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A pilot neighborhood study towards establishing a benchmark for reducing electromagnetic field levels within single family residential dwellings

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HIGHLIGHTS

- EMF field audits were performed on houses in an urban Toronto neighborhood.
- AC magnetic, electric, high-voltage transient and radio frequencies
- Baseline statistics verified a previous study's strategies for EMF reductions.
- The household EMF averages were compared to a leading international standard.
- Potential causes for elevated electromagnetic frequency levels are highlighted.

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ABSTRACT

Electromagnetic fields (EMF) permeate the built environment in different forms and come from a number of sources including electrical wiring and devices, wireless communication, 'energy-efficient' lighting, and appliances. It can be present in the indoor environment directly from indoor sources, or can be transmitted through building materials from outside sources. Scientists have identified it as an indoor environmental pollutant or toxin that has ubiquitously plagued developed nations causing a variety of adverse health effects such as sick-building syndrome symptoms, asthma, diabetes, multiple sclerosis, leukemia, electro-hypersensitivity (EHS), behavior disorders, and more. There is currently no international consensus on guidelines and exposure limits. This paper presents the results of 29 EMF field audits in single family residential dwellings located within an urban neighborhood in Toronto (Canada). The following EMF spectra were evaluated: radio frequency, power frequency electric fields, power frequency magnetic fields and high frequency voltage transients. The field audits were conducted in order to provide initial baseline statistics to be used in future studies and in order to be compared to a low-cost EMF reduction design incorporated within the Renovation2050 research house — located within the test neighborhood. The results show the low-cost reduction strategy to be effective, on average reducing exposure by 80% for high-intensity EMF metrics. Research of this nature has not been conducted with relation to the built environment and can be used to spark an industry movement to design for low-exposure to EMF in a residential context.

1. Introduction

Electromagnetic energy propagates by fields which are commonly referred to as EMF. EMF exposure is complex and unavoidable in the built environment as it comes in different forms of energy from a number of sources including common electrical wiring, devices, wireless communication, common residential fluorescent based lighting, and appliances. EMF can radiate within the indoor environment directly from indoor sources, or through the building envelope from exterior sources. EMF pollution is defined as exposure to electronic source magnetic or electric fields, radio waves, and poor quality power commonly referred to as "dirty electricity"; the distortion of clean electricity with higher frequency electromagnetic energy, this interference is formally known as high frequency voltage transients. EMF emanating from electrical wires is referred to as low frequency EMF or power frequency; EMF from radio waves is referred to as radio frequency radiation or high frequency radiation.

Scientists have identified EMF as an indoor environmental pollutant or toxin that has ubiquitously plagued developed nations causing a variety of adverse health effects similar to sick-building syndrome symptoms such as asthma, diabetes, multiple sclerosis, leukemia,

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electro-hypersensitivity as well as sleep and behavioral disorders, among others (Genuis and Lipp, 2012; Hardell and Sage, 2008; International Agency for Research on Cancer (IARC), 2002). Furthermore, for those persons suffering from electromagnetic hypersensitivity, EMF pollution presents many more minor and severe health risks (Genuis and Lipp, 2012). While the severity of these health effects is somewhat controversial, EMF exposure is clearly of great concern, affecting even real-estate values in certain countries (Burnett and Yaping, 2002). While many studies have shown that the highest EMF exposure among children under the age of 18 occurs at home (Li et al., 2007) few studies have examined the causes of that exposure in the single-family house as a baseline for comparison to EMF reductive procedures. It is not the intention of this paper to evaluate epidemiological aspects of EMF, rather to assess strategies to mitigate exposure in the built environment.

Renovation2050 is an ongoing research project led by Dr. Russell Richman comprising the full deep energy retrofit of a detached single family dwelling located in downtown Toronto, Canada in order to support the development of the Sustainable Renovation Index. The Sustainable Buildings Group at Ryerson University currently conducts a number of research projects using Renovation2050 as the case study. As a part of Renovation2050, low cost strategies to reduce exposure to EMF were incorporated in the pre-design phase and constructed as integrated processes throughout the project. In order to gage the relative and geographical effectiveness of the mitigation strategies, in-situ EMF levels were compared to both pre-retrofit and surrounding neighborhood levels.

