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Comparison of Extremely Low Frequency Electromagnetic Waves in Different Parts of Residential Houses in Yazd City

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A R T I C L E I N F O

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ABSTRACT

Introduction: Extremely low frequency (ELF) waves are less than 300 Hz. Electrical devices with city electricity are one of the most important sources of generating ELF waves. The main objective of this research was to investigate and compare the magnetic fields produced by ELF electromagnetic fields (ELF-EMF) waves in different parts of residential houses in Yazd city.

Material and Methods: Thirty-three houses were selected, and an EMF-828 was used (made in Taiwan) for ELF-EMF intensity measurement in three parts of the kitchen, living room, and bedroom and three modes of Normal, OFF, and ON electrical instruments.

Results: Two-way ANOVA was used to compare two-by-two ELF waves in three modes: OFF, Normal, and ON. A significant value was obtained (p-value=0.036) in OFF and ON modes in the living room. Similar results were for kitchen (p-value=0.014) in two modes of ON and OFF. However, there was not a significant relationship (p>0.05) between the mean intensity of ELF-EMF waves and the studied building parameters.

Conclusion: The mean intensity of the ELF waves in different modes was not the same in kitchen and was in the order of ON> Normal> OFF that could be related to high-wave generation equipment. The comparison of mean intensity of ELF-EMF waves in different locations of the investigated houses was much lower than the standard level set by ICNIRP. Preventing the simultaneous use of high-power electrical instruments led to both save consumption and reduce EMF-ELF waves exposure risk.

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Introduction

Non-ionizing waves are a part of electromagnetic waves that do not change the structure of atoms when they are absorbed by the material. These groups will also have destructive effects on different tissues depending on their nature. For example, infrared waves cause cataracts or even blindness if they come into contact with the naked eye. Also, natural non-ionizing waves, such as sunlight rays and electrical devices, are also considered generators of non-ionizing waves [1].

Exposure to ELF electromagnetic fields (ELF-EMF) caused by the production, transmission, and

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distribution of electric power is unavoidable. Electromagnetic waves are one of the most widespread factors that are scattered everywhere. Electromagnetic waves are also produced by electrical current-carrying equipment, in-house wiring, medical equipment, and electrical devices. Electromagnetic radiation includes electric and magnetic fields that oscillate in their respective phases and are perpendicular to the direction of wave propagation. Electric and magnetic fields are produced by any cabling or equipment that carries electric current, such as overhead or ground power lines, in-house wiring, medical equipment, electrical equipment, etc. [2].

Extremely low frequency (ELF) includes electric and magnetic waves less than 300 Hz. For example, electrical devices that work with electric cities are one of the most important sources of generating electric and magnetic fields with ELF. The voltage and electric current of the city are alternating, and the frequency of their changes is 50 Hz, or 50 revolutions per second. Around the overhead transmission lines, as the distance from the central wire increases, the intensity of the electric field decreases rapidly. Special attention has been paid to the waves emitted by equipment. Many devices and equipment produce electromagnetic waves, and household electrical equipment also has this specification [1].

ELF biological effects are much disputed. In 2002, IARC revealed a monograph classifying ELF magnetic fields as "possibly human's carcinogens". This classification led to denote an agent for which there is limited evidence of carcinogenicity in humans and less than sufficient evidence for carcinogenicity in experimental animals. This classification was according to epidemiological studies demonstrating a pattern of a two-fold increase in childhood leukemia associated with average exposure to residential power-frequency magnetic field above 0.3 to 0.4 μT [3]. According to studies conducted by Suhnel and Berg (2003), it is necessary to investigate electromagnetic waves exposure to determine their health effects. Studies have shown that in South Africa, there is not enough data on residential exposure to ELF magnetic field levels. However, there are studies on the spread of health effects from exposure to ELF magnetic fields worldwide[4]. Studies have shown that high-intensity ELF magnetic fields may lead to genetic defects, damage to DNA, increase in certain types of cancers, depression, fatigue, headaches, sleep disorders, and adverse effects on pregnancy. The World Health Organization (WHO) believes that there are not enough studies related to the mentioned effects, so they have not set a standard. Therefore, a few international standards and regulations of permissible contact limits with ELF-EMF are available [5]. For example, the International Commission on Non-Ionizing Radiation Protection (ICNIRP) has identified a value of 1000 for the public as Microtesla. Due to the potential health effects of ELF in recent years, much attention has been paid to measuring their occupational and public exposure [6].

