Environmental Engineering and Management Journal

August 2018, Vol.17, No. 8, 1825-1830
http://www.eemj.icpm.tuiasi.ro/; http://www.eemj.eu

"Gheorghe Asachi" Technical University of Iasi, Romania

EXTREMELY LOW-FREQUENCY ELECTROMAGNETIC FIELD DUE TO POWER SUBSTATIONS IN URBAN ENVIRONMENT

Parvin Nassiri[1*], Mohammad Reza Monazzam[1], Seyed Abbas Hosseyni[1], Kamal Azam[2], Pedram Jafari Shalkouhi[3]

[1]*Department of Occupational Health Engineering, The School of Public Health, Tehran University of Medical Sciences, Tehran, Iran*
[2]*Department of Epidemiology and Biostatistics, The School of Public Health, Tehran University of Medical Sciences, Tehran, Iran*
[3]*Department of Environmental Engineering, Faculty of Natural Resources and Environment, Science and Research Branch, Islamic Azad University, Tehran, Iran*

Abstract

The objective of this paper is to measure magnetic flux density and electric field intensity due to selected power substations in the city of Tehran to evaluate the difference between the measured parameters and threshold levels specified in relevant standards. Hence, three types of power substations of 63, 230 and 400 kV were randomly selected. Based on confidence level of 95% (α =0.05), 250 measurements were made at various distances from power substations. It is found that the results of data analysis were well below the recommendations in ICNIRP (2010) while, a previous study by Nassiri et al. (2012) with regard to electromagnetic field due to power substations in the city of Tehran revealed that most of the studied population (64.8%) was suspected to have mental disorders. Therefore, to study electromagnetic field due to power substation in urban environment, the adverse effect of electromagnetic field on human beings must be investigated rather than just environmental measurement of electromagnetic field.

Key words: electric field intensity, magnetic flux density, power substation

Received: June, 2013; Revised final: August, 2014; Accepted: October, 2014; Published in final edited form: August, 2018

1. Introduction

The electricity plays an important role in people's life. Both electric and magnetic fields exist close to the lines and appliances which transport electricity. Since the late 1970s, the questions with regard to the negative effects of exposure to these extremely low frequency (ELF) electric and magnetic fields (EMF) on health have been raised. Since then, many researchers have successfully resolved the important issues and narrowed the focus of future study. Biological effects due to exposure to high levels of electromagnetic fields (above 100 μT) have been reported. External ELF magnetic fields can induce electric fields and currents in our body. Also, high levels of ELF magnetic fields cause nerve and muscle stimulation and changes in nerve cell excitability in the central nervous system (WHO, 2007).

With regard to long-term effect of ELF magnetic field, many scientific studies have focused on leukemia in children (WHO, 2007). Furthermore, a number of other negative health effects have been investigated for possible relationship with ELF magnetic field exposure. These consist of physiological and psychological disorders such as: cancers among children and adult, depression illness, suicide disease, cardiovascular diseases, reproductive dysfunction disorder, developmental diseases,

* Author to whom all correspondence should be addressed: e-mail: nassiri@sina.tums.ac.ir; Mobile: +989121230502; Phone / Fax: +982188951390

immunological modifications illness, neurobehavioral effects and neurodegenerative disorders (Gontarz and Szulim, 2016; WHO, 2007).

Lindgren et al. (2001) studied the ELF magnetic fields in an urban environment. Despite outdoor environments are often considered as low level areas with regard to ELF magnetic fields, they found that outdoor exposures to ELF magnetic fields should be included in exposure assessments and risk evaluations. Dlugosz et al. (1989) investigated magnetic flux density in an urban environment and concluded that *"ambient power line magnetic field levels at urban residences can be reliably characterized on a one-time site inspection using a hand-held magnetic field meter and a simple wiring classification system"*. Nassiri et al. (2011) measured ELF magnetic flux density near hospitals and found that the mean, minimum, and maximum values of ELF magnetic flux density were 0.165 ± 0.08, 0.018 and 0.52 μT, respectively. Sharifi Fard et al. (2011) measured magnetic field due to 230 kV power substations and concluded that all the measured values were below the ACGIH standard. Barsam et al. (2012) studied the effect of ELF electromagnetic field exposure on sleep quality in high voltage substations in a city environment and found a positive correlation coefficient between occupational exposures to ELF electromagnetic field and sleep quality.

