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Extremely Low Frequency Magnetic Flux Densities Measured Near Hospital in Tehran

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ABSTRACT: The ever increasing rate of power consumption has led to an increase in public exposure to extremely low frequency magnetic fields (ELF-MFs) and brought severe concerns about their health effects. Considering previous studies and the facts about potential health effects of these fields, the present study aimed to evaluate the ELF-MF flux densities from power distribution lines near hospitals in Tehran. ELF-MF measurements were performed according to IEEE standard procedures-Std 644-1994 near the hospitals entrances using HI-3604 Power Frequency Field Strength Measurement System during three different time periods (i.e. 12-3 AM, 9-12 AM, 6-9 PM). The results were analyzed using One-Way ANOVA Test. Mean, minimum, and maximum values of ELF-MF flux densities were 0.165 ± 0.08 µT, 0.018 µT, 0.52 µT, respectively. There were no statistically significant differences in ELF-MF flux densities neither among different hospital groups nor among different time periods. The ELF-MF flux densities from power distribution lines around Tehran hospitals were much less than the standards values, implying that it can be considered only in epidemiological studies. In fact, in the case of powerful sources, magnetic field intensity is declined rapidly by distance and is limited to a few meters around the sources. This subject is considered as one of the main reasons for contradictory results in previous studies. Results of the present study can be used as a part of hospital patients' exposure to quantify the total exposure levels of patients as a critical and sensitive group in Tehran hospitals.

Key words: Extremely Low Frequency, Magnetic flux density, Hospital, Power distribution line, Sensitive groups

INTRODUCTION

Nowadays, with increasing rate of power consumption, extremely low frequency magnetic fields (ELF-MFs) from power distribution lines as well as electric house-hold appliances are known as "electromagnetic pollution" or "electrosmog" (Paniagua *et al.*, 2007). These fields are classified as non-ionizing electromagnetic radiation. Normal and high-voltage power transmission and distribution lines are known as the main sources of ELF-magnetic fields in urban areas. Although ELF-magnetic fields only appear when the electric current flows in cables, some concerns remain since these cables are extended across urban areas.

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Human body can not directly perceive ELF-magnetic fields. However, exposure to these fields can lead to adverse impacts on human health. Numerous studies have been conducted in different countries to assess the health effects of ELF-electromagnetic fields, reporting various impacts due to exposure to these fields including behavioral and neurophysiologic changes (Capone *et al.*, 2009), genotoxic effects (Crumpton *et al.*, 2004), childhood leukemia (Green *et al.*, 1999a; Fulton *et al.*, 1980; London *et al.*, 1991), and childhood cancer (Wertheimer *et al.*, 1979). Herdell and sage (2008) also reported some other impacts of ELF-magnetic fields. However, results from other studies have shown that the relationship between human's health and exposure to ELF-magnetic field is often poor or non-existent (Otto *et al.,* 2007; Green *et al.,* 1999b; Feychting *et al.,* 1993; Tynes *et al.,* 1997). This is why standards and guidelines for exposure to ELF-magnetic fields are only published by ICNIRP (1998). On the other hand, WHO believes that results from the available studies are not conclusive to compile a valuable guideline (WHO, 1998).

According to the concerns mentioned above, different studies have been carried out to determine the ELF-magnetic field flux densities in urban areas (Straume *et al.,* 2008; Paniagua *et al.,* 2007; Paniagua *et al.,* 2004; Joseph *et al.,* 2008; Grandolfo *et al.,* 1993), houses (Clinard *et al.,* 1999; Schuz *et al.,* 2000; Thuroczy *et al.,* 2008; Szabo *et al.,* 2007; Moriyama *et al.,* 2005), and occupational environments (Mee *et al.,* 2009; Kaune *et al.,* 1993) in developed countries. However, no study has been found to assess the ELF-magnetic field flux densities around health care centers. Evaluation of exposure level of such critical groups to these fields is not performed and human exposure levels to ELF-magnetic fields from power distribution lines are yet questioned.

This study, therefore, aimed to evaluate ELF-magnetic field flux densities from power distribution lines near hospitals (one of the most sensitive areas in large cities like Tehran) during different time periods (12-3 AM, 9-12 AM, 9-6 PM) and to compare the obtained results with international standards. Results of the present study can be used as a part of hospital patients' exposure to quantify the total exposure levels of patients as a sensitive group in Tehran hospitals.

MATERIALS & METHODS

The study was performed in Tehran, capital of Iran, located at the latitude of 51° 8' to 51° 37' N and the longitude of 35° 34' to 35° E. It has approximately 9 million inhabitants. Besides, there are 156 hospitals in the city. According to the results of the pilot study, 30 hospital locations in different areas of the city were randomly selected. To present a reliable average of ELF-magnetic flux density near health centers, measurements were conducted in 30 sampling sites around each location. The measurements were carried out at the border lines of the selected locations, mainly close to main entrances of hospital buildings. Fig. 1 shows the distribution of hospitals in Tehran.

