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Measurement and analysis of power-frequency magnetic fields in residences: Results from a pilot study

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A B S T R A C T

Aim: Extremely low-frequency magnetic fields (ELF-MFs) are emitted by electrical household appliances, wiring, meter boxes, conductive plumbing, power lines and transformers. Some of the studies investigating the link between ELF-MFs and health problems have not adequately characterized the magnetic field exposure of subjects, as they did not always measure residential magnetic fields or measure in locations where residents are most exposed. Considering this, there is a need for good quality assessments of residential ELF-MFs in different geographical regions to collect general public exposure data and to identify high sources of magnetic fields. Such studies have the potential to add significant scientific knowledge about residential exposure and appropriate precautions to reduce exposure, improve the quality of life and substantially reduce health care costs.
Subject and methods: In this work, we analyzed the ELF-MFs from 3163 datasets collected from 100 houses in Australia. Measurements were carried out in different geographical locations and were assessed for compliance with the International Commission on Non-Ionizing Radiation Protection (ICNIRP) Guidelines. Then we compared our measurements with another twenty-three peer-reviewed studies, published 1987–2015, reporting magnetic field measurements in residences.
Results: The observed average (geometric mean) magnetic field values were; bed 0.85, bedroom 1.39 mG, baby cot 0.39 mG, children's play area 0.47 mG, and family room 0.30 mG. Our results show considerable variation in the fields to which residents are typically exposed, particularly in beds (21.83%) and bedrooms (33.33%) where the percentage of measurements greater than 4 mG was considerable. Some emissions exceeded the general public exposure levels of the ICNIRP Guidelines, with the potential for residents to be exposed above these levels. However, away from electrical appliances, the average field in all rooms was 0.30–1.39 mG. We show that simple precautions can be applied to reduce exposure to ELF-MFs in residences and thereby minimize potential risks to health and wellbeing.
Conclusion: Our investigation provides a new data collection model for future surveys, which could be conducted with larger samples to verify our observations. Additionally, this data could be useful as a reference for researchers and those members of the general public who do not have access to the necessary measuring equipment.

1. Introduction

Electric and magnetic fields are ubiquitous, especially in industrialized countries, and are generated by the production and distribution of electricity (50 Hz in Australia and Europe and 60 Hz in North America). A large proportion of the population is exposed to electricity in their everyday activities (from lighting, electrical wiring, transportation [1], etc.). For this reason, the biological effects of electromagnetic fields (EMFs) and their possible consequences for people's health are of great importance and have attracted considerable scientific debate [2].

The two international documents, which form the basis of standards in many countries, are the Guidelines of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) [3], and the standard of the Institute of Electrical and Electronics Engineers (IEEE). The ICNIRP Guidelines allow general public exposure to 2000 mG and the IEEE standard allows exposure to 9040 mG [4].

The limits (see Table 1) in the ICNIRP and IEEE documents are designed to prevent a small number of adverse effects from short-term exposure to power frequency fields and do not prevent all identified biological effects or long-term effects, and exposures to residential and

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Table 1
General public exposure levels of ICNIRP exposure guidelines for 50/60 Hz magnetic fields.

Guidelines	Year	General public exposure levels (mG)
ICNIRP Exposure Guideline [3]	2010	2000
IEEE Standard [4]	2002	9040

occupational fields that complied with these limits have been associated with health problems.

A number of epidemiological studies have found an association between ELF-MFs and childhood leukemia. Elevated risks for this disease were found at magnetic fields of 2, 3 and 4 mG. In 2002, the International Agency for Research on Cancer (IARC) classified fields of above 4 mG as Class 2B ("possible") carcinogens, in the same category as lead. In 2007, the World Health Organisation (WHO) reaffirmed this classification [5]. Other studies have shown that ELF-MFs change brain wave patterns during sleep, including reducing REM sleep, which is important for memory and learning. ELF-MFs have further been shown to reduce the quality and quantity of sleep, which can lead to reduced performance, and increased risk of accidents. However, there is no generally-accepted mechanism that can explain all the biological effects reported in the literature [6–9].

There are many sources of ELF-MFs in residences. The main external sources are nearby power lines (above and below ground), transformers and substations and internal sources include wiring, meter boxes, appliances and conductive plumbing.

Conductive plumbing is a side-effect of the electrical safety practice that requires wiring to be earthed to the water pipe. As a result, metal water pipes can conduct ELF-MFs into homes and this can cause high exposures for residents, particularly if water pipes run near beds. The passage of current through water pipes can also unbalance current flowing through the active and return wires of the home, potentially increasing magnetic fields throughout the wiring. This is because fields from active and return wires, running close together, help cancel each other out. In 1989 the Electric Power Research Institute (EPRI) found that conductive water pipes were one of the highest sources of residential exposure. In 1979, Nancy Wertheimer found an association between conductive plumbing in residences and childhood cancer [10].

