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STREET LEVEL MAGNETIC FIELDS WITHIN THE CITY OF KINGSTON, ONTARIO, CANADA

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Abstract

Magnetic flux density associated with power lines was measured in three communities within the City of Kingston (population 123,000), Ontario, Canada during a two-week period in August 2003. Spot measurements were taken during the day (0900–1700 h) and in the evening (1700–2100 h) Monday to Friday at intersections, along the sidewalk, and at the front door of buildings on both sides of the street. The mean magnetic flux density for downtown commercial, downtown residential, and suburban residential was 28, 3.2, and 4.0 mG respectively. Of the almost 4000 measurements taken in this study, 76% were above 2 mG, the lower limit associated with childhood leukemia in epidemiological studies. More specifically, the downtown commercial, downtown residential, and suburban communities had 97%, 68% and 42% of readings above 2 mG respectively. As many as 64% of the measurements in the commercial district were above 12 mG, which has been associated with enhanced growth of human breast cancer cells *in vitro* and 54% were above 16 mG, which has been associated with increased risk of miscarriages. Day and evening measurements within each community were similar with some exceptions. Magnetic flux densities at intersections were similar or slightly higher than values measured along residential streets and were significantly higher than street values in the Kingston's commercial district. Exposure to street level magnetic fields may be considerable in some communities posing a potential risk to delivery personnel, street vendors, utility employees, maintenance workers, police, and others who spent time in this environment. These outdoor environments are important sources of electromagnetic field exposure for certain types of occupations but they may also contribute signficiantly to non-occupational exposure and should be included when calculating exposure estimates.

Introduction

The strength of the electric and the magnetic fields[1] at intersections within the business district of 60 communities in south-central Ontario was documented in 2002 [1]. Of these 60 communities, the highest magnetic flux density was reported along Princess Street in Kingston, a city with a population of 123,000. The mean magnetic flux density along Princess Street was 47 mG with a range from 1.8 to over 100 mG. Other communities with high magnetic flux densities include Simcoe Street in Oshawa (30 mG), Dundas Street in London (23 mG), George Street in Peterborough (21 mG), and Yonge Street in Toronto (19 mG). The magnetic fields along Princess Street were generated by underground utility lines and transformers that were just below the sidewalk.

These high magnetic fields recorded earlier in Kingston [1] prompted this follow-up study. Was Princess Street unique or were magnetic flux densities generally high in this city? In an attempt to answer this question three communities within Kingston were selected for further study: A downtown commercial community that included Princess Street; a downtown residential community; and a suburban residential community.

Method

Magnetic flux density was measured with an omni-directional Trifield^{TM} meter, which was handheld, battery operated, and calibrated by the manufacturer. It has a sensitive range for magnetic flux densities from 0.2 to 3 mG with a resolution of 0.2 mG. In the high range, the meter can measure magnetic flux densities from 1 to 100

[1] *Magnetic field* and *magnetic flux density* are used interchangeably although the former is scientifically correct.

mG with an accurancy of ±20% at its mid-range. The Trifield meter measures frequencies from 30 to 500 Hz and hence harmonics associated with 60 Hz power distribution are detected. Measurements with this meter were taken at waist height (100 cm). Three communities were selected for study, a downtown commercial community; a downtown residential community; and a suburban residential community. For each community, 8 street segments (a portion of the street with a minimum of 20 buildings) were monitored.

Measurements were taken on both sides of the street at the front door of buildings, in the middle of the sidewalk (if present) or along the road edge (if sidewalk absent) aligned with the front door of each building, and at intersections. Sources of magnetic fields were identified where possible. Measurements were taken Monday to Friday during the day (0900 to 1700 h) and in the evening (1700 to 2100 h).