Despite outdoor environments are often considered as low level areas with regard to electromagnetic fields, the objective of this study is to measure magnetic flux density and electric field intensity due to selected power substations in the city of Tehran to find the difference between the measured parameters and threshold levels specified in relevant standards.

2. Material and methods

In this study power substations of same type but with different capacities including 63 kV (4 samples), 230 kV (4 samples) and 400 kV (2 samples) were randomly selected from different parts of Tehran city (Figs. 1-3). The number of samples (measurements) was determined based on statistical point of view. It means that based on confident level of 95% (α = 0.05), 250 measurements were made at the sources and at the horizontal distances of 1, 10, 20, 30, 40 and 50 m from the vertical projection of power substations' fences on ground surface. Meanwhile, there were no remarkable objects that can intensify or attenuate electromagnetic field in measurement area. In addition, all measurements were made in sunny weather.

The measurements of electromagnetic field were made using HI-3604 ELF Meter according to IEEE standard (1994). The frequency response of the instrument ranges from 30-2000 Hz. The sensitivity of the instrument for magnetic field ranges from 0.01 to 2000 μT and for electric field from 1 V/m to 199 kV/m. In order to guarantee the accuracy of magnetic field measurement, a magnetic field was produced by a Helmholtz nuclear spiral. In the spiral part of the instrument a sinus wave was produced (based on the nuclear spiral dimensions) and then measured in μT. Moreover, in order to guarantee the accuracy of electric field measurement two aluminum square plates with the dimension of 30 cm were used. A sinus voltage was transmitted along the plates and then the measurement was made based on dividing the used voltage to the distance between the plates (V/m). SPSS software was used for data analysis.