Although many studies have been conducted with the aim of exposure to wave detection in residential areas, limited studies have been conducted regarding measurements in different parts of the house under different conditions. Therefore, the main purpose of this study is to compare values of ELF-EMF waves in different parts of residential houses in Yazd city.

Materials and Methods

Sampling and Study area

Equation (1) was used for sample size detection [7];

$$n = z^2 \times \sigma^2/d^2 \qquad (1)$$

In this equation, $z = 1.96$, $d = 0.05$, and $\sigma = 0.087$. Sample size of 33 houses was calculated for the present study and ELF-EMF measurement was randomly investigated (Fig.1). In order to determine the sample size, in addition to considering the average estimate, it was considered that Yazd consists of several regions, and the sample size was selected based on the number of regions (50 regions).

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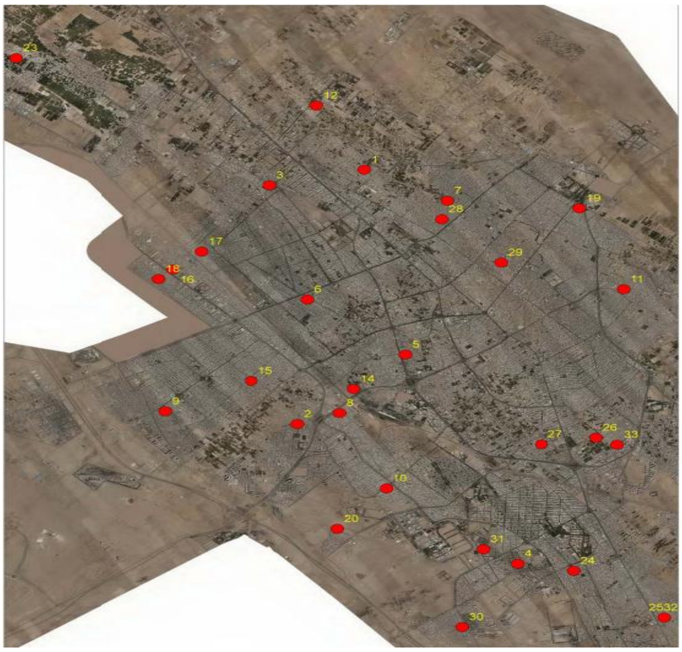

Figure 1: Map of sampling points in Yazd

First, based on a random list generated by SPSS software version 26, 33 regions were randomly selected from 50 regions in Yazd city. In the next step, a house was randomly selected from the center of the region and measured.

Measurements were made using an EMF-828 (made in Taiwan). EMF-828 is an instrument that can measure the magnetic induction from 0.01 µT to 2 mT, and the frequency range is about between 30 and 300 Hz. It has three measurement lengths: 20 µT, 200 µT, and 2000 µT [8]. The precision of the measurement is in the order of 0.01 µT for the measurement extent of 20 µT, 0.1 µT for the measurement extent of 200 µT, and 1 µT for the measurement extent of 2 mT [9].

The calibration of the device is done based on international standards, ISO 9001 Quality Management System Certified by SGS [10]. EMF-828 can measure all three components of the magnetic induction (Bx, By, and Bz), so that the total intensity of the magnetic induction can be determined by the expression:

$$B = (B_x^2 + B_y^2 + B_z^2)^{1/2} \quad (2)$$

Before each measurement, the instrument was switched Off about 10 minutes with the aim of adapting to the environmental adapting condition[10], and then used.