To make a better understanding of magnetic field's exposure, hospitals were classified into five groups, including: 1) Northern, 2) Western, 3) Southern, 4) Eastern, and 5) Central hospitals.

The HI-3604 Power Frequency Field Strength Measurement System, which is able to evaluate both electric and magnetic fields from 50/60-Hz power transmission and distribution lines, was used to measure the ELF-magnetic field flux density. This device has a probe that is 16.5 cm in diameter and is able to evaluate ELF-magnetic flux densities in the range of 0.1 mG - 20 G.

There are different guidelines for evaluation of ELF-magnetic fields from power distribution lines (NIOSH, 1998; IEEE, 1995). In this study, measurements were taken at the height of 1 m above the ground according to IEEE standard procedures (Std 644-1994). As the nature of the human body is non-magnetic, it can neither perturb the magnetic field nor interfere with the operation of the sensor. Hence, the operator could carry the HI-3604 meter and observe the readings. To collect the data uniformly, point measurements were carried out around hospital borders and also in front of the main entrance of hospitals. Since the HI-3604 meter measures ELF-magnetic flux density in a single vector, the resultant magnetic field was calculated by the following equation (IEEE, 1995):

$$B_R = \sqrt{B_{max} + B_{min}} \qquad (1)$$

As ELF-magnetic field flux density is related to current transmission through electric wire and as power consumption fluctuates during a period of 24 hr, measurements were taken in three different periods of time according to the pattern of power consumption during the day. These periods are classified as follows: 1) 6-9 PM as the maximum power consumption period; 2) 12-3 AM as the minimum power consumption period; 3) 9-12 AM as the mid power consumption period. It is noteworthy that the sampling points remained the same in the three mentioned time periods. To minimize the effects of weather conditions like temperature, humidity, precipitation, etc., all of the measurements were carried out in winter over a very short period of time (i.e. during sunny days over day time and during clear sky over night time).

Data analysis was performed using SPSS (version 15). Since the measurement data had a normal frequency distribution, according to the result of One-Sample Kolmogorov-Smirnov Test ($P > 0.05$), One-Way ANOVA test with a significance level of $P < 0.05$ was used. In addition, the overall mean ELF-magnetic flux density is reported accompanying the standard deviation value.

RESULTS & DISCUSSION

Table 1 summarizes the statistics of ELF-magnetic field flux densities in five different hospital groups during different periods of time. It was found that mean values for different hospital groups were close to each

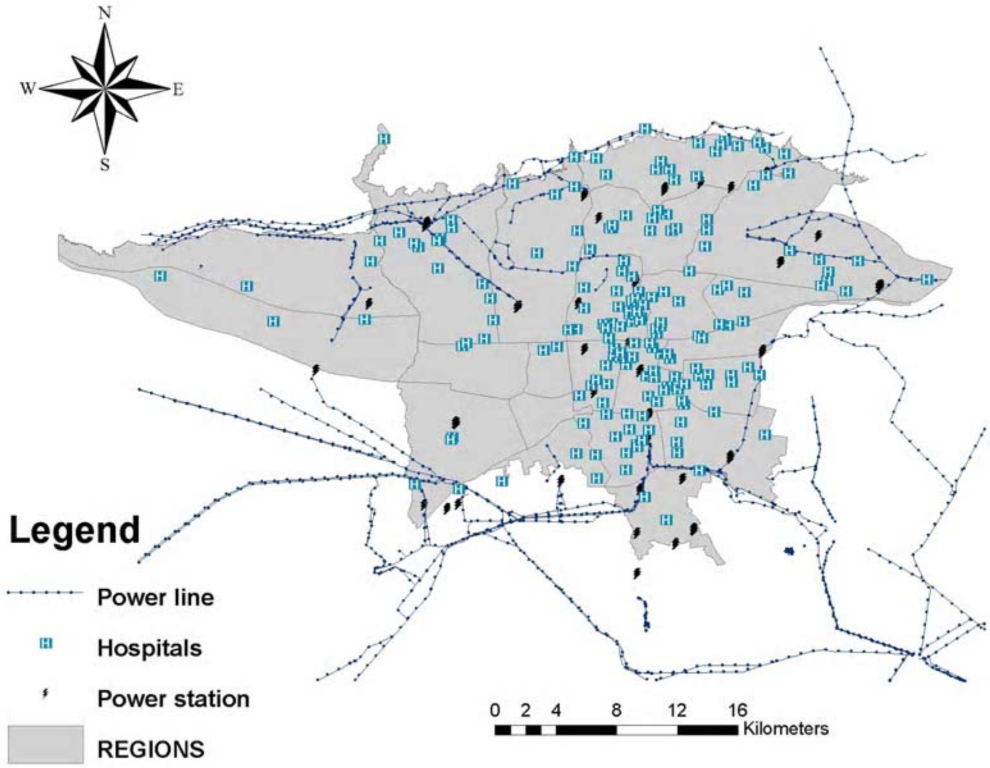

Fig. 1. Location of hospitals, power stations and high-voltage power transmission lines in Tehran