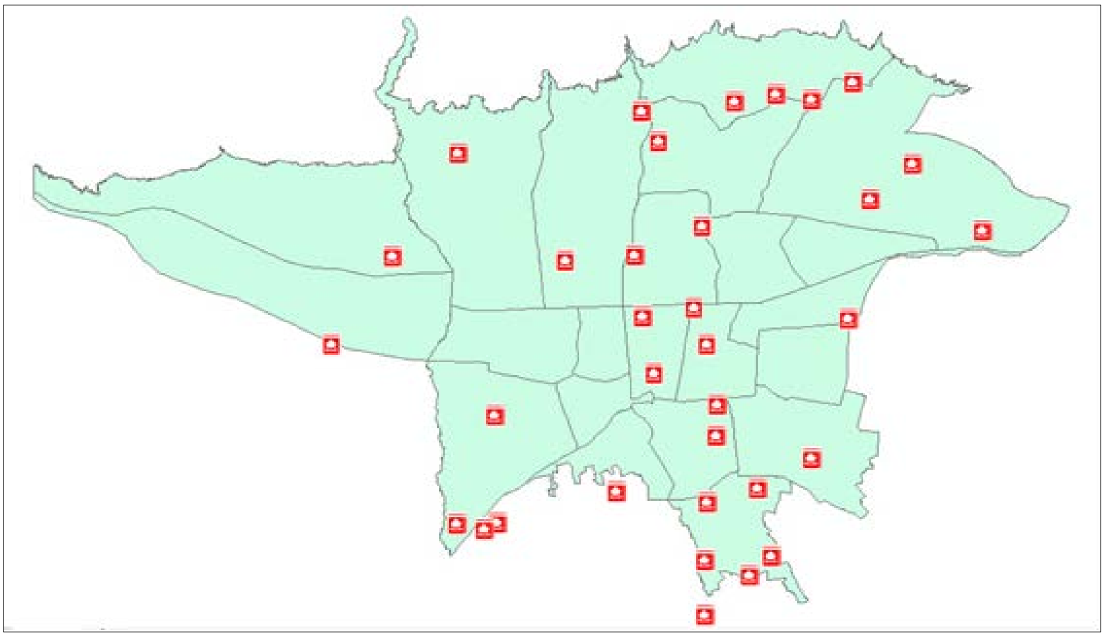

Fig. 1. Location of 63 kV power substations in the city of Tehran

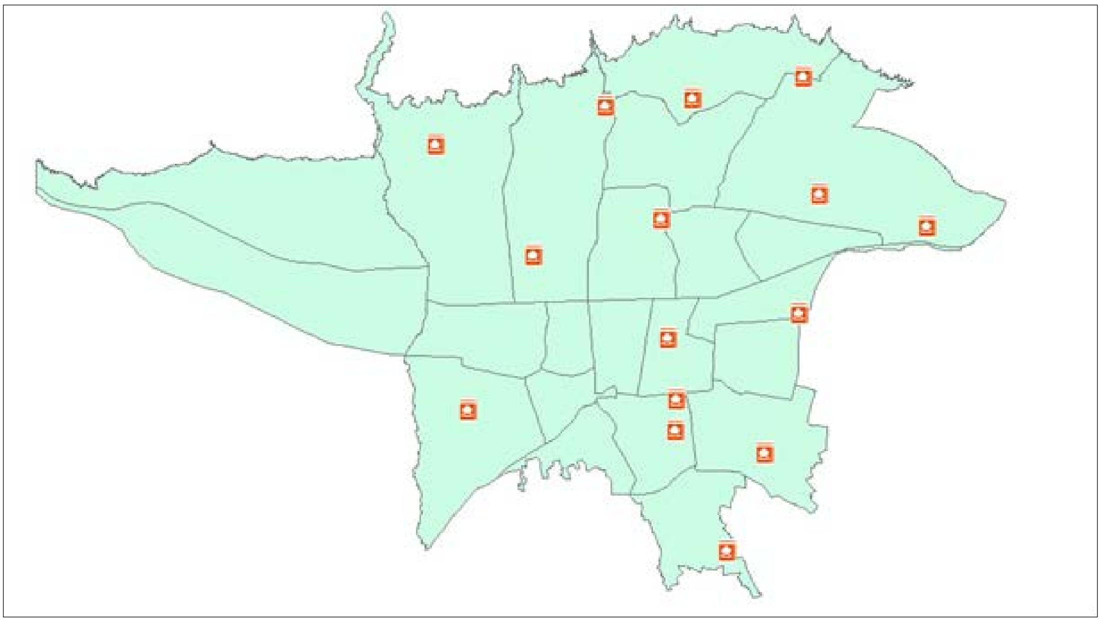

Fig. 2. Location of 230 kV power substations in the city of Tehran

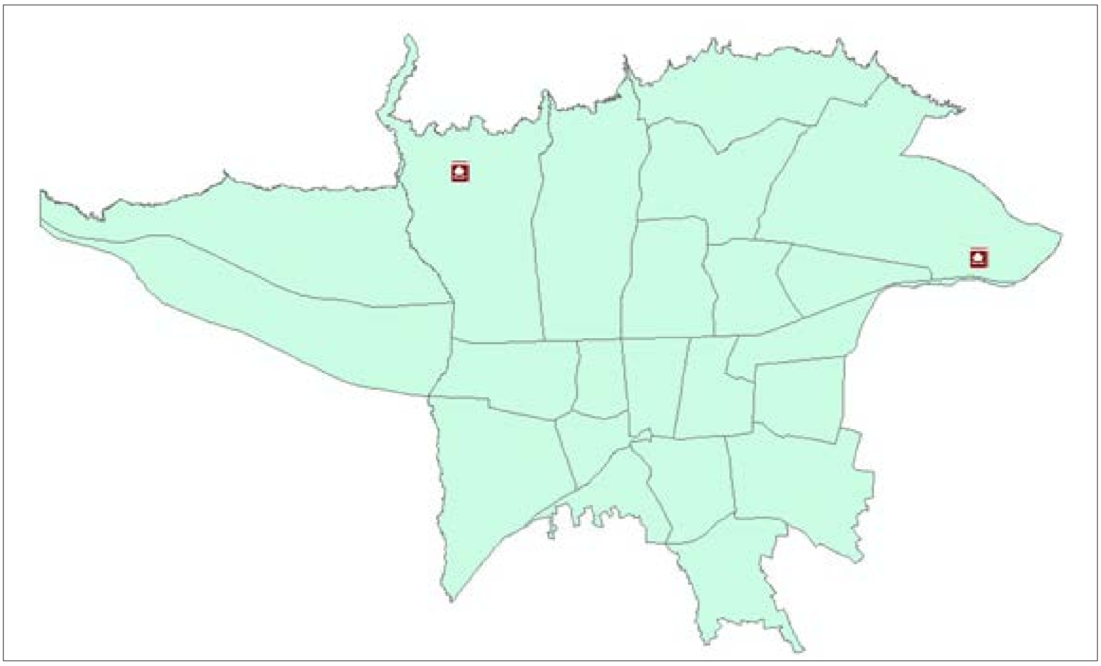

Fig. 3. Location of 400 kV power substations in the city of Tehran

3. Results and discussion

The measured magnetic flux density due to 63 kV power substations ranges from 0.0221 to 7.27 μT and the measured electric field intensity due to 63 kV power substations ranges from 0.780 to 1521 V/m (see Table 1).

As shown in Table 2 the measured magnetic flux density due to 230 kV power substations ranges from 0.033 to 18.6 μT and the measured electric field intensity due to 230 kV power substations ranges from 1.150 to 1647 V/m. In Table 3 the measured magnetic flux density due to 400 kV power substations ranges from 0.222 to 27.5 μT and the measured electric field intensity due to 400 kV power substations ranges from 5.8 to 3610 V/m. In addition, magnetic flux density measured at various distances from power substations is shown in Figs. 4-6. Also, electric field intensity measured at various distances from power substations is shown in Figs. 7-9.

According to ICNIRP (2010), the reference values of the electric field intensity and magnetic flux density at 50 Hz (rms values) for public exposure are 5 kV/m and 200 μT respectively. Tables 1-3 show that all the magnetic flux density and electric field intensity values are well below the recommended values by ICNIRP (2010). In contrast, Straume et al. (2008) measured ELF-magnetic flux density in a city environment and reported that the average levels for summer, cold weather and snowy weather were 0.13, 0.85, and 0.90 μT respectively.

