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# Survey of public exposure to extremely low-frequency magnetic fields in the dwellings

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**Abstract**

**Background:** Extremely low-frequency electromagnetic fields (ELF-EMFs) are generated from indoor electrical appliances and wiring. In 2002, the International Agency for Research on Cancer (IARC) classified ELF magnetic fields as possibly carcinogenic to humans (Group 2B). Therefore, the aim of this study as the first ever study conducted in Tehran was to survey the public exposure to ELF magnetic fields in dwellings, in 2018.

**Methods:** In this study, 102 houses were selected using convenience sampling method. The magnetic field was measured based on the IEEE std 644-1994 standard using TES-1393 EMF tester. Spot measurements were done in three different rooms including kitchen, living room, and bedroom of each residential.

**Results:** The average value of measurements taken in dwellings was 0.1 μT. There was a significant difference between total value of magnetic flux density and background level of magnetic flux density among 102 dwellings. There was also a non-significant difference among magnetic fields collected from kitchen, living room, and bedroom. The ELF magnetic fields collected from television and computer in different distances present that MFs decrease rapidly with increasing distance from the source.

**Conclusion:** According to the statistical analysis, the average value of ELF magnetic field in Tehran, Iran, is the same as the recommended value provided by the International Commission on Non-Ionizing Radiation Protection (ICNIRP).

**Keywords:** Extremely low-frequency, Dwelling, Electromagnetic field, Public exposure, Indoor exposure

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## Introduction

Electromagnetic fields generated from both natural and artificial sources exist everywhere in our environment as the use of electricity has been on the rise over recent decades. People therefore are exposed to these fields every day in the work place, environment, and at residential. Power lines, electrical wiring, and most appliances all produce extremely low-frequency electromagnetic fields (ELF-EMFs). These fields are components of non-ionizing part of electromagnetic field spectrum, which most operates at a frequency of 50-60 Hz. At residential, electromagnetic fields surrounded residential wiring and all electrical appliances (refrigerator, television, computer, etc) (1, 2). Residential exposure to ELF fields depends on the number and type of electrical appliances in use in the dwelling, the position of household electrical wiring, power consumption in the neighborhood and the distance between dwellings and from the power distribution system. Although most appliances are used for only short periods of time and moving even a short distance from most electrical appliances reduces exposure rapidly, survey of personal exposure to ELF-EMFs emitted by these devices should be considered (3).

ELF-EMFs are classified as possibly carcinogenic to humans (Group 2B) by the International Agency for Research on Cancer (IARC) in 2002, based on the results from several epidemiological studies on the possible association between ELF-MF and its health effects (e.g., childhood leukemia) (3-7).

According to the World Health Organization (WHO) guidelines that categorizes electromagnetic fields into 3 main groups, ELF-EMF has a frequency ranges from 0 to 300 Hz (2). Electric fields are produced whether or not a device is turned on, whereas magnetic fields are produced only when electric current is flowing, which usually requires a device to be turned on. In addition, electric fields are easily shielded or weakened by walls and other objects, while magnetic fields can pass through

buildings and most other materials (4). Hence, this study was conducted to assess public exposure to ELF-MF in the dwellings of Tehran, Iran. Assessment of children exposure to ELF-IF shows that indoor levels of ELF-MF were higher than its level in parks and playgrounds (8). According to Martínez-Sámano et al, it is necessary to conduct exposure surveys to discover health effects of ELF magnetic fields on human (9).

Although some other studies on laboratory animals have described the effects of ELF magnetic field on the nervous system, animal development, and melatonin production, the evidence for such effects is weak and ambiguous. According to a review study by Schüz, recent analyses for childhood brain tumor have shown little evidence for an association with ELF-MF, also, at exposures more than 0.4 μT (10). In addition, the finding that ELF-MF may cause childhood leukemia is considered to be still valid. However, no conclusion concerning possible human health risks can be drawn from these data. Nevertheless, the aim of this study was to survey public exposure to extremely low-frequency magnetic fields in the dwellings, and it also attempts to raise public awareness about indoor ELF-MFs in Tehran, Iran.