To facilitate community comparisons of potential risk factors associated with magnetic field exposure, the field intensity (FI) classification scheme developed by Havas [1] was used in this study. This classification scheme uses the traffic light analogy for exposure (green=low; amber=medium; red=high; black=very high exposure). Mean magnetic field values below 2 mG are green; between 2 and 9.9 mG are amber; between 10 and 29.9 mG are red; and at or above 30 mG are black. This classification scheme is based on results from epidmiological and laboratory studies that have associated exposure with biological responses, refered to as biomarkers in the present study. These biomarkers include a doubling of childhood leukemia at 2 to 4 mG [2,3] (amber); increased growth of estrogen responsive human breast cancers cells at 12 mG [4,5,6,7] (red); increased risk of spontaneous miscarriages at 16 mG [8] (red); and increased incidence of chromosomal aberrations in peripheral lymphocytes between 20 and 120 mG [9] (red to black).

Results & Discussion

Within the last decade, progress has been made in documenting electromagnetic fields found in various locations, near high voltage transmission lines [10], near houshold appliances [11]), within homes [12], and within the workplace [13]. However, knowledge about electromangetic fields found on city streets is limited to just a few studies [1,14,15].

In a recent study Princess Street in Kingston was reported to have the highest magnetic fields of the 60 communities tested in south-central Ontario [1]. Values at the intersections on Princess Street in 1998 were 47 mG on average with a range of 1.8 to greater than 100 mG [1]. The community with the second highest magnetic flux density was Simcoe Street in Oshawa (30 mG). Even Yonge Street in Toronto (19 mG) had much lower magnetic fields than did Princess Street. The high magnetic flux density along Princess Street was associated with the underground utility distribution system that was located immediately under the sidewalk.

Was the magnetic field measured on Princess Street unique or did Kingston have higher than average magnetic fields when compared with other urban centres in Ontario?

In an attempt to answer this question three communities in Kingston were selected for further study. Of the three community types (downtown commercial, downtown residential, and suburban residential), the highest magnetic flux density was found in the downtown commercial district (mean 28 mG) (Table 1). Within this community the highest values were observed at intersections (mean 38.5 mG; range 21-55 mG). Magnetic fields were lower along the street (mean 28 mG; range 12-45 mG) and at the front door of buildings (mean 16.5 mG; range 6-27 mG) (Table 1, Figure 1). King Street (45 mG) had the highest magnetic fields, followed by Bagot Street (39 mG), and then Princess Street (36 mG) (Table 2). Montreal Street had the lowest magnetic flux density of the 8 commercial streets monitored and even this street had average day and evening magnetic fields of 12 mG. The magnetic fields at intersections along Princess Street were similar in 2003 to the original monitoring conducted in 1998 [1] (Figure 2). What this study shows is that Princess Street is not an anomaly. A considerable section of downtown Kingston has high magnetic fields at street level associated with electrical power distribution.

Many of the downtown commercial buildings are multistoried structures located within 2 or 3 meters of the road edge. Since most of the utilities are underground, the highest magnetic field readings are likely to be on the main floor and in the basement. This study was conducted a few days after a major power blackout in Ontario and in several north-eastern American states and the Ontario government advised power conservation. Hence the values reported in this study are likely to be lower than under normal power usage for this time of year.

Table 1. Summary of magnetic flux density data for three communities within the City of Kingston, ON, Canada. Measurements taken at intersections, along city streets, and at the front door of buildings Monday to Friday during the day (0900-1700 h) and evening (1700-2100 h). Data are colour-coded based on field intensity (FI) classification scheme that incorporates various biomarkers (amber for childhood leukemia; red for breast cancer and miscarriages; and black for chromosomal aberrations) [1]. Eight street segments consisting of a minimum of 20 buildings were monitored for each community type (n=3960).

Downtown residential homes consisted of 1 to 2 storey buildings with small front yards. The majority of the streets had overhead electrical utilities adjacent to the road in the front. Hence rooms facing the street on the second floor are much closer to the overhead utilities lines and are likely to have higher magnetic fields that those recorded at the front door. Magnetic fields in the downtown residential communities averaged 3.2 mG and were considerably lower than in the commercial district (Table 1). Intersection, street, and building values were similar. Some buildings with magnetic flux densities higher at the front door than along the street had service drops near the front door. Some of the highest values were measured at intersections where overhead distribution lines running both north/south and east/west often overlap. Average values for all but one street were below 10 mG (Table 2). Day and evening values were similar (Table 1).