Table 1. Measured magnetic flux density and electric field intensity due to 63 kV power substations

Field Type	***Number of Samples***	***Min***	***Max***
Magnetic flux density (μT)	100	0.0221	7.27
Electric field intensity (V/m)	100	0.780	1521

Table 2. Measured magnetic flux density and electric field intensity due to 230 kV power substations

Field Type	***Number of Samples***	***Min***	***Max***
Magnetic flux density (μT)	100	0.033	18.6
Electric field intensity (V/m)	100	1.150	1647

Table 3. Measured magnetic flux density and electric field intensity due to 400 kV power substations

Field Type	***Number of Samples***	***Min***	***Max***
Magnetic flux density (μT)	50	0.222	27.5
Electric field intensity (V/m)	50	5.8	3610

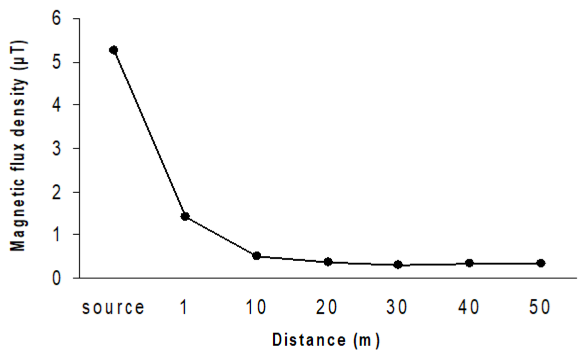

Fig. 4. Magnetic flux density measured at the source and at the distances of 1, 10,20,30,40 and 50 m from 63 kV power substations

Moreover, the exposure of the general public due to distribution substations of 11/0.22-0.4 kV was investigated by Joseph et al. (2008). They found that the measured momentary magnetic field values ranged from 0.025 to 47.39 μT. Als o, they reported that the measured electric fields ranged from 0.1 to 536 V m (-1). Furthermore, Paniagua et al. (2004) reported that the measured median power frequency field levels ranged from 0.04 to 0.11 μT in urban environments in Spain. In addition, Al-Badi (2012) measured the low frequency magnetic and electric fields due to conductors carrying current in the Oman electric power system and concluded that all the values were below the recommended values by ICNIRP (2010).