## Materials and Methods

This study was conducted in 2018 in Tehran (Iran), with about 730 $km^2$ area and 8 244 535 million population. A total of 102 residential from the study society (Tehran city) were selected using convenience sampling method while two limitations were considered: First, all selected residents were located in a distance of at least 80 m from power lines, and second, their area was ranged from 60 to 100 $m^2$. Figure 1 presents the distribution map of 102 sampling points in Tehran, Iran.

A three axis TES-1393 EMF tester (SAENCO) was chosen for spot measurement of MF at frequency of 50 Hz with bandwidth range of 30 to 2000 Hz and magnetic field range of 0 to 2000 mG (6). The device was calibrated by IMAN MOHIT Company before the study for making sure of its accuracy. The values of ELF magnetic fields were achieved from spot measurements taken in three rooms of each residential including kitchen, living room, and bedroom (children's bedroom was preferable) and specific distances from distinct household appliances (television and computer). Measurement procedure was based on the IEEE Std 644-1994 standard setting the device in the center of each room at a height of 1 meter above the ground (11-15).

Supplemental information was collected using a questionnaire which was filled in by the owner of each dwelling. Details about 3 following segments were collected:

1. Characteristics of the building like type of the residence, materials used in the construction of the building, and duration of occupation.
2. Data on family members living in the house such as the number of adults and children and hours of being in the kitchen, living room, and bedroom during 24 hours.
3. Number of household appliances like refrigerator, washing machine, lighting lamps, etc. which exist in the house during measurements, the duration of using each appliance, and typical distance between operator and each equipment as they were in use.

Background ELF magnetic fields were measured in the center of the kitchen, living room, and bedroom under the condition that the refrigerator was in its functioning mode despite other appliances were disabled (switched off

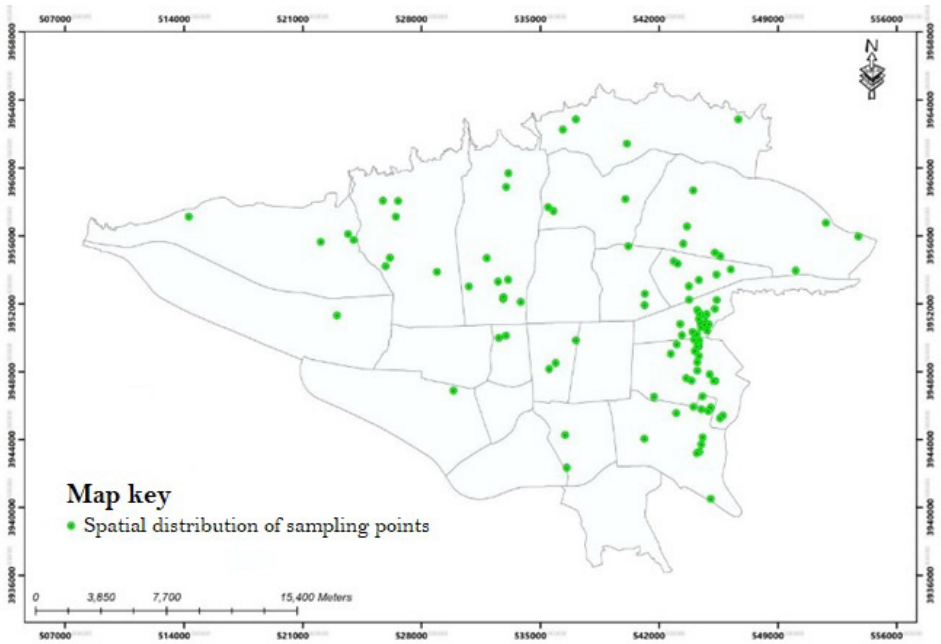


**Figure 1.** Distribution map of sampling points in Tehran

and unplugged). The duration of each measurement was 5 minutes.

Measurement of magnetic fields were also taken under the condition that appliances were enabled whereas refrigerator and television were in their operating mode.

