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# PASSENGER EXPOSURE TO MAGNETIC FIELDS ON GO-TRAINS AND ON BUSES, STREETCARS, AND SUBWAYS RUN BY THE TORONTO TRANSIT COMMISSION, TORONTO, CANADA

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## *Abstract*

Magnetic flux density was measured in the passenger compartment of buses, streetcars, subways and GO-trains that move millions of commuters daily in the Greater Toronto Area. The highest magnetic fields were found in subways (mean 30 mG, range 3 to 100 mG), followed by streetcars (mean 30 mG, range 2 to 100 mG), buses (mean 11 mG, range 1 to 50 mG) and the GO-train (mean 2 mG, range 1.2 to 2.8 mG). The magnetic field increased with acceleration and deceleration and varied with seat location and this was most obvious in subways and streetcars. All seats on subways, 98% of seats in streetcars, 85% in buses, and 38% on the GO train exceeded 2 mG, the magnetic field associated with childhood leukemia. The magnetic fields in the Toronto public transit system are higher than in most residential and occupational settings and are cause for concern considering that several studies have reported increased incidence of breast cancer, brain tumors, and leukemia among transit employees. Commuters with electrical sensitivity may have difficulty using some forms of public transit and as many as 2% of the 1.4 million daily revenue passengers in the Greater Toronto Area may be electrically sensitive. If the magnetic fields obtained in this study are representative of the transit system, then steps need to be taken to reduce magnetic field exposure of both commuters and transit employees.

## Introduction

Electric and magnetic fields[1] (EMF) have become significant environmental issues around the world. The number and diversity of EMF sources are increasing with possible effects to public health. According to criteria used by the International Agency for Research on Cancers (IARC), extremely low frequency electromagnetic fields have been identified as a "possible" human carcinogen [1]. In addition to cancers, studies have found associations between EMF exposure and miscarriages, amyotrophic lateral sclerosis, and sleep disturbances [2]. Some people are extremely sensitive to this form of energy. Symptoms among electrically sensitive individuals include headaches, flu-like symptoms, chronic fatigue, fibromyalgia, poor quality sleep, tightness in the chest, eye discomfort, skin disorders, dizziness, nausea, and difficulty concentrating [3]. As many as 2 percent of the Swedish population have identified themselves as hypersensitive to electric or magnetic fields [4]

Magnetic fields associated with transportation systems have not been documented in great detail with some exceptions [5, 6]. In large urban centres, where millions of people use public transit, this form of transportation may contribute significantly to daily magnetic field exposure. In this report, exposure of passengers in the Greater Toronto Area (GTA) to magnetic fields in subways, buses, streetcars and GO-trains are compared

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

## Method

Passenger exposure to magnetic fields was measured during the fall of 2003 in 4 modes of public transit: buses, streetcars, subways, and GO-trains. 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 higher range, the meter can measure magnetic flux densities from 1 to 100 mG with an accurancy of +20% at its mid-range. This particular 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 chest height while seated (80 to 100 cm above the floor).

A total of 54 seats on 10 buses selected at random in the Steeles/Sheppard area of northern Toronto were monitored for magnetic fields. Readings were taken at 10-second intervals while the buses were in motion. Streetcars (65 seats on 10 streetcars) in downtown Toronto bounded by Gerrard, Union Station, Broadview, and Bathurst were monitored at 5-second intervals while in motion. Magnetic fields were measured at 5-second intervals in 6 different compartments in the GO-train (10 seats per compartment) while the train was in motion between Union Station and Pickering. A total of 54 seats were monitored on 5 east/west-bound and 5 north/south-bound subways. The monitoring used for subways differed in that measurements were taken during acceleration, motion, and deceleration rather than at 5- or 10-second intervals. Generally magnetic fields were much higher during acceleration and deceleration compared with steady motion of the subway trains. To provide an integrated magnetic flux density for passenger exposure at a particular seat, the duration of acceleration and deceleration was noted and values were time-weighted.

## Results & Discussion

In comparing EMF exposure between the four forms of public transit the lowest magnetic fields were recorded on GO-trains (mean 2 mG, range 1.2 to 2.8 mG), followed by buses (mean 11 mG, range 1 to 50 mG) and then by streetcars (mean 30 mG, range 2 to 100 mG) and subways (mean 30 mG, range 3 to 100 mG) (Table 1).