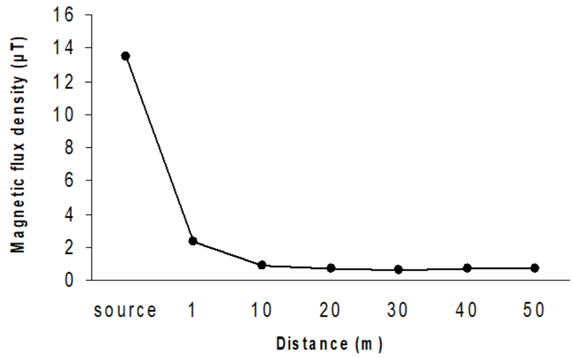

Fig. 5. Magnetic flux density measured at the source and at the distances of 1, 10,20,30,40 and 50 m from 230 kV power substations

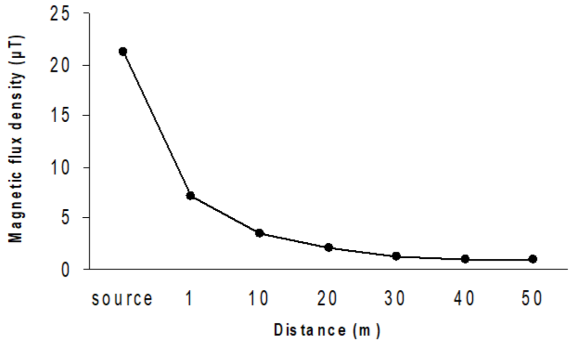

Fig. 6. Magnetic flux density measured at the source and at the distances of 1, 10,20,30,40 and 50 m from 400 kV power substations

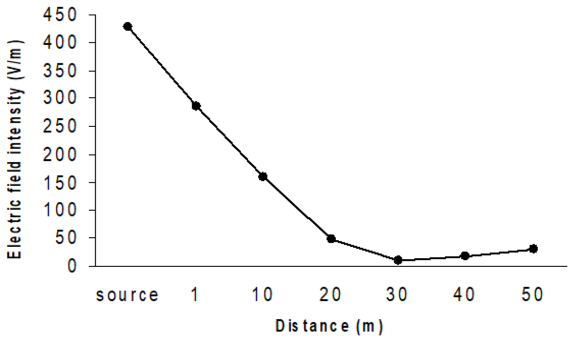

Fig. 7. Electric field intensity measured at the source and at the distances of 1, 10,20,30,40 and 50 m from 63 kV power substations

The results of one-sided variance analysis are summarized in Table 4. Table 4 indicates that there is a statistical relationship between the logarithm of magnetic flux density due to 63, 230 and 400 kV power substations ($P<0.05$). Also, Table 4 shows a statistical relationship between the logarithm of electric field intensity due to 63, 230 and 400 kV power substations ($P<0.05$). Table 5 shows statistical relationships between the logarithmic mean of magnetic flux density due to 63, 230 and 400 kV power substations ($P<0.05$).

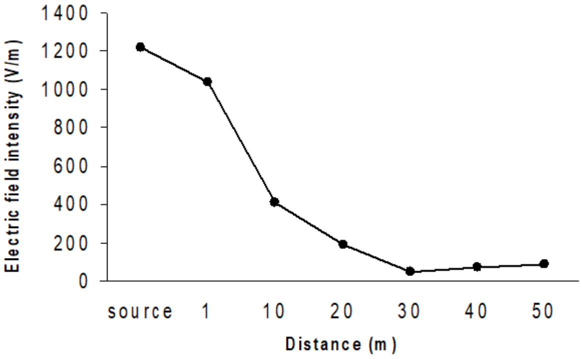

Fig. 8. Electric field intensity measured at the source and at the distances of 1, 10,20,30,40 and 50 m from 230 kV power substations

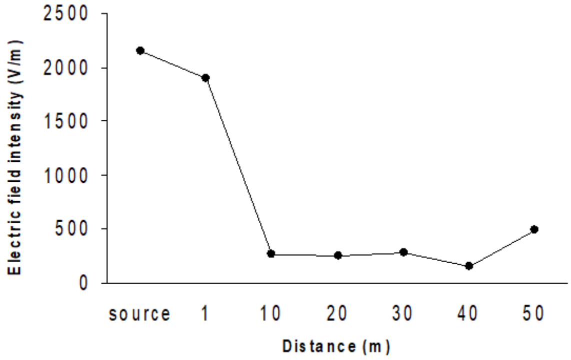

Fig. 9. Electric field intensity measured at the source and at the distances of 1, 10,20,30,40 and 50 m from 400 kV power substations