Bungalows and two-story homes with large front yards were characteristic of the suburbs. The electrical utilities were generally located underground at the road edge in the front of the homes and occasionally on overhead utility poles in the rear of the homes. Magnetic flux densities for the suburban residential communities averaged 4.0 mG and values were slightly higher in the evenings (Tables 1, 2). A few streets had magnetic flux densities above 10 mG along the street and at intersections but mean values at the front door of residences along these streets did not exceed 4 mG (Table 2).

Magnetic Flux Density (mG) for the City of Kingston, ON, Canada

Community		Intersection			Street			Building		
		min	mean	max	min	mean	max	min	mean	max
Downtown Commercial	day	21	39	54	13	29	44	7.5	17	27
	evening	22	38	55	12	27	47	6.2	16	24
x=28 mG, n=1940	all	21	38.5	55	12	28	47	6.2	16.5	27
Downtown Residential	day	1.5	3.6	6.2	1.9	2.6	4.7	1.9	3.0	4.6
	evening	2.2	4.5	11	1.9	2.8	5.0	2.0	3.0	4.0
x=3.2 mG, n=988	all	1.5	4.1	11	1.9	2.7	5.0	1.9	3.0	4.6
Suburban Residential	day	0.6	4.9	14	0.5	4.8	14	0.6	1.5	2.9
	evening	0.6	5.8	15	0.5	5.5	14	0.6	1.8	3.4
x=4.0 mG, n=1032	all	0.6	5.4	15	0.5	5.2	14	0.6	1.7	3.4

Colour Code	MFD (mG)	Exposure
black	≥ 30	very high
red	10 - 29.9	high
amber	2 - 9.9	medium
green	< 2.0	low

Lindgren et al. [14] documented power frequency magnetic fields within a 1 km^2 section of Goteborg, Sweden that contained a mix of residential and commercial buildings and was an area frequented by pedestrian traffic. They report an arithmetic mean of 3.4 mG for this area with a peak value of 97 mG. Magnetic flux densities above 10 mG were recorded near distribution pillars, substations, shoplifting alarms, and other electrical devices. This area of Goteborg has similar magnetic flux densities to the two residential communities within Kingston.

D'Amore et al. (1997) [15] conducted a field survey in the town of Turin, Italy. Based on approximately 12,000 measurements in 10 districts, the mean magnetic flux density was 1.9 mG, considerably lower than the communities monitored in Kingston.
Of the almost 4000 measurements taken in this study, 76% were above 2 mG, the lower limit associated with childhood leukemia in epidemiological studies [2,3]. More specifically, the downtown commercial, downtown residential, and suburban communities had 97%, 68% and 42% of readings above 2 mG respectively. These

magnetic flux densities are unlikely to be identical to values inside homes since the magnetic field decreases rapidly with distance away from distribution lines and since appliances and indoor wiring can contribute to residential exposure. This study does not provide any information on indoor magnetic flux densities and whether Kingston homes have high or low magnetic fields is not known at this time.

The same cannot be said for business in the commercial district that have high magnetic fields at the front door. Often cash registers in retail stores are located near the entrance and some restaurants offer curb-side dining. Magnetic field exposure of patrons and employees in these circumstances is likely to be high.

As many as 64% of the measurements in the commercial district were above 12 mG, which has been associated with enhanced breast cancer proliferation *in vitro* [4,5,6,7], and 54% were above 16 mG, which has been associated with increased risk of miscarriages [8]. Magnetic flux densities above 12 mG exceed most electrical occupations. Deadman et al. [16] reported a mean magnetic flux density of 1.66 mG for electrical workers with a maximum of 3.4 mG based on personal monitors worn for one week. According to the current study, individuals working at the many businesses located in the downtown commercial district in Kingston, and particularly street vendors, delivery personal, maintenance workers, police, utility employees could be expected to have higher magnetic field exposures than many electrical workers [13]. What this study shows is that exposure to street level magnetic fields may be considerable in some communities, posing a potential risk to people who spent time in this environment.