Table 1. Magnetic flux densities (MFD) for different forms of public transit and percentage of seats with MFDs above biologically critical endpoints. See text for details. Readings taken in Toronto and in the Greater Toronto Area during the fall of 2003.

| Public Transit | Compartments | Seats | Readings | MFD (mG) mean | MFD (mG) range | Percentage of Seats ≥ 2 mG | Percentage of Seats ≥12 mG | Percentage of Seats ≥ 16 mG |
|---|---|---|---|---|---|---|---|---|
| GO Train | 6 | 60 | 780 | 2 | 1.2 - 2.8 | 38% | 0% | 0% |
| Bus | 10 | 54 | 609 | 11 | 1 - 50 | 85% | 37% | 20% |
| Streetcar | 10 | 65 | 1143 | 30 | 2-100 | 98% | 54% | 49% |
| Subway | 10 | 54 | 417 | 30 | 3 - 100 | 100% | 62% | 57% |
| Total | 36 | 216 | 2907 | | | | | |

Results obtained in this study are similar to other studies of magnetic fields in transit systems [5,7,8]. The magnetic field values for the Toronto subway system (30 mG) fall midway between the Boston subway (3.4 mG) and the subway in Washington DC (60 mG). The GO train from Toronto to Pickering has lower magnetic fields (2 mG) than either the electric MAGLEV commuter train (30 mG) or the Amtrak non-electric commuter train between NY and New Haven (3.5 mG for 60 Hz fields) [7,8]. However, only one train was monitored in this study and this may not represent all GO trains. Toronto buses have similar but slightly lower magnetic flux densities (11 mG) than buses in the Dietrich and Jacob study (17 mG) [5].

The magnetic field exposure of passengers in the Toronto transit system is high compared with residential exposure and many forms of occupational exposure. According to the 1000 home survey (cited in [1]) 50 percent of the homes had magnetic fields below 0.6 mG and less than 1 percent of the homes exceeded 6.6 mG. This is based on measurements taken in the centre of rooms. Measurements near appliances may be higher [9].

The time-weighted magnetic field exposure of electrical occupations derived from job titles is estimated to be 1.2 mG at the 25th%, 1.7 mG at the 50th%, 2.7 mG and the 75th%, and 6.6 mG at the 95th% [1]. Therefore, only 5% of electrical occupations are exposed to magnetic fields above 6.6 mG during a regular workday. This is much lower than the average magnetic fields on subways, streetcars, and buses documented in the present study. The highest magnetic field exposures (time-weighted) are for railroad engineers (40 mG), linemen (36 mG), electricians and tailors (30 mG), machinists (27 mG), and welders (20 mG) [2]. Therefore, magnetic field exposure on some forms of public transit is higher than one might experience at home and in other workplace environments.

In large urban centres like Toronto, many people depend on public transportation. In 2003, there were approximately 1.4 million revenue passengers using TTC and GO transit daily [10,11]. For electrically sensitive individuals this form of transit may create serious problems. Some electrically sensitive people feel uncomfortable in certain stores where the high intensity lighting becomes unbearable leading to headaches, confusion, and fatigue. If hypersensitivity to electromagnetic fields in the Canadian population is similar to the Swedish population (2%) then as many as 28 thousand of the 1.4 million daily revenue passengers in the Greater Toronto Area may be experiencing some form of discomfort [3,4].

Daily exposure to magnetic fields of commuters is short-lived compared with public transit employees, especially drivers and conductors. The fact that magnetic fields on streetcars, subways and buses are higher than for most electrical occupations is cause for concern, especially for the employees. Although exposure of drivers to magnetic fields was not measured in this study, it is likely to be similar to passenger exposure and that is a cause for concern since prolonged exposure to much lower magnetic fields have been associated with various forms of cancer [2].

A number of studies have been published showing health effects among transportation workers associated with EMF exposure. One study in Norway [12] and another in Sweden [13] reported increased rates of male breast cancer for electrical transport workers. While the number of cases in these studies was small (2 to 4) the relative risk was high (4 to 8-fold increase). Other studies reported an increased risk of cancer morbidity and higher incidence of leukemia and brain tumors among train employees and railway drivers [14,15,16].

One caveat to Table 1 is that these average values may be slightly misleading since seats on the various forms of public transit within one bus or within one subway compartment can differ considerably (Tables 2, 3, 4, 5). For example, on buses (Table 2), the magnetic flux density averaged 11 mG but ranged from 1 to 50 mG for individual seats. Also while 50% of the buses had magnetic fields at or lower than 6 mG, some had average values above 20 mG.

Passengers on streetcars are exposed to magnetic fields between 2 and 100 mG (based on 10 streetcars and 65 seats) and on any one streetcar the seat values can range considerably (4 vs. 100 mG on streetcar 4121 for example) (Table 3).

Variability of the magnetic flux density within subway compartments was considerable (Table 4). Subways and streetcars had the highest magnetic fields on average and because so many people use these forms of transportation, they are the one that needs to be properly managed to reduce exposure of both the public and transit employees.