The device was placed parallel to the ground, and at a height of one meter from it, the photocell of the device was facing the source, and the measuring person was in the middle of each station. Then, the intensity of ELF-EMF (as Microtesla) was measured. The measurements were carried out in three parts of houses, including the kitchen, living room, and bedroom, respectively. Also, the measurements were performed in three modes of electrical instruments: OFF, Normal, and ON status.

The OFF mode was defined as all electronic devices in the house being turned off, Normal mode was related to normal life, and ON mode was related to all electronic devices being ON. It should also be noted that electrical devices, including refrigerators, televisions, dishwashers, washing machines, meat grinders, etc., are commonly used at home.

Statistical analysis

SPSS software version 26 was used for statistical analysis. Simple t-test, two-way ANOVA, and repeated measures ANOVA tests were used for data analysis. Pearson's correlation was used to determine the relationship between

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building parameters and the mean intensity of ELF-EMF waves in different modes in the house.

Results

Mean intensity of ELF electromagnetic waves

Table 1 shows the results of mean intensity of ELF wave measurements in kitchen, living room, and bedroom in Normal, OFF, and ON modes.

Table 1: ELF-EMF waves intensity (µT) in different points of houses in Yazd city

Mode	Measured points		
	living room	Kitchen	Bedroom
ON	0.060 ± 0.069	0.080 ± 0.100	0.059 ± 0.084
Normal	0.080 ± 0.132	0.052 ± 0.081	0.081 ± 0.132
OFF	0.038 ± 0.044	0.041 ± 0.049	0.045 ± 0.071

As shown in Table 1, the mean intensity values of ELF-EMF waves in bedrooms, kitchens, and living rooms in normal conditions were 0.081±0.132, 0.052±0.081, and 0.080 ± 0.132 µT, respectively. Also, the mean intensity of ELF-EMF waves in the bedroom, kitchen, and living room in ON mode was 0.059 ± 0.084, 0.080 ± 0.100, and 0.060 ± 0.069 µT, respectively. The mean intensity of ELF-EMF waves in the bedroom, kitchen, and living room in OFF mode were 0.045 ± 0.071, 0.041 ± 0.045, and 0.038 ± 0.044µT, respectively.

The comparison of the results with the ICNIRP standards shows that ELF-EMF measured values were much lower than international standards (ICNIRP: 1000 µT for public exposure) (P-value = 0.000) [6].

The effect of other variables on the mean intensity of the ELF-EMF waves

The effect of some other parameters such as building age, building area, number of floors, and building type (villa and apartment) was also investigated (Table 2).

Table 2: The relationship between building parameters and ELF-EMF Intensity waves

Building parameter	Correlation	Kitchen			Living room			Bedroom		
		Normal	ON	OFF	Normal	ON	OFF	Normal	ON	OFF
Age	Pearson Correlation	0.029	- 0.066	0.030	- 0.010	.000	0.078	0.040	- 0.104	- 0.116
	Sig. (2-tailed)	0.874	0.714	0.870	0.955	0.999	0.666	0.826	0.566	0.520
Area	Pearson Correlation	- 0.140	0.047	- 0.105	- 0.180	- 0.183	- 0.134	- 0.109	- 0.114	- 0.076
	Sig. (2-tailed)	0.438	0.794	0.561	0.315	0.308	0.456	0.547	0.526	0.675
Floors	Pearson Correlation	- 0.120	- 0.201	- 0.123	0.007	0.058	- 0.066	- 0.180	- 0.100	- 0.078
	Sig. (2-tailed)	0.506	0.261	0.496	0.968	0.747	0.714	0.317	0.580	0.665

As shown in Table 2, there was not a significant value (> 0.05) between the age of the building, the area of the building, the floor numbers, and the mean intensity of the ELF-EMF wave in ON, OFF, and Normal modes.