2. Materials and methods

2.1. Research design

A neighborhood field study of 29 houses within 0.4 km of Renovation2050 was conducted to create a baseline EMF map representing typical levels for the Toronto single family residential building typology. The houses were selected by circulating an invitation to participate to approximately 300 houses on two neighboring streets and all 29 respondents were accepted into the study. As this was a preliminary study without a specific hypothesis statistical test was not performed. Questionnaires were collected and EMF field measurements were performed in 29 houses surrounding the test house. This paper presents results from both the Renovation2050 case study and the neighborhood field study. Due to the lack of international consensus on guidelines for prolonged EMF exposure limits for living spaces, these results are compared to the conservative BauBiologie Maes guidelines and those published by academics studying in this field (Baubiologie Maes, 2003; Havas and Olstad, 2008) rather than the limits set out by the ICNIRP (International Commision on Non-Ionizing Radiation Protection, 2009). Conclusions are presented with respect to effectiveness of low cost mitigation strategies employed in Renovation2050 and trends observed during the field study relating aspects of residential building typology to EMF exposure.

2.2. Instrumentation

Three instruments were used in this study, each addressing a different element or spectrum of EMF ranging from power grade magnetic and electric fields to longer wavelength radio frequency radiation such as cell phone networks and Wi-fi. The instruments used were as follows:

SPECTRAN NF-5030: Manufactured by the Aaronia Corporation, this spectrum analyzer was used on two different settings to assess both AC electric and magnetic fields in the 1 Hz to 10 MHz range.

SPECTRAN HF-6080: Also built by the Aaronia Corporation, this instrument was employed to analyze the EMF spectrum ranging from 10 MHz to 8 GHz.

Stetzerizer microsurge meter: Invented, built and sold by Stetzer Electric Inc., this unit detects and evaluates the presence of high voltage transients, dirty electricity, and displays the result as a range between 0 and 1999 GS units. Each GS unit is equal to 0.02 μA in an 800 pF capacitor bridging the positive and negative terminals of a 120 V wall socket. This unit covers the 10 kHz to 100 kHz frequency band (Graham, 2005).

2.3. Neighborhood field study

The field study comprised two elements: (1) a paper survey providing background and contextual information and (2) a site visit incorporating the EMF measurement throughout the house performed under regular occupancy conditions.

The questionnaire was an introductory tool for attracting and documenting the interest and consent of potential participants. It also served to provide preliminary context for analysis of the results from the EMF field testing. Information gathered included: number and type of household appliances, types and configurations of household heating and electrical systems, wireless networks and lighting, window and bed and mattress types, renovation levels and dates (if any). Window types were recorded to evaluate if low-e, or any other, coatings reduced EMF transmission. Furniture types were included to explore possible links between large amounts of metal and EMF levels in sleeping areas. This information was later evaluated for relevance and correlation to compare trends identified from the field study.

The field testing comprised a 45–60 minute visit to each household. Spot and trawling measurements were compiled in one or multiple locations in each room and floor in the home. Apparent baseline values for each room (or area) were recorded, in addition to local spikes and surges when possible efforts were taken to locate the cause of any abnormally high measurements. In addition, certain areas known to cause EMF surges, such as electrical panels, electrical service and major appliances were examined and measured.

The following spectra of EMF were measured:

1. AC electric fields: Baseline readings in the center of the room were taken, followed by a brief search of the room to determine whether any hot spots existed due to appliances, transformers or unusual wiring, among other causes. When measuring electric fields, it is important for the instrument to be placed on a non-conducting surface and not touched by the surveyor as human electric fields will affect the measurements when in contact with the monitor.
2. AC magnetic fields: Similar to the AC electric fields, baseline readings in the center of the room were taken. Since human touch does not affect the readings, the room was then trawled along the walls, ceiling and floor in an effort to locate isolated hot-spots possibly caused by appliances, transformers or unusual wiring.
3. Radio frequency radiation: Readings for RF radiation were taken in the center of each room. Since these are longer wavelength signals, the placement of the instrument in different areas of the room did not yield significantly differing results. The scanning equipment was set to scan in the xy plane and moving throughout the room provided omnidirectionality.
4. Dirty electricity: Readings were taken using every available electrical socket in each room and a baseline was recorded as well as any individual sockets that displayed higher than the baseline readings. Focus was also placed on known transformer based switches and lighting.

The results from the neighborhood field study were compiled and analyzed on an individual dwelling, street and neighborhood basis. These results were then compared to the Renovation2050 test house for further evaluation of the EMF reductions achieved as a result of a previous parallel study (Siddiqui, 2010). Finally, these results were