The GO train was the cleanest form of public transit based on magnetic field readings in 6 compartments and a total of 60 seats. Magnetic flux density did not exceed 2.8 mG at any of the seats measured. However, since only one GO Train was monitored this might not be representative of the GO-system in general. More monitoring is recommended.

Three different biological endpoints associated with magnetic field exposure have been identified in the literature: namely 2 to 4 mG that has been associated with a 2-fold increased risk for childhood leukaemia with residential exposure [17]; 12 mG associated with an increase in the growth of human breast cancers cells *in vitro* [18]; and 16 mG associated with increased risk of miscarriages during the first trimester of pregnancy [19].

Table 2. Magnetic flux density (MFD) in Toronto buses monitored during the fall of 2003. Readings taken at 10-second intervals while bus was in motion. Seats and buses were selected at random.

| Bus # | Route | from Station | seats | MFD (mG) | | readings |
|---|---|---|---|---|---|---|
| | | | | mean | range | (n) |
| 7134 | 43 | Kennedy | 5 | 5 | 1-9 | 73 |
| 7099 | 85 | Sheppard E | 5 | 5 | 1-10 | 58 |
| 7091 | 53 | Steeles E | 5 | 5 | 2-11 | 47 |
| 7087 | 53 | Finch Station | 5 | 6 | 1-10 | 52 |
| 7121 | 53 | Finch Station | 6 | 6 | 1-11 | 95 |
| 7104 | 53 | Steeles E | 4 | 6 | 1-14 | 45 |
| 2805 | 43 | Steeles E | 6 | 13 | 3-23 | 75 |
| 6671 | 25 | Don Mills | 6 | 14 | 2-26 | 58 |
| 6653 | 25 | Don Mills | 6 | 22 | 2-50 | 65 |
| 7404 | 25 | Don Mills | 6 | 24 | 15-38 | 41 |
| | | Bus total/average/range | 54 | 11 | 1-50 | total=609 |

Table 3. Magnetic flux density (MFD) in Toronto streetcars monitored during the fall of 2003. Readings taken at 5-second intervals while streetcar was in motion. Seats and streetcars were selected at random.

| Streetcar | Station | seats | MFD (mG) | | readings |
|---|---|---|---|---|---|
| | | | mean | range | n |
| 4125 | Bathurst to Exhibition | 6 | 19 | 4-61 | 104 |
| 4184 | Dundas to Gerrard | 7 | 24 | 5-56 | 128 |
| 4041 | Broadview via King | 7 | 24 | 2-59 | 140 |
| 4010 | Broadview to Dundas | 7 | 25 | 2-88 | 122 |
| 4024 | Gerrard to Broadview | 7 | 25 | 3-92 | 114 |
| 4177 | Broadview via Dundas | 7 | 26 | 2-55 | 123 |
| 4053 | Dundas via Dundas W | 6 | 34 | 3-74 | 98 |
| 4150 | Exhibition to Union | 6 | 34 | 2-100 | 90 |
| 4158 | Dundas W to King | 6 | 45 | 4-91 | 103 |
| 4121 | Bathurst to Exhibition | 6 | 43 | 4-100 | 121 |
| | streetcar total/average/range | 65 | 30 | 2-100 | total=1143 |

All of the seats on subways exceeded the 2 mG magnetic field associated with childhood leukaemia; 62% exceeded the 12 mG associated with enhanced breast cancer growth; and 57% exceeded the 16 mG associated with miscarriages (Table 1). The results for streetcars were similar. The percentages for buses were slightly lower and for the GO-train they were significantly lower (Fig. 2).

Table 4. Magnetic flux density (MFD) in Toronto subways monitored during the fall of 2003. Readings were taken during acceleration, motion and deceleration and were time-weight to give an average time-weighted seat value. Seats and subway compartments were selected at random.

| Subway Compartment | Stations | seats | MFD (mG) mean | MFD (mG) range | readings n |
|---|---|---|---|---|---|
| | **North/South** | | | | |
| 5235 | North York to St. Clair | 2 | 16 | 16-17 | 18 |
| 5278 | Finch to Downsview | 4 | 25 | 3-38 | 93 |
| 5335 | Finch to Bloor/Yonge | 4 | 32 | 17-54 | 66 |
| 5154 | Dundas W to Kipling | 4 | 23 | 5-41 | 24 |
| 5161 | Finch to Bloor/Yonge | 5 | 47 | 5-100 | 30 |
| | **East/West** | | | | |
| 5873 | Bay to Jane | 6 | 17 | 3-32 | 36 |
| 5123 | Ossington to Islington | 4 | 37 | 7-100 | 30 |
| 5049 | Victoria Park to Bay | 6 | 34 | 3-100 | 36 |
| 5037 | Victoria Park to Bloor/Yonge | 5 | 34 | 7-87 | 36 |
| 5046 | Bloor/Yonge to Islington | 6 | 37 | 7-92 | 48 |
| | subway total/mean/range | 46 | 30 | 3-100 | total=417 |