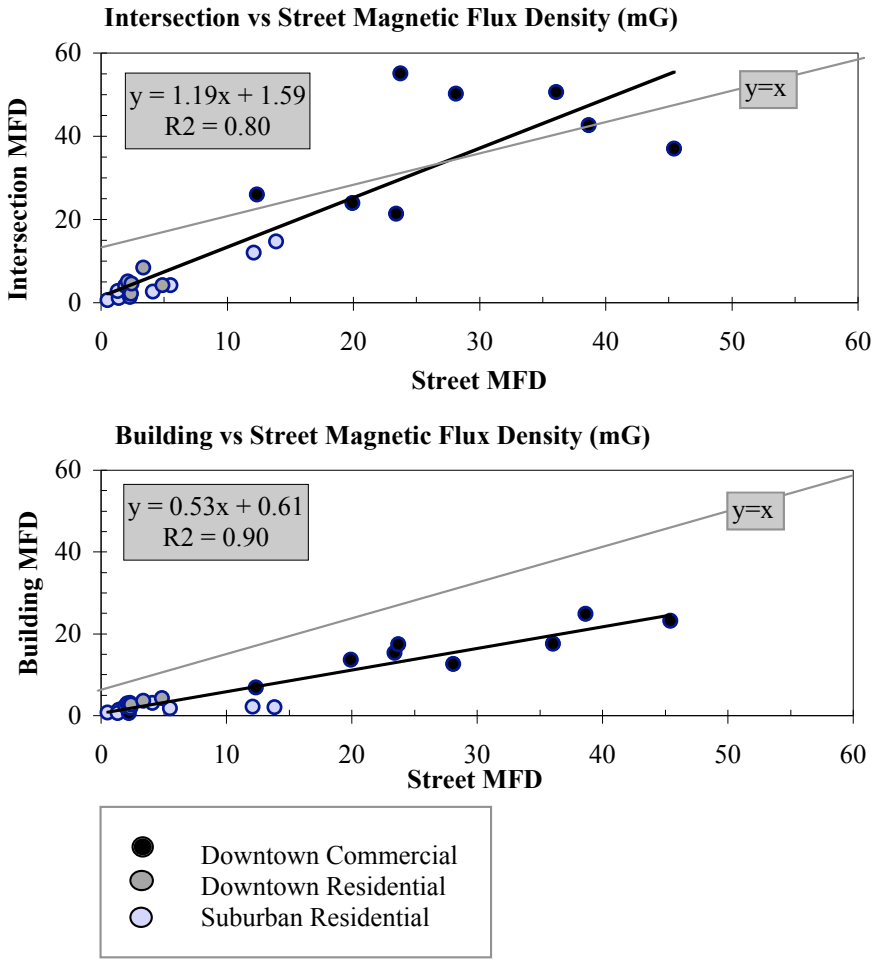


Figure 1. Comparison of magnetic flux density at the front door of buildings, on the street, and at intersections in three communities in Kingston, ON.

Table 2. Magnetic flux density values for different streets in the downtown commercial core, in a downtown residential community, and in a suburban residential community within the City of Kingston, Ontario; August 2003.

Suburban Residential (SUR)

	Day			Evening			Day & Evening		
Street	Building	Street	Intersctn	Building	Street	Intersctn	Building	Street	Intersctn
Glen Castle	0.8	0.5	0.6	0.8	0.5	0.6	0.8	0.5	0.6
Truman	1.4	1.5	1.3	1.4	1.3	1.1	1.4	1.4	1.2
Terraceview	0.6	1.1	2.7	0.8	1.5	2.9	0.7	1.3	2.8
Compass	0.6	2.1	4.3	0.8	2.3	4.4	0.7	2.2	4.4
Waterloo	1.2	5.0	3.7	2.5	6.0	4.8	1.9	5.5	4.3
Portsmouth	2.9	3.9	2.4	3.4	4.3	3.1	3.2	4.1	2.8
Kimberly	2.0	9.9	9.5	2.4	14.3	14.6	2.2	12.1	12.1
Old Colony	2.1	14.1	14.6	2.2	13.6	14.9	2.2	13.9	14.8
SUR Mean	1.5	4.8	4.9	1.8	5.5	5.8	1.6	5.1	5.3

Downtown Residential (DTR)