In addition, in the living room of each house, measurements were conducted to obtain ELF magnetic fields from television (TV) and computer (PC) or laptop at different distances; the results are presented in Table 1.

Finally, temperature, humidity, and air pressure of each residential were recorded using Multi-Purpose Anemometer GM 8910 at the end of all measurements.

## Results

### *Results of ELF-MFs measurements in the dwellings*

The mean value of indoor ELF-MFs achieved from spot measurements conducted in 102 dwellings in Tehran, Iran, is 0.1 μT, which is the same as the recommended value provided by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). The mean value of ELF-MFs for each house is presented in shown in Figure 2.

In addition, Figure 3 shows background level of ELF magnetic fields in the dwellings. The ELF-MFs obtained under the condition which refrigerator and television were in their functioning mode, are presented in Figure 4.

According to the correlation between the results obtained from three rooms of each residential and based on Figure 5, there was no strong association between different locations in a residential.

### *Results of ELF-MFs generated from television*

The mean value of ELF-MF measured at distances of 0.3, 2.5, 4, and 5 m from television while only television and refrigerator were in their functioning mode, was $0.138 \pm 0.117$, $0.114 \pm 0.052$, $0.05 \pm 0.115$, and $0.031 \pm 0.1$ μT, respectively. Also, the results of spot measurements under the condition that in addition to television and refrigerator, lightning lamps of the residential were also switched on was $0.140 \pm 0.119$, $0.116 \pm 0.052$, $0.113 \pm 0.086$, and $0.1 \pm 0.029$ μT (Table 2).

### *Results of ELF-MFs generated from laptop and computer*

Based on the data collected from spot measurements, the ELF-MF strength decreased as the distance from monitor increased. The mean values of ELF-MFs measured at distances of 0.3, 0.5, and 0.6 m from computer were $0.104 \pm 0.065$, $0.101 \pm 0.074$, and $0.088 \pm 0.034$ μT, respectively (Table 2).

Arc GIS 10.3 using inverse distance weighting (IDW) interpolation method was used for plotting zoning map of magnetic field strength in the dwellings in Tehran as presented in Figure 6.

### *Data collected from the questionnaire*

#### *Devices used in the dwellings*

According to Table 2 that presents type of devices used in 102 dealings in Tehran, Iran, three types of television were considered. It was discovered that LED is the most common kind of television.

Moreover, in 2% of dwellings, LCD and CRT televisions were used at the same time.

Among laptop and computer, laptop is more common which was used in 44% of dwellings. Both laptop and computer were also used in 15% of dwellings.

As shown in Table 2, side-by-side refrigerators were used in 87% of dwellings. In addition, both side-by-side refrigerator and freezer and refrigerator were used at the same time in 5% of dwellings.

**Table 2.** Percentage of using different types of some of the home appliances

| Name of Appliance | Type of Appliance | Percentage of Use (%) |
|---|---|---|
| Television | LED | 52 |
| | LCD | 4 |
| | CRT televisions | 10 |
| Computer and laptop | Laptop | 44 |
| | Computer | 33 |
| | CRT monitors | 2 |
| Refrigerator | Side-by-side refrigerator | 87 |
| | Freezer and refrigerator | 18 |

**Table 1.** ELF magnetic field from TV and PC or Laptop

| Distance from TV (m) | ELF from Television | |
|---|---|---|
| | Plugged-in Appliances during Measurement | Plugged-in Appliances during Measurement |
| 0.3 | Refrigerator and TV | Refrigerator, TV, and lighting lamps |
| 2.5 | Refrigerator and TV | Refrigerator, TV, and lighting lamps |
| 4 | Refrigerator and TV | Refrigerator, TV, and lighting lamps |
| 5 | Refrigerator and TV | Refrigerator, TV, and lighting lamps |
| **Distance from Laptop or PC (m)** | **ELF from Laptop or PC** | |
| | **Plugged-in Appliances during Measurement** | **Plugged-in Appliances during Measurement** |
| 0.3 | Refrigerator and laptop or PC | Refrigerator, laptop or PC, and lighting lamps |
| 0.5 | Refrigerator and laptop or PC | Refrigerator, laptop or PC, and lighting lamps |
| 0.6 | Refrigerator and laptop or PC | Refrigerator, laptop or PC, and lighting lamps |