Table 3 shows the relationship between the building type and the mean intensity of the ELF-EMF waves in different conditions.

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Table 3: The relationship between building type and ELF-EMF waves

		Kitchen			Living room			Bedroom		
		Normal	**ON**	**OFF**	**Normal**	**ON**	**OFF**	**Normal**	**ON**	**OFF**
Villa	Mean	0.051	0.089	0.039	0.084	0.056	0.032	0.094	0.059	0.042
	SD	0.069	0.117	0.046	0.158	0.077	0.040	0.157	0.098	0.080
Apartment	Mean	0.054	0.060	0.044	0.075	0.067	0.047	0.053	0.058	0.049
	SD	0.052	0.060	0.057	0.059	0.055	0.052	0.052	0.049	0.052
p-value		0.89	0.89	0.450	0.803	0.860	0.68	0.391	0.413	0.967

As shown in Table 3, there was not a significant value (> 0.05) between the building type and the mean intensity of the ELF-EMF waves in different modes.

Comparison of the mean intensity of the ELF-EMF *waves in different conditions*

The results of repeated measures ANOVA has shown that there was a significant difference in OFF, Normal, and ON modes (p-value = 0.005), so it could be found that the mean intensity of ELF-EMF waves in different conditions was significantly different from the others for each building location.

Fig. 2 shows the mean intensity of ELF-EMF waves in OFF, Normal, and ON modes.

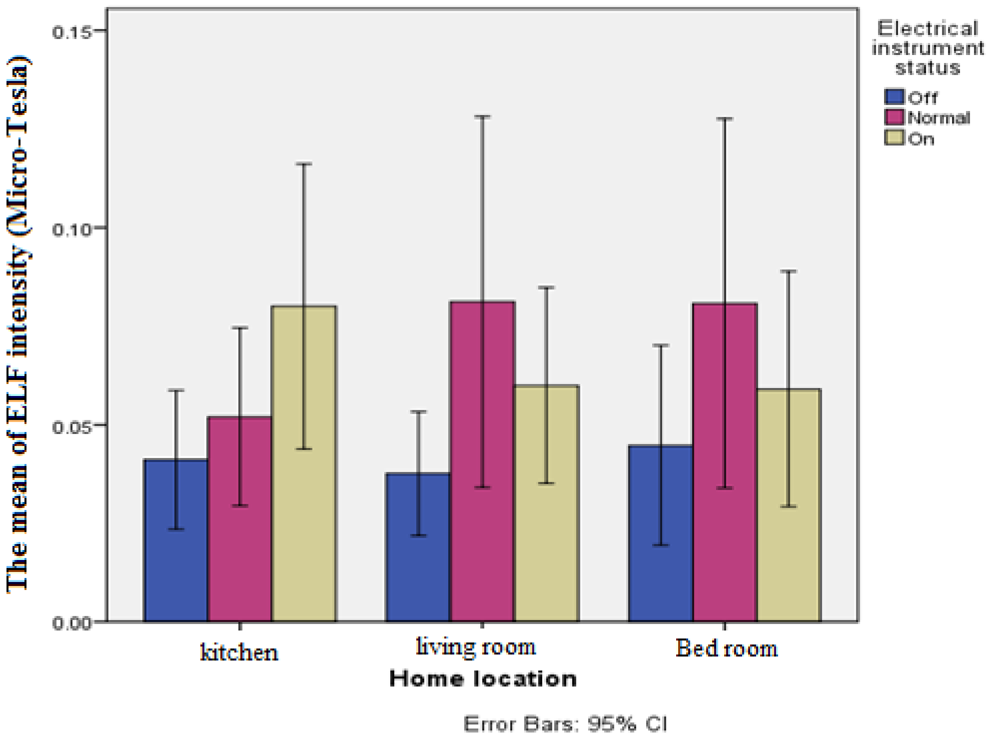

Figure 2: The mean intensity of ELF-EMF waves

As shown in Fig. 2, it could be found that the mean intensity of ELF-EMF waves in the kitchen is at its highest when all the electrical appliances are in ON mode, then in the Normal mode, and when all the electrical devices are in OFF mode, their values are minimum. However, there was no significant difference between the mean intensity of electromagnetic waves in OFF, Normal, and ON modes and different conditions of bedroom and living room.