Table 5. Magnetic flux density (MFD) in GO train compartments monitored during the fall of 2003 between Union Station and Pickering in the Greater Toronto Area. Readings taken at 5-second intervals while train was in motion. Seats were selected at random.

| Go Train Compartment | seats | MFD (mG) mean | MFD (mG) range | readings (n) |
|---|---|---|---|---|
| 2000 | 10 | 1.6 | 1.2-1.9 | 130 |
| 2508 | 10 | 1.7 | 1.4-1.9 | 130 |
| 2224 | 10 | 1.9 | 1.4-2.1 | 130 |
| 2234 | 10 | 2.0 | 1.8-2.4 | 130 |
| 2007 | 10 | 2.7 | 2.2-2.8 | 130 |
| 2107 | 10 | 2.1 | 1.8-2.3 | 130 |
| GO Train total/mean/range | 60 | 2.0 | 1.2-2.8 | total=780 |

One could interpret these results to suggest that it is unsafe for pregnant women or woman with breast cancer to ride on subways, streetcars, and possibly on some buses in Toronto. However time spent using public transit is short (often less than 1 to 3 hours daily) and is much less than one would spend at home or at work, which is where some of the studies were done that found associations with various forms of cancer [2]. At this time whether there are cumulative effects for magnetic field exposure is not known but such effects are probable based on occupational studies [2]. Long-term exposure to moderately elevated magnetic fields may be comparable to a short-term exposure to very high fields and intermittent magnetic field exposure may be relevant as well as time spent above a certain magnetic field strength level [16,19].

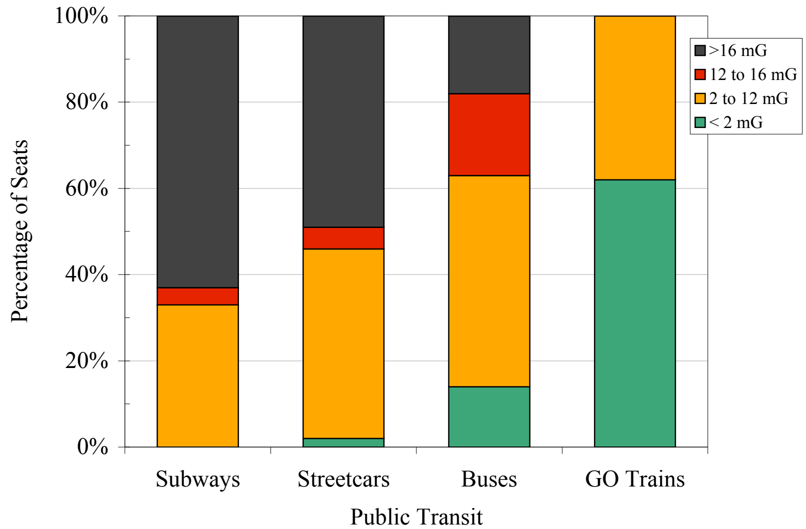


Figure 4. Percentage of seats on Toronto subways, streetcars, buses, and GO trains that exceed 3 biologically significant end-points, namely 2 mG associated with childhood leukaemia, 12 mG associated with growth of human breast cancer cells, and 16 mG associated with miscarriages. Magnetic flux density was monitored during the fall of 2003.

## Conclusion & Recommendations

The present study reports low magnetic fields in GO trains in the Greater Toronto Area (GTA) and high magnetic fields in Toronto subways, streetcars, and buses. Magnetic fields for Toronto transit are comparable to other public transit systems but are much higher than in most residential and occupational settings. This is a concern for electrically sensitive passengers that may number as much as 2 percent of the 1.4 million daily revenue paying commuters in the GTA. Although exposure of transit employees (conductors) was not measured in this study, it is likely to be similar to passenger values and that is a cause for concern since much lower magnetic fields have been associated with various forms of cancer, and epidemiological studies of transit workers have reported increased incidence of breast cancer, leukaemia, and brain tumours. Monitoring exposure of transit employees, especially drivers and conductors, to electromagnetic fields is recommended.

The present study measured magnetic field exposure of passengers. It did not determine the source of these fields (i.e. whether they were generated internally or externally by nearby power lines for example). This type of information (internal vs. external generation of the magnetic field) is critical for management purposes and more studies that focus on sources of these magnetic fields are needed since this initial study of the Toronto Transit system documents such high field strengths.

More GO trains need to be monitored for magnetic fields and monitoring the exposure of employees needs to be a high priority. If the values obtained in this study are representative of the Toronto transit system then steps need to be taken to reduce magnetic field exposure in subways, streetcars, and buses.

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