Table 1.The ELF-magnetic field flux densities in five different hospital groups during various periods of time

Hospital Classification	Periods of time	ELF-Magnetic Field Flux Density (µT)			
		Min	Max	Mean	SD
Central (n=8)	9-12 AM	0.043	0.458	0.160	0.096
	6-9 PM	0.037	0.465	0.180	0.088
	0-3 AM	0.040	0.468	0.193	0.086
Western (n=4)	9-12 AM	0.020	0.431	0.085	0.109
	6-9 PM	0.023	0.437	0.092	0.105
	0-3 AM	0.018	0.487	0.093	0.104
Northern (n=5)	9-12 AM	0.025	0.519	0.178	0.101
	6-9 PM	0.018	0.502	0.168	0.096
	0-3 AM	0.027	0.517	0.174	0.097
Southern (n=4)	9-12 AM	0.125	0.460	0.191	0.066
	6-9 PM	0.120	0.404	0.213	0.062
	0-3 AM	0.110	0.487	0.208	0.066
Eastern (n=9)	9-12 AM	0.031	0.429	0.162	0.075
	6-9 PM	0.071	0.455	0.167	0.065
	0-3 AM	0.052	0.432	0.163	0.073

other (around a tenth µT). The overall mean value of ELF-magnetic flux densities in all hospital groups during different time periods was 0.165 µT ± 0.080. Minimum and maximum values were 0.018 µT and 0.52 µT, respectively, which are equivalent to 0.02% and 0.5% of the ICNIRP guideline values.

Table 2 presents the percentage of the measurements falling in each range. As it can be seen from Table 2, in most of the cases (59.1%), ELF-magnetic field flux densities were higher than the threshold limit of 0.2 µT; the baseline value in epidemiological studies (Schuz and Ahlbom, 2008), while all of them fell well below the ICNIRP guideline values (there was no value more than 0.52 µT).

Finally, mean values of ELF-magnetic field flux densities for different groups and time periods were analyzed using One-Way ANOVA Test. As it was expected, no significant difference was observed in ELF-magnetic field flux densities among five different hospital groups (P Value > 0.05). It was assumed that changing the time period and power consumption, ELF-magnetic field flux density is also altered, but no statistically significant difference was seen through different time periods of measurements (P > 0.05). Since there is a moderate topographic slope from north to south in Tehran, another test was carried out to evaluate the difference between ELF-magnetic field flux densities among hospitals at various altitudes. Nevertheless, no statistically significant difference was observed (P > 0.05), indicating that the elevation difference in Tehran is not as prominent as other factors to be considered.

A number of studies have addressed the impacts of ELF-magnetic fields on children (Feychting *et al.*, 1993) and adults (Mee *et al.*, 2009), and it's level in urban environment (Paniagua *et al.*, 2007), while the present study concerns ELF-magnetic field flux densities near hospitals (as sensitive points in an urban area). It was found that although the power consumption is differed during the day), we failed to distinguish the differences in ELF-magnetic field flux densities during different periods. However, the survey of Straume et al. (2008) reported that exposure to magnetic field is varied in different seasons as a result of variations in power consumption. This can be attributed by two important reasons. Firstly, the relatively large standard deviation of the data may prevent from distinguishing the differences in ELF-magnetic flux densities over different periods of time or in different locations. Secondly, the sample size may have not allowed us to detect such differences.

One of the advantages of the present study was conducting measurements during a short period of time to prevent from effects of confounding variables like season or weather conditions. The other point is that fluctuations of ELF-magnetic field flux density due to changes in the power consumption can be observed when we were close to the field source. Such findings were also reported by those studies performed adjacent to transformer stations. However, ELF-magnetic field flux density was very low in far distances, so no flux density alterations can be detected in the points far from the sources.

No significant difference was statistically observed in ELF-magnetic field flux densities among five different hospital groups, while Paniagua *et al.*, (2007) reported that ELF- magnetic field flux density is varied throughout urban areas, which can be attributed to the distance from source of the field. In some situations, measurements are performed close to the field source, while reserve condition can be seen for far distances. It should be noted that in the present study the difference in ELF-magnetic field flux densities could not be detected, as no powerful sources such as electric transmission lines or power stations existed near the measurement points.