Two-way ANOVA was used to compare two-by-two waves for the living room in three modes of OFF, Normal, and ON. According to the results, living room had a significant value

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(p-value = 0.036) in OFF and ON modes. Similar results were achieved for the kitchen. In other words, there was a significant value (p-value = 0.014) in two modes of ON and OFF for kitchen. However, the results showed that there was not a significant value in three modes of ON, OFF, and Normal for bedroom location.

Discussion

The present study was conducted to determine the mean intensity of ELF-EMF waves emitted from electrical devices in residential houses in Yazd city.

The results of the present study are presented in three sections. The first is related to the points measurements (Table 1). The second is related to the comparison of each point in ON/OFF and Normal modes and is debated on the comparison of the mean intensity of ELF waves with the other building parameters. The last finding concludes that there is a significant relationship between the kitchen and the living room in three modes.

The results of the mean intensity of the ELF waves (Table 1) showed that the mean intensity of waves in the kitchen was not the same in different modes of OFF, ON, and Normal. The mean intensity in the kitchen was the highest when all electrical instruments were ON> Normal > OFF. In a study conducted by G.Mezei et al. (2001) on household appliances and exposure to 60 Hz magnetic fields in houses, they found that the amount of exposure to electromagnetic waves during the use of each category of devices is different. However, it was highest when using microwave ovens, coffee grinders, electric shavers, and hair dryers. Their results showed that the mean exposure levels were 0.6 µT or higher for microwave ovens and coffee grinders and higher than 0.3 µT for electric shavers and hair dryers. For other devices, the average exposure levels were less than 0.2 µT, which is consistent with the results of the present study [11]. However, for the living room and bedroom, the mean ELF results did not show a significant difference in two modes of ON and Normal conditions. It could be related to their electrical instrument types that in ON modes do not have stronger ELF waves compared to the Normal mode.

Akinlolu A. Ponnle et al. (2022) showed that the electromagnetic waves and the power consumption of the device depend on the age of the device and device manufacturer. Devices with magnets, coils, and electric motors produce a stronger ELF than devices with heating elements. At a distance of 3 cm from the device, the highest value of the obtained ELF was 85.5 µT and the lowest value of the obtained ELF was 4.28 µT. This research confirms the relationship between household electrical appliances and the electromagnetic waves. According to the results obtained from the present study and similar studies, it can be found that since many electronic devices are used in the kitchen, high values of ELF intensity waves can be related to the electrical devices in the kitchen [12]. It should be noted that there was no high-voltage power cable within 500 meters of the measured points, so the effect of this parameter was eligible [13].

The comparison of the results with the ICNIRP standards shows that the mean intensity values of the ELF-EMF were much lower than international standards (ICNIRP: 1000 µT for public exposure) (P-value = 0.000) [6]. Razieh Saeed et al. (2019) showed that the minimum and maximum intensity of ELF-EMF waves were 31.4 and 0.1 µT, respectively, around high-pressure lines. Based on the ICNIRP standards, the minimum intensity of the magnetic field was 93.4% and the maximum was 2.5%, all of which were lower than the exposure limit [14]. In a study conducted by Shamsh et al. (2018), the amount of ELF waves from high-voltage transmission lines of household appliances in residential houses was investigated, and the receiving limits were much lower than the maximum permissible exposure limits (PEL) of the ICNIRP standard [15]. Fuka Rathbe et al. (2018) showed that the exposure levels of ELF-EMF waves at all distances were lower than the ICNIRP guidelines, and waves decreased by increasing distance from the source. It should be mentioned that the results of the present study are consistent with similar studies [16] .