Table 4. Statistical analysis of logarithm of magnetic flux density and logarithm of electric field intensity due to 63, 230 and 400 kV power substations

		Sum of squares	***Degree of freedom***	***Average of squares***	***F***	***P value***
Logarithm of magnetic flux density	Between power substations	11.249	2	5.625	16.797	0.00
	Among power substations	82.710	247	0.335		
	Total	93.960	249			
Logarithm of electric field intensity	Between power substations	24.257	2	12.128	15.924	0.00
	Among power substations	188.120	247	0.762		
	Total	212.377	249			

In addition according to Table 6 there are statistical relationships between the logarithmic mean of electric field intensity due to 63, 230 and 400 kV power substations ($P<0.05$). The results revealed that there are statistical relationships between the logarithmic mean of magnetic flux density at the source and at the distances of 1 and 10 m from power substations ($P<0.05$). Furthermore, according to Figs. 4-6 there are considerable differences between the magnetic flux density values at the sources and at the distances of 1 and 10 m from power substations.

Moreover, the results indicated the statistical relationships between the mean of electric field intensity at the distances of 1, 10, 20, 30, 40 and 50 m from the power substations ($P<0.05$). Also, as can be seen in Figs. 7-9 there are considerable differences between the electric field intensity values at the distances of 1, 10, 20, 30, 40 and 50 m from power substations.

Two regressive models were obtained based on the measured magnetic flux density and electric field intensity as follows (see Eqs.1 and 2):

$$B = 0.1(10^{0.885+0.002T-0.023X}) \quad (1)$$

where B is the magnetic flux density (μT), T is the type of power substation (kV) and X is the distance from source (m).

$$E = 10^{2.153+0.002T-0.038X} \quad (2)$$

where E is the electric field intensity (V/m), T is the type of power substation (kV) and X is the distance from source (m).

Table 5. Comparison between logarithmic mean of magnetic flux density due to 63, 230 and 400 kV power substations

Power Substation (kV)		***P-value***	***Confident Level of 95%***	
			Low level	***High level***
63	230	0.015	-0.3619	-0.0395
	400	0.000	-0.7783	-0.3834
230	63	0.015	0.0395	0.3619
	400	0.000	-0.1827	-0.5776
400	63	0.000	0.3834	0.7783
	230	0.000	0.1827	0.5776

Table 6. Comparison between logarithmic mean of electric field intensity due to 63, 230 and 400 kV power substations

Power Substation (kV)		***P-value***	***Confident Level of 95%***	
			Low level	***High level***
63	230	0.000	-0.6961	-0.2100
	400	0.000	-1.1157	-0.5203
230	63	0.000	0.2100	0.6961
	400	0.016	-0.6627	-0.0672
400	63	0.000	0.5203	1.1157
	230	0.016	0.0672	0.6627

Based on Tables 1-3 and Eqs.(1) and (2), the minimum safe distances from power substations were determined. With regard to magnetic flux density the minimum safe distances from 63, 230 and 400 kV power substations were 63 m, 71 m and 75 m respectively. In addition, with regard to electric field intensity the minimum safe distances from 63, 230 and 400 kV power substations were 73 m, 87 m and 102 m respectively. Meanwhile, the low levels of magnetic flux density and electric field intensity (see Tables 1-3) were considered for calculation of the minimum safe distances from power substations. In contrast, Joseph et al. (2008) obtained the minimum distance of 5.4 m for daily exposure to 0.4 μT ELF electromagnetic field. Also, Qin et al. (2012) measured electromagnetic radiation due to high-voltage lines. Their results revealed that the electromagnetic radiation decreases proportionally to the distance from the lines.

Furthermore, the epidemiological investigations have demonstrated the relationship between exposures to ELF magnetic fields above 0.4 μT and leukemia among children (HPA, 2004). In contrast, the results of the present paper revealed that, in some cases, the magnetic flux density values exceeded 0.4 μT. Nevertheless, the specialized International Agency for Research on Cancer of WHO has classified power frequency magnetic field under conditions of prolonged exposure as “the possible carcinogenic to humans”(Group 2B). It means that 2B is not a real health risk (IARC, 2011).