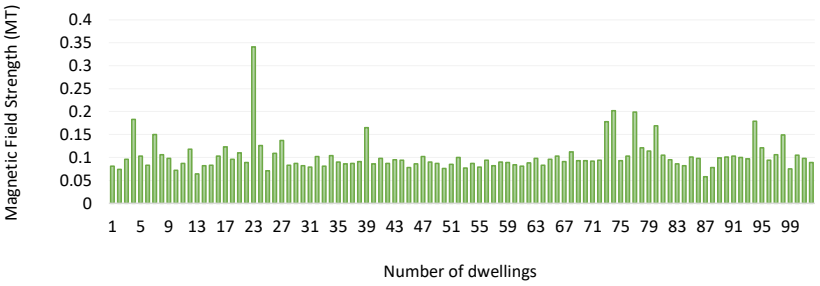


**Figure 2.** Average value of ELFMFs in 102 dwellings.

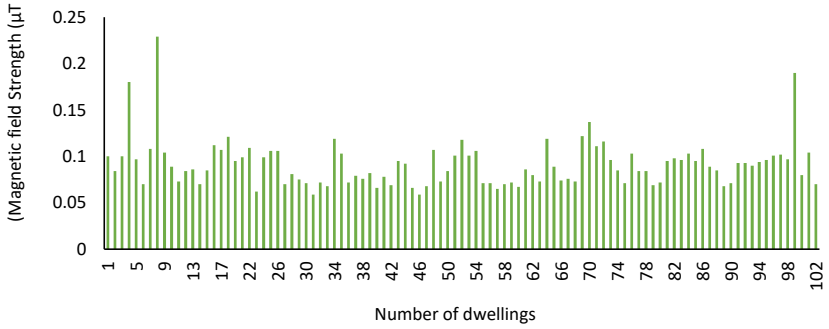


**Figure 3.** Background level of ELFMFs in 102 dwellings.

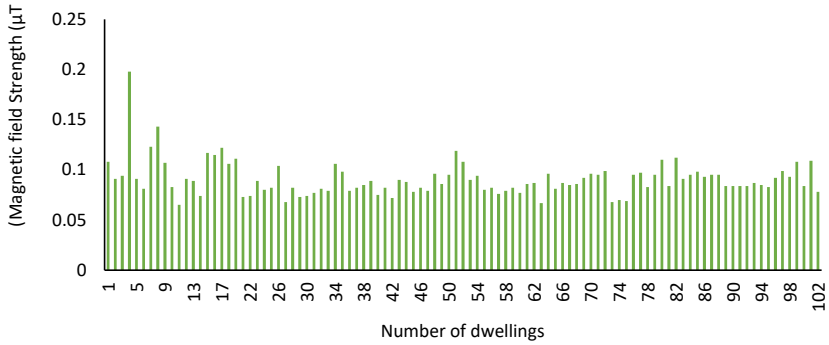


**Figure 4.** ELFMFs measured in 102 dwellings while refrigerator and television were switched on.

### *Structure of dwellings*

In about 67% of dwellings, the age of the buildings ranged from 5 to 20 years and only 10% aged more than 30 years.

## Discussion

Numerous studies have been conducted to assess the exposure to ELF magnetic fields in different countries over recent decades. So, as far as residential exposure to these fields is concerned, the aim of this study as the first ever study conducted in Iran, was to survey the public exposure to ELF-MFs in 102 dwellings in Tehran, Iran.

The results of spot measurements show that the mean value of ELF-MFs, which is the same as the ICNIRP reference level, is acceptable.

Due to disaffiliation of most dwelling owners, measurement of background level of ELF magnetic field in all residential conducted while all devices except refrigerator were switched off (unplugged).