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The authors could not find similar studies related to building parameter effects; however, the present study showed that there is no significant difference between studied parameters. More research studies are required to demonstrate the current finding.

The results of ELF-EMF measurements (in two-by-two waves for each section) showed that there is a significant relationship between the mean intensity of electromagnetic waves in the living room and kitchen in OFF and ON modes. It could be related to some parameters such as television, laptop, and telephone, living room space, design of environments, electrical wiring type, the distance from the building to the street, and also various electrical devices in the kitchen. In a study by Jesus M. Paniagua et al. (2004), they found that values of point measurements taken in streets were below the ICNIRP standard, although 30% exceeded 0.2 μT[17]. In another study conducted by Angela Iagar et al. (2017), measurements were taken at different distances from devices and in different modes of operation. The overall results of the measured devices showed that at a distance of 0.2 meters from TV, the power density is more than 280 times the safety level. At a distance of 1.48 m, the power density decreases by 3.5 times but remains 80 times higher than the maximum permissible value [18]. The results of a study by Park J et al. (2020) showed that ELF-EMF exposure in student seating positions was mostly caused by electrical appliances, electronic wiring, and distribution boxes, but the exposure level decreased by increasing distance [19].

The results of bedroom ELE-EMF wave measurements showed that there is no relationship between the main intensity of electromagnetic waves in OFF, Normal, and ON modes. In a study by Ilaria Liorni et al. (2016) in Italy, eighty-six children were selected. Personal and bedroom measurements were taken for each child in two different seasons. The main results of this study showed that the values obtained in bedrooms were < 3 μT and the geometric mean values in bedroom measurements were < 0.4 μT[20]. Johannes Tomitch et al. (2010) measured electrostatic fields, very low-frequency electric fields, and very low-frequency magnetic fields in residential bedrooms in Austria. Their results were much lower than the ICNIRP standard level, which is consistent with the results of the present study. A study conducted by Ghanbari et al. showed that the average value of the ELF magnetic field in Tehran, Iran, was the same as the recommended value provided by ICNIRP [21].

Conclusion

The main objective of this research was to investigate and compare the mean intensity of ELF-EMF waves in residential houses in Yazd city (three parts kitchen, living room, and bedroom, and three modes of Normal, OFF, and ON electrical instruments). The main results showed that there is a significant relationship between kitchen ($p < 0.05$) and living room ($p < 0.05$) with mean intensity of ELF-EMF in OFF and ON instrument modes. However, there was not a significant relationship ($p > 0.05$) between the mean intensity of ELF-EMF waves and the studied building parameters, such as age, number of floors, building type, and area.

The study finding showed the comparison of the average ELF-EMF in all of the surveyed points and conditions. It should be noted that all of the measurements were lower than the ICNIRP standards. Although high-wave generation equipment such as microwaves could generate high ELF-EMF waves, it should be used rarely. Despite the fact that the measurements were less than the permissible limit for exposure to the public (ICNIRP), due to the possibility of radiation during the day from other sources, it is necessary to prevent the simultaneous use of high-consumption electrical devices at home as much as possible. This will be achieved both in terms of saving consumption and reducing wave exposure**.** Hence, more research on measurements in residential homes is recommended.

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Conflict of Interest

No potential conflict of interest is reported by the authors.

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Ethical Approval

This study has been approved by the Ethics Committee of Shahid Sadoughi University of Medical Sciences (IR.SSU.SPH.REC. 1401.142).

Authors' contributions

This article is based primarily on a student project prepared by M.Sc student Rabi haghighi. All authors contributed to the study conception. Experimentation and data collection were performed by Rabi haghighi and Negar Zare Banadkooki. Data analysis was conducted by Sara Jambarsang, Fahimeh Teimouri, and Rohollah Fallah Madvari. The draft manuscript was written by Negar Zare Banadkooki and Fahimeh Teimouri. All authors read and approved the final manuscript.

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