	Day			Evening			Day & Evening		
Street	Building	Street	Intersctn	Building	Street	Intersctn	Building	Street	Intersctn
Rideau	2.6	1.9	4.1	2.1	1.9	4.2	2.4	1.9	4.2
Colbourne	2.9	2.0	4.9	3.1	2.2	5.3	3.0	2.1	5.1
Chatham	3.5	2.6	1.5	2.7	2.0	1.2	3.1	2.3	1.4
Bagot	2.5	2.1	2.0	2.8	2.5	2.6	2.7	2.3	2.3
Quebec	1.9	2.3	2.1	2.0	2.4	2.2	2.0	2.4	2.2
Earl	2.3	2.2	4.2	3.1	2.6	5.1	2.7	2.4	4.7
Synderham	3.4	3.1	6.2	4.0	3.6	10.8	3.7	3.4	8.5
Montreal	4.6	4.7	4.1	3.9	5.0	4.3	4.3	4.9	4.2
DTR Mean	3.0	2.6	3.6	3.0	2.8	4.5	3.0	2.7	4.1

Downtown Commercial (DTC)

	Day			Evening			Day & Evening		
Street	Building	Street	Intersctn	Building	Street	Intersctn	Building	Street	Intersctn
Montreal	7.5	13.2	22.7	6.2	11.5	29.3	6.9	12.4	26.0
Ontario	14.3	19.9	25.0	13.0	19.9	22.9	13.7	19.9	24.0
Queen	15.0	23.2	21.2	15.9	23.6	21.6	15.5	23.4	21.4
Wellington	19.9	24.4	56.5	15.0	23.0	53.8	17.5	23.7	55.2
Brock	13.4	29.5	54.6	11.8	26.7	45.9	12.6	28.1	50.3
Princess	16.8	40.0	53.7	18.4	32.1	47.7	17.6	36.1	50.7
Bagot	27.2	41.6	43.7	22.5	35.7	41.6	24.9	38.7	42.7
King	23.0	44.0	36.4	23.5	46.8	37.8	23.3	45.4	37.1
DTC Mean	17	29	39	16	27	38	16.5	28.4	38.4

Magnetic Flux Density (mG)		
black	≥ 30	very high
red	10 - 29.9	high
amber	2 - 9.9	medium
green	< 2.0	low

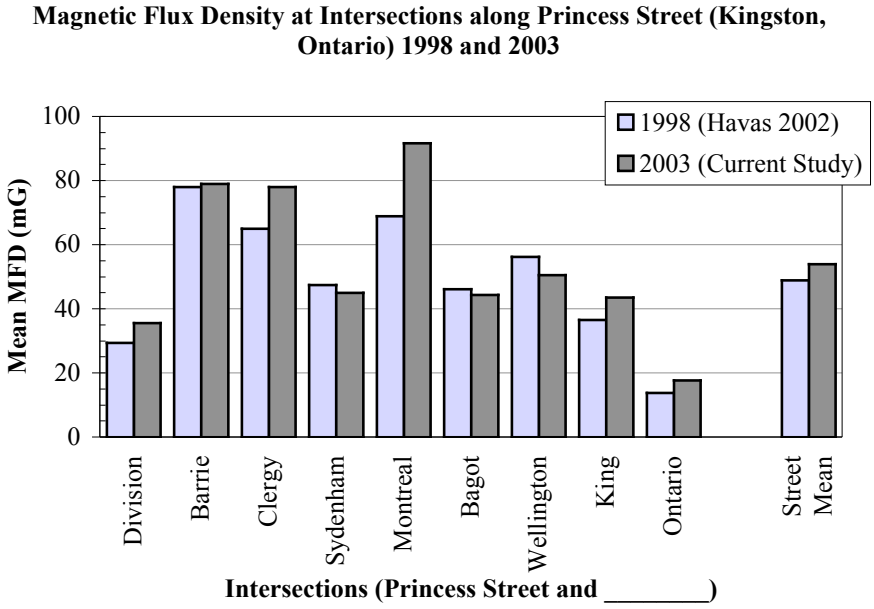


Figure 2. Comparison of 1998 vs 2003 data for magnetic flux density measured at intersections along Princess Street in Kingston, Ontario, Canada.