4. Conclusion

It is found that the measured electric field intensity and magnetic flux density due to power substations were well below the recommendations in ICNIRP (2010) while, Nassiri et al. (2012) measured electric and magnetic field due to 400 kV power substations in the city of Tehran and found that most of the studied population (64.8%) was suspected to have mental disorders.

Therefore, to study electromagnetic field due to power substation in urban environment, the adverse effect of electromagnetic field on human beings must be investigated rather than just environmental measurement of electromagnetic field.

Acknowledgement

The authors are grateful for financial support given by the Department of Environment of Iran; grant no.2-b-8006-386.

References

Al-Badi A.H., (2012), Measurement and analysis of extremely low frequency electromagnetic field exposure in Oman, *Journal of Electromagnetic Analysis and Applications*, **4**, 333-339.

Barsam T., Monazzam M.R, Haghdoost A.A., Ghotbi M.R., Dehghan S.F., (2012), Effect of extremely low frequency electromagnetic field exposure on sleep quality in high voltage substations, *Iranian Journal of Environmental Health Science & Engineering*, **9**, 1-7.

Dlugosz L.J., Byers T., Vena J., Zielezny M., (1989), Ambient 60-Hz magnetic flux density in an urban neighborhood, *Bioelectromagnetics*, **10**,187-196.

Gontarz S., Szulim P., (2016), Evaluation of the impact of environmental hazards associated with mechanical faults in BLDC electric motors, *Environmental Engineering and Management Journal*, **15**, 491-504.

HPA, (2004), Radiation Protection Services, Radiation Protection Division of the UK, Health Protection Agency, On line at: https://www.phe-protectionservices.org.uk/cms/article.php?article=1766

IARC, (2011), IARC classifies radiofrequency electromagnetic fields as possibly carcinogenic to humans, The WHO/International Agency for Research on Cancer, Press Release N 208, On line at: http://www.iarc.fr/en/media-centre/pr/2011/pdfs/pr208_E.pdf

ICNIRP, (2010), International Commission on Non-Ionizing Radiation Protection, Guidelines for limiting exposure to time-varying electric and magnetic fields (1 Hz to 100 kHz), *Health Physics*, **99**, 818-836.

IEEE Standard, (1994), Standard procedures for measurement of power frequency electric and magnetic fields from AC power lines, Transmission and Distribution Committee of the IEEE Power Engineering Society, Std 644.

Joseph W., Verloock L., Martens L., (2008), Measurements of ELF electromagnetic exposure of the general public from Belgian power distribution substations, *Health Physics*, **94**, 57-66.

Lindgren M., Gustavsson M., Hamnerius Y., Galt S., (2001), ELF magnetic fields in a city environment, *Bioelectromagnetics*, **22**, 87-90.

Nassiri P., Asghari M., Farvaresh E., Safari H., Monazzam M.R., Ghaemian N., (2012), General health status of residents nearby high voltage substations in Tehran, Iran, *Advances in Environmental Biology*, **6**, 2558-2563.

Nassiri P., Monazzam M.R., Yunesian M., Sowlat M.H., Safari M.H., Momen Bellah Fard S., Hosseini S.A., (2011), Extremely low frequency magnetic flux densities measured near hospital in Tehran, *International Journal of Environmental Research*, **5**, 1035-1040.

Paniagua J.M., Jiménez A., Rufo M., Antolín A., (2004), Exposure assessment of ELF magnetic fields in urban environments in Extremadura (Spain), *Bioelectromagnetics*, **25**, 58-62.

Qin Q. Z., Chen Y., Fu T. T., Ding L., Han L. L., Li J. C., (2012), The monitoring results of electromagnetic radiation of 110-kV high-voltage lines in one urban location in Chongqing P.R. China, *Environmental Monitoring and Assessment*, **184**, 1533-1540.

Sharifi Fard M., Nassiri P., Monazzam M.R., (2011), Measurement of the magnetic fields of high-voltage substations (230 kV) in Tehran (Iran) and comparison with the ACGIH threshold limit values, *Radiation Protection Dosimetry*, **145**, 421-425.

Straume A., Johnsson A., Oftedal G., (2008), ELF-magnetic flux densities measured in a city environment in summer and winter, *Bioelectromagnetics*, **29**, 20-28.

WHO, (2007), Electromagnetic fields and public health, Fact sheet N 322, World Health Organization.