A B S T R A C T

This study was initiated to determine and compare daily occupational exposure (OE) and non-occupational exposure (NOE) of three employee groups of teachers, maintenance workers and secretarial staff in a Canadian school district. The time-weighted average (TWA) individual OE for subjects ranged from 0.4 - 3.8 milligauss (mG), and the TWA NOE ranged from 0.2 - 7.1 mG. TWA OE and NOE were 1.2 mG and 1.5 mG for teachers, 1.8 mG and 1.2 mG for maintenance workers, and 2.9 mG and 2.1 mG for secretarial staff. The differences between TWA OE and NOE of each group and also among the three groups were not statistically significant. OE and NOE of secretarial staff exceeded 10 mG 9.0% and 6.4% of the time – significantly ($p < 0.001$) higher rates than those of OE and NOE of teachers (1.0% and 1.4%) and maintenance workers (2.8% and 0.1%). Exposures were well below recommended criteria.

A B R É G É

Cette étude a été menée pour déterminer et comparer l'exposition professionnelle (EP) et l'exposition non professionnelle (ENP) quotidiennes de trois groupes d'employés, à savoir le personnel enseignant, le personnel chargé de l'entretien et le personnel des services de secrétariat, dans un district scolaire du Canada. S'agissant de l'EP, la moyenne individuelle pondérée en fonction du temps, se situait entre 0,4 et 3,8 milligauss (mG), et entre 0,2 et 7,1 milligauss pour l'ENP. La moyenne individuelle pondérée en fonction du temps pour l'EP et pour l'ENP étaient de 1,2 mG et 1,5 mG respectivement pour le personnel enseignant, de 1,8 mG et de 1,2 mG respectivement pour le personnel chargé de l'entretien, et de 2,9 mG et 2,1 mG respectivement pour le personnel des services de secrétariat. Les différences entre les moyennes pondérées en fonction du temps de l'EP et de l'ENP de chaque groupe ainsi que parmi les trois groupes ne sont pas apparues statistiquement significatives. L'EP et l'ENP du personnel des services de secrétariat dépassaient 10 mG dans 9 % et 6,4 % du temps, soit des taux nettement plus élevés ($p < 0,001$) que ceux de l'EP et de l'ENP du personnel enseignant (1 % et 1,4 %) et du personnel chargé de l'entretien (2,8 % et 0,1 %). Ces taux d'exposition étaient bien inférieurs aux recommandations.

Exposure of School Employees to Extremely Low Frequency Magnetic Fields

Farhang Akbar-Khanzadeh, PhD, Denny K. Bitovski, MS

Exposure to extremely low frequency magnetic fields (MFs) has recently been at the centre of a growing controversy associated with health concerns.¹ Exposure to MFs, which basically is due to the flow of electricity, is inevitable and it is disconcerting to suspect that something as useful as electricity could be a potential health hazard.

While most researchers believe adverse effects from MFs are low, they also note that higher doses may affect biological cells² or create certain types of disorders.^{3,4} Recent governmental reviews have concluded that existing evidence does not show a link between chronic diseases and exposure to MFs.⁵ There is no scientific consensus except that further research is needed on exposure to MFs. Furthermore, the majority of studies have focussed on workers exposed to high levels of MFs, and only a limited number of studies have been performed in public places such as school environments.

In Canada, concern surrounding the controversy of exposure to MFs has extended from school employees to children, prompting some school officials to take "prudent and reasonable actions (such as gathering information on exposures, determining MF levels, sharing information with parents and teachers)." This means using low-cost methods (such as increasing distance between subjects and the source) to reduce exposure to MFs. A few studies have recently been conducted

in Canadian schools to assess the levels of MFs,⁶⁻⁸ but these studies have limited the exposure assessment to area (fixed location) monitoring and have not involved personal monitoring.