Despite the potential for ELF-MFs to impact on health, there are few good studies on magnetic field exposures in residential situations [11–13]. A protocol developed by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) recommends that measurements be recorded in the centre of a room and at one meter above floor level [12]. However, this method does not provide information about the exposures that individuals receive in places where they spend time – such as beds, favourite chairs, desks and kitchen benches. Our paper records measurements in these positions to identify real-life exposures.

In new buildings, substantial reductions in ELF-MF exposure can be achieved by appropriate design. In existing buildings, exposures can be reduced by removal of or distance from sources and remediation. However, it is important to base actions on reliable measurements, which can identify the actual fields and their sources, rather than taking arbitrary or expensive actions to reduce exposure, which might or might not be warranted.

New approaches are required to reduce the scientific uncertainty about the association between residential power frequency, 50/60 Hz extremely low frequency magnetic fields (ELF-MF) and health problems such as headaches, fatigue, memory, sleep, low immunity, heart palpitations, skin rashes, brain tumours and childhood leukemia. It is possible that some of the studies on the link between ELF-MFs and health problems have not adequately characterized the magnetic field exposure of subjects, as they did not always measure residential magnetic fields. Hence, there is a need for good quality assessments of residential ELF-MFs in different geographical regions to collect exposure data, identify any consistent trends and detect associations. Such studies have the potential to add significant scientific knowledge about the impact of ELF-MFs and a range of health problems.

The main aim of this work was to measure and analyze ELF-MF exposure in residential situations, to collect general public exposure data and to identify high sources of magnetic fields. The results provide a better understanding of sources of residential exposure and appropriate precautions to reduce exposure, improve the quality of life and substantially reduce health care costs.

The remainder of this paper is organized as follows. In Section 2, we explain the experimental set up, data collection and analysis. Then, in Section 3 we compare the exposure values with the ICNIRP exposure guideline in order to quantify the effects and have provided simple precautions that can be applied to reduce exposure to ELF-MFs in residences. Section 4 concludes the paper.

2. Materials and methods

For this preliminary study, we collected 3163 datasets from 100 houses in different geographical regions (Melbourne, Sydney, Gold Coast and Brisbane) in Australia. Magnetic field levels were measured with an EMDEX II triaxial device (Enertech Consultants, Campbell, CA, USA) with a wide frequency range of 40–800 Hz (broadband mode). In the present study, magnetic fields were measured by spot and continuous scale of measurements. Measurements were recorded in milliGauss (mG). The sampling rate of the meter was set to 1.5 s. The device contains three orthogonally-oriented magnetic field sensor coils (induction coils). Hence, the magnetic fields in the X, Y and Z-axes and the harmonics were considered. This was useful for measuring electromagnetic fields from alternating current (AC) up to 1300 mG (10 mG = 1 μT) with a measurement accuracy of ± 5%. "spot measurements (or point-in-time)" were taken firstly to identify and describe sources of MF. Then "continuous measurements" were taken and averaged values were recorded to compare with the homogeneous fields reference levels from ICNIRP exposure guidelines.

2.1. Selection of homes

Houses were selected from different geographic areas of Sydney, Melbourne and Brisbane, to provide a good cross-section of socio-economic status. Phone contact was made with householders during which the procedure for measuring magnetic fields was explained. In the case of householders who agreed to participate, appointments were booked for the testing at a time convenient to the householder. Most measurements were conducted on weekdays, however, a few were conducted in the evening. The householder was rung or emailed to confirm the booking prior to the date of testing. A total of 100 homes were included in the study. It was observed that the houses tested showed a considerable spread in age, construction and design.

2.2. Magnetic field measurements

Measurements were conducted by a technically-trained electrical engineer with extensive experience in measuring electromagnetic fields. Previous studies have measured magnetic fields at 1 m above the ground in the centre of the room. In our study, we chose to measure fields in locations where people spent time (such as beds, lounges, desks), which were rarely in the middle of the room. This enabled us to capture fields from wiring in walls and skirting boards and those water pipes that ran along the outside of the house. Previous studies [12] have measured low-power conditions in which most electrical appliances are turned off, to simulate exposure while sleeping at night. In our study, we measured high-power conditions, with high-current appliances (such as the oven) turned on. This is to simulate exposure during the night when appliances such as off-peak electric hot water systems are operating. It was thought particularly important to measure fields in