposure distributions and variability is useful for the planning of future studies, site selection, and avoid hotspot locations. The main EMF sources contributed in non-ionizing radiation exposure in Baghdad city refers to FM radio stations, GSM mobile base stations, TV transmitters (UHF and VHF), AM radio stations, and Wi-Fi access points. The maximum contribution is caused by FM radio stations and GSM mobile base stations. The introduced GIS environmental maps for EMF exposure in Baghdad can be used to calculate EMF exposure form each source at any geographical location, these maps showed a higher exposure level distributed through residential areas as large number of GSM mobile base stations expected and FM radio station transmitters which was located in such areas. More maps can be developed for other cities in Iraq using the same algorithm and more accurate maps can be developed for smaller areas.

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