Personal monitoring, the preferred method of evaluating individual exposure, is especially useful for monitoring those who move from place to place and engage in a variety of activities. Furthermore, the assessment of both occupational exposure (OE) and non-occupational exposure (NOE) would demonstrate the contribution of the workplace to overall daily exposure. This research was initiated to: 1) measure MF levels in different areas at representative schools; 2) determine 24-hour exposures of all three employee groups of teachers, maintenance workers and secretarial staff; and, 3) compare OE and NOE.

METHODS

Study location and subjects

This study was performed in an Ontario School District with 55 schools employing 1,645 teachers, 168 maintenance workers and 153 secretarial staff. The study included 5 high schools representing approximately 400 classrooms, and 3 elementary schools representing approximately 50 classrooms.

Randomly selected full-time teachers, maintenance workers and secretarial staff were recruited for the study. Each participant read and signed an approved informed consent form.

Exposure monitoring

For each subject, 24-hour (one cycle of occupational and non-occupational) personal exposure data were collected by a dosimeter (EFM Company, model

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EmdexC-509). This instrument has the capability to data-log average magnetic flux density at specific pre-set time intervals (i.e., one minute) from 0.1 mG (milligauss) to 100.0 G in the frequency range of 40 to 1,600 Hz. Each subject was asked to record on a log sheet as frequently as possible the type and time of his/her activities, and potential sources of exposure. The recorded data in the dosimeter were downloaded into a personal computer for statistical analysis.

Area monitoring was performed in classrooms, mechanical rooms, offices, and hallways by using a direct-reading MF meter (Holiday Industries, model HI-3604 ELF) held by the researcher at each location for approximately one minute until the reading was completed. The instrument measures magnetic flux densities from 0.1 mG to 20 G in the frequency range of up to 2 kHz. It should be noted that in this report, "levels of MFs" means "magnetic flux density."

Data analysis

The data were analyzed using SPSS software. Descriptive statistics were used to introduce the exposure to MFs, and t-tests and chi-square tests (Kruskal-Wallis Test) were used to determine differences between OE and NOE. The least significant difference of a One-Way ANOVA and chi-square tests were utilized to determine differences in exposure among the three employee groups.

RESULTS AND DISCUSSION

Personal exposure to MFs

Study subjects, ranging in age from 35-55 years, included 8 male teachers, 8 male maintenance workers, and 8 female secretarial staff. All subjects were monitored for OE and NOE. One teacher and two maintenance workers did not complete the non-occupational monitoring period. Subjects' exposures are summarized in Table I.

The results of monitoring OE and NOE for each study group (Table II) show that teachers had less OE than NOE; whereas both maintenance workers and secretarial staff showed more OE than NOE. The overall exposure of secretarial staff (2.41 ± 3.97 mG) was higher than that for either

Subject Group	Exposure Type	No. of Subjects	Individual No. of 1-min Samples min - max	Average Sampling Time (hours)	Individual Mean Exposure (mG) min - max
Teacher	OE	8	88 - 499	7.6	0.4 - 2.5
	NOE	7	955 - 991	16.3	0.6 - 5.1
Maintenance Worker	OE	8	432 - 544	8.3	0.7 - 3.8
	NOE	6	906 - 960	15.5	0.2 - 2.6
Secretarial Staff	OE	8	468 - 653	8.6	0.5 - 7.9
	NOE	8	932 - 960	16.0	0.6 - 7.1

Subject Group	Exposure Type	No of 1-min Samples	Magnetic Flux Density (mG)		
			mean (SD)	median	min-max
Teachers	OE (n=8)	3252	1.2 (1.9)	0.5	0.0 - 23
	NOE (n=7)	7276	1.5 (3.3)	0.6	0.0 - 66
Maintenance Workers	OE (n=8)	3963	1.8 (6.3)	0.7	0.0 - 155
	NOE (n=6)	5586	1.2 (1.3)	0.7	0.0 - 11
Secretarial Staff	OE (n=8)	4147	2.9 (3.8)	1.4	0.0 - 32
	NOE (n=8)	7661	2.1 (4.1)	0.8	0.0 - 47