The overall mean value of ELF-magnetic field flux density was significantly lower than the ICNIRP guidelines (1998) (0.165 µT, i.e. only 0.16% of the guideline value). The maximum value observed was 0.52 µT, which is almost 0.5 % of the guideline value.

Table 2. Classification of the measurements based on ELF-magnetic field values

Ranges	Percentage in each Range			
	9-12 AM	6-9 PM	12-3 AM	Total
< 0.1 µT	20.0	20.0	23.3	21.1
0.1 -0.2 µT	23.0	20.0	16.6	19.8
0.2-0.52 µT	57.0	60.0	60.1	59.1

On the other hand, considering the value of 0.2 µT, which is used in epidemiological studies as the baseline for distinction between exposed and non-exposed groups (Paniagua *et al.*, 2007), 59.1 % of the cases were above the threshold.

Considering the ELF magnetic field flux densities, different results have been obtained by previous studies. For instance, Grandolfo *et al.*, (1993) reported that ELF-magnetic field flux density in urban areas varies from about 100 nT to about 1 mT (average of 10 µT), depending on proximity to the powerful sources. In a study conducted by Paniagua et al., (2004) in Spain, values of the spot measurements taken in the streets were all below the ICNIRP guideline value; however, 30% surpassed the baseline value of 0.2 µT where the maximum value was 7.3 µT. In another study conducted by Paniagua et al., (2007) in Spain, the overall mean and maximum values of ELF-magnetic field flux densities were 0.105 µT and 7.3 µT, respectively, where 86 % of the values were below the baseline value of 0.2 µT. The results reported by all of the aforementioned studies are consistent with those obtained by the present study. In Belgium, the ELF-electromagnetic fields from distribution substations were investigated by Joseph *et al.*, (2008). The overall mean value of ELF-magnetic field spot measurements (2.06 µT) was higher than those reported by other studies mainly due to the proximity to strong sources of ELF-electromagnetic fields. In addition, ELF-magnetic field flux densities fell within the range of 0.025 to 47.39 µT. The levels of ELF-magnetic flux densities reported by all of the aforementioned studies, except from the study of Paniagua (2007), were higher than those presented in this study. This can be due to the fact that in the above studies, ELF-magnetic field flux densities were measured at the points far from and near to the sources, and these values were then averaged. The advantage of the present study is that only magnetic fields far from the sources as an important factor in environmental conditions and human exposure (with consideration of sensitive groups) were measured, so that the results are not destructed by high values obtained near the ELF-magnetic field sources. All of the results acquired from mentioned studies cover the range of obtained values in both near to and far from the sources in Grandoflo research (Grandoflo *et al.*, 1993).

CONCLUSION

According to the mentioned points, it can be stated that the high levels of ELF-magnetic field flux densities observed near transformations are decreased by distance from the sources to the point that the fluctuations in magnetic field flux densities cannot be detected and it will reach the background level very fast. Therefore, ELF-magnetic field exposure levels of people living close to the transformer stations are still lower than the ICNIRP guidelines and they can be important only when to the long-term exposure and increased risk of cancer are considered (according to the baseline value of 0.2 µT). Comparing the results of this study with existing literature, it can be concluded that the levels of ELF-magnetic field in open spaces close to health centers were higher than those observed at homes (Clinard *et al.*, 1999; Schuz *et al.*, 2000; Thuroczy *et al.*, 2008), but were lower than those found in occupational environments (Mee *et al.*, 2009; Kaune *et al.*, 1993). It is noteworthy that ELF-magnetic field levels in residences located directly above transformers are much higher than those living in typical houses (Szabo et al., 2007; Moriyama et al., 2005). Contribution of the magnetic fields in urban environments to total exposure of public or sensitive groups to ELF-magnetic fields can be estimated by Paniagua et al., (2007):

$$B_c = \frac{B(t).h'.d'}{h.d} \qquad (2)$$

Where, B(t) is the mean value of magnetic flux density; h' is the number of hours per work day; d' is the number of days per work year; h and d are the number of hours per day and per year respectively.

In this equation, total exposure of a specific group can be computed by accumulating their exposure levels in different environments. For instance, beside the magnetic field exposure through ambient air, residential exposure with workers exposure should also be considered. Therefore, evaluation of the extremely low frequency magnetic fields exposure in bedridden patient as one of the prominent sensitive groups can be computed using the obtained results of this study and Paniagua equation. Further researches are necessary to evaluate the patient's total exposure to ELF-magnetic fields through electric devices used inside hospitals.

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