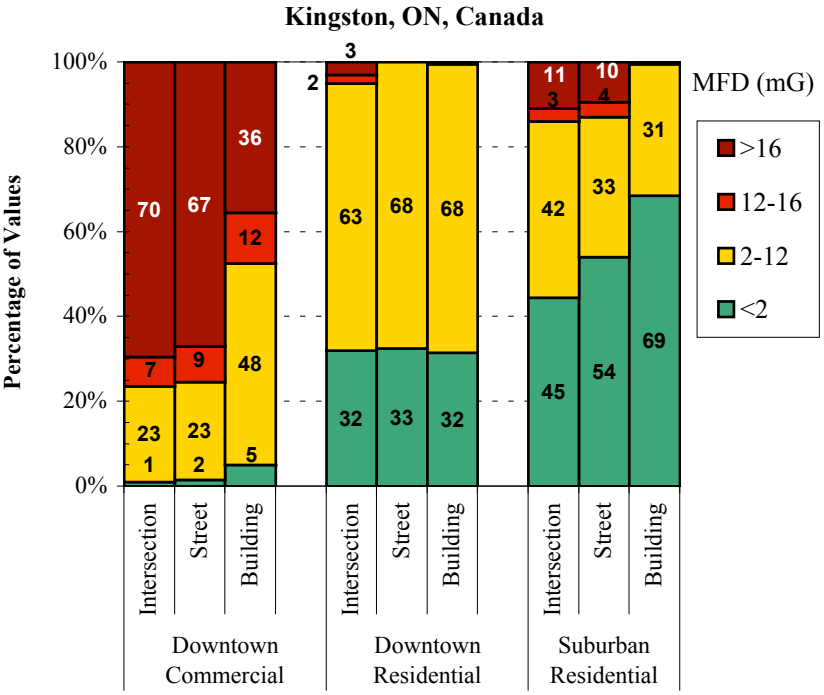


Figure 3. Percentage of magnetic flux density (MFD) measurements taken in three communities within the City of Kingston, Ontario. that exceed certain biomarkers associated with an increased risk of childhood leukemia (2 mG); with enhanced growth of human breast cancer cells in vitro (12 mG); and with increased incidence of miscarriages (16 mG).

Conclusions

The magnetic fields along streets, particularly in the downtown commercial district, in Kingston, ON are high. These streets have much higher magnetic flux densities than Goteburg Sweden [14], Turin Italy [15] and 59 other urban centres monitored in Ontario [1]. Indeed, street maintenance workers, postal carriers, and others

who spend time in this environment on a daily basis may be exposed to magnetic fields that exceed exposure in many electrical occupations [13]. Many of the magnetic flux densities readings in the Kingston commercial district exceed values that have been associated with childhood leukemia (2 mG), enhanced breast cancer growth (12 mG), miscarriages (16 mG), and chromosomal aberrations (20 mG) and this needs to be taken seriously [2,3,4,5,6,7,8,9].

Magnetic fields in the dowtown residential community are much lower than in the commercial district but even in this community more than 60% of the streets had values above 2 mG and these values are associated with an increased risk of childhood leukemia. Homes located on streets with higher magnetic fields need to be monitored and steps need to be taken to reduce children's exposure especially in the bedroom. In some cases moving a bed a few meters further away from the power line is all that is needed.

The suburban residential community had the lowest magnetic field readings. Many of the distribution lines in this community are underground and the magnetic field, although high immediately above the underground cables, decreases rapidly with distance. The large front yards contribute to lower magnetic fields at the front door of residences in the suburbs. Sources of magnetic field exposure inside the home in this community are likely to include electrical appliances and indoor wiring rather than the outdoor distribution system [17].

This study may help Kingston Utility determine other areas in Kingston where magnetic fields are likely to be elevated at street level based on wiring configuration both above and below ground. We recommend that (1) magnetic flux densities at street level be reduced, especially where pedestrian and vehicular traffic is considerable; (2) magnetic field exposure of municipal workers, postal carriers, police, and utility employees who spend considerable time on city streets be monitored; and (3) the City of Kingston adopt a policy of prudent avoidance regarding electromagnetic field exposure.

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