Based on the results, 66% of dwellings were exposed to ELF-MFs lower than 0.1 µT. Higher exposure found in 31% of dwellings (> 0.1 µT) and as presented in Figure 2, only 2% were exposed to ELF-MFs at exactly 0.1 µT.

Compared to the present study, the results of a study conducted in Germany showed that magnetic field strength in only 1.4% of dwellings were higher than 0.2

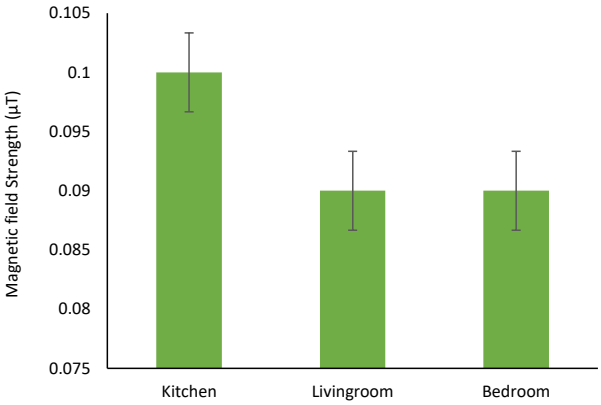


**Figure 5.** Comparison of ELF-MFs measured in different rooms of each dwelling.

μT (14). In addition, exposure to lower magnetic fields in 90% of dwellings (< 0.2 μT) was found in Sweden, in 2010 (15). Another study conducted in 100 dwellings in Germany reported that ELF-MF levels in 90% of samples were lower than 0.2 μT (16).

During deliberation, it was revealed that the mean value of ELF-MFs in some points (number 4, 8, 23, and 99) were higher than 0.15 μT. Also, after switching on the refrigerator and television, an unexpected reduction in ELF magnetic field was observed in two of the residential (number 8 and 99), which should be increased. It is presumed that being located near big malls which have telecommunication tower and generators, can be the reason of higher exposure level observed in these houses (17). Magnetic field strength measured at different distances from television in point 13 and 21 were 0.95 and 0.75 μT, respectively. After evaluation and based on the data collected through the questionnaire, it was found that CRT televisions generate higher levels of magnetic fields.

In addition, there is another presume about the reason of higher magnetic field strength observed at a distance of 4 m from television in contrast to the distance of 2.5 m. Going near to walls and other ELF sources used in neighborhood can be the reason because the graph is downtrend. Due to inaccessibility of laptop and computer in some houses, measurement of ELF-MFs conducted in 92% of dwellings and the graph of magnetic field strength at 3 various distances is downtrend. Higher exposure levels were found at points 11, 26, and 63 (> 0.4 μT). Two possible reasons including type of computer (CRT) and being located near walls or other ELF sources were considered.

Evaluation of normality was done using Shapiro-Wilk and Kolmogorov-Smirnov tests. Q-Q plot also confirmed that all data were not normal as presented in Figure 7. The results of normality tests are also presented in Table 3.

According to the results of chi-square test, there was a significant difference between total value of magnetic flux density and background level of magnetic flux density among 102 dwellings, while based on the logistic regression analysis, there was a non-significant difference among magnetic fields collected from kitchen, living room, and bedroom.

The following limitations exist in the present study:

1. Method of choosing sampling points (not accidental)
2. Lack of authority in dwellings for switching on and off home appliances for measurement

Numerous studies have focused on the health effects of ELF fields in Iran and other countries. For example, Hasanzadeh et al investigated the effect of ELF-MFs on