n = number of subjects, SD = standard deviation

Site	Height from Floor (m)	Area			
		Classroom	Mechanical Room	Office	Hallway
High School (n=5)	0.5	0.3 (0.1)*	5.5 (2.3)	0.3 (0.1)	0.3 (0.1)
	1.0	0.3 (0.1)	7.0 (2.8)	0.3 (0.1)	0.4 (0.2)
	1.5	0.3 (0.1)	8.3 (3.0)	0.4 (0.1)	0.3 (0.2)
Elementary School (n=3)	0.5	0.2 (0.1)	2.5 (2.2)	0.4 (0.0)	0.3 (0.1)
	1.0	0.2 (0.1)	3.2 (2.8)	0.3 (0.0)	0.3 (0.1)
	1.5	0.3 (0.1)	5.1 (4.8)	0.4 (0.0)	0.3 (0.1)

* Value is mean (standard deviation)

teachers (1.36 ± 2.82 mG) or maintenance workers (1.44 ± 4.17 mG). Also, both OE and NOE of secretarial staff were higher than comparable exposures for either teachers or maintenance workers. The differences did not achieve statistical significance as expected given the small sample size of subjects and schools. The small sample size also limits the generalizability of the results.

The background MF levels usually range from 0.5 to 4 mG.⁹ Laboratory experiments with cells have reported effects at field levels of approximately 10 mG.¹⁰

Thus, to examine the exposures of subjects to higher levels of MFs, levels more than 10 mG were arbitrarily defined as "higher than normal." OE and NOE of secretarial staff which exceeded 10 mG 9.0% and 6.4% of the time were significantly ($p < 0.001$) higher than the comparable OE and NOE of teachers (1.0% and 1.4%) and maintenance workers (2.8% and 0.1%). The number of 1-minute OE exceeding 10 mG for maintenance workers and secretarial staff was significantly ($p < 0.001$) higher than the number of their own 1-minute NOE exceeding 10 mG.

Teachers, representing science, humanities, technical departments and elementary level teaching, spent approximately 75% of a working shift in their own classrooms. A typical classroom environment consisted of several sources of magnetic fields such as computers, fluorescent lights and audio-visual equipment.

Technology teachers recorded higher occupational readings than other teachers, mainly due to the electrically powered equipment used in the classroom. For example, Teacher No. 6 recorded a reading of 12 mG when working near a computer. The OE readings of Teacher No. 5 indicated several high readings including one at 19 mG, which was due to using a high voltage generator in the classroom. In comparison, his NOE generally remained below 5 mG.

Teacher No. 3 reported that he lived within 50 metres of a high-voltage overhead electric power distribution line. In his bedroom, MF readings up to 15 mG were noted, making his NOE the highest in the group.

Maintenance workers moved throughout the school, except for break periods when they would ordinarily spend time in the office areas. The main source of their exposures included vacuum cleaners, floor-buffing machines and power tools. For example, when a floor-buffing machine was used, a reading of 26 mG at a distance of 0.5 m from the source was recorded.

In general, maintenance workers' OE appeared to be low (median 0.7 mG) and consistent. Nonetheless, it was common for most maintenance workers to work near or with electrical devices and on some occasions they recorded unusually high readings. Three subjects (Nos. 2, 4, and 5) showed sporadic and intermittent high readings. Maintenance worker No. 1 showed readings of 3 to 6 mG over a two-hour period while using a vacuum machine. Subject No. 7 recorded exposure levels up to 12 mG while working in an electrical room which contained an electrical service panel for main power supply to the school. This subject showed the highest peak NOE; while he was working with powered electrical appliances in the kitchen area, his exposure reached levels of up to 115 mG.

Maintenance worker No. 6. recorded OE between 3 to 9 mG while working in the "electrical room" for several hours. Another source of exposure was an electric vacuum cleaner, generating 10-14 mG MFs. The NOE for this subject reached up to 9 mG during a one-hour period in the morning when the subject was close to electric power equipment around the house.

Secretarial staff recorded the highest overall average exposures (2.9 mG). They usually worked in the office areas and their movement around the school was limited. In general, secretarial staff showed high exposure readings