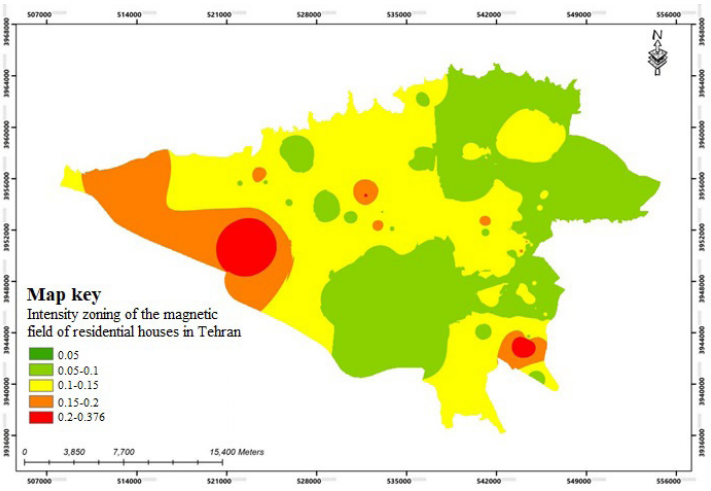


**Figure 6.** Zoning map of residential magnetic field strength in the dwellings in Tehran

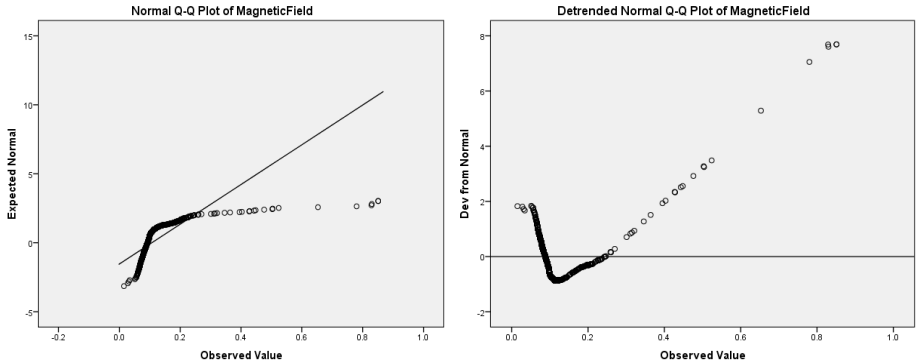


**Figure 7.** Normal and Detrended Q-Q plot of magnetic field

**Table 3.** Results of normality tests

| Normality Tests | | | | | | |
|---|---|---|---|---|---|---|
| | Kolmogorov-Smirnov[a] | | | Shapiro-Wilk | | |
| | Statistic | df | Sig. | Statistic | Df | Sig. |
| Magnetic field | 0.301 | 1206 | 0.000 | 0.432 | 1206 | 0.000 |

[a] Lilliefors significance correction.

neuroblastoma cells and found that ELF-EMFs are capable of being carcinogenic. Moreover, measurements and computational modelling were conducted in the MOBI-Kids case-control study to assess the ELF exposure of the brain through the use of mobile and cordless phones (5,18). The aim of another study was to survey the relationship between exposure to ELF fields and the risk of childhood leukemia and the results showed that ELF-EMF may cause leukemia in children (10).

Further research in the following segments is recommended:

1. Select more samples for measuring residential ELF-MFs in Tehran.
2. Carry out 24-h measurements using portable devices and personal dosimeters.
3. Measure children exposure to ELF-MFs in indoor areas (homes, kinder gardens, and schools) in Tehran.

## Conclusion

According to the statistical analysis, the average value of ELF magnetic field in Tehran is 0.1 μT, which is the same as the recommended value provided by the ICNIRP. Obviously, ELF magnetic field value in residential with more electrical appliances was higher. Hence, further research on spot and long-term measurements in dwellings at the same time is recommended.

## Acknowledgements

The authors would like to thank the Laboratory of Physical Factors of Department of Occupational Health of Shahid Beheshti University of Medical Sciences for technical support and providing device for conducting measurements.

## Ethical Issues

This study was approved by the Research Ethics Committee of Shahid Beheshti University of Medical Sciences (Ethical code: IR.SBMU.PHNS.REC.1397.12) and all ethical considerations have been considered. Authors hereby certify that all data collected during the study are as stated in the manuscript, and no data from the study has been or will be published separately elsewhere.

## Competing Interests

Authors declare that there is no conflict of financial or organizational interests.

## Authors' Contributions

Study conception and design, data collection and drafting the manuscript were done by GHGH and AE. Data analysis and interpretation were performed by SKH. All authors critically revised and approved the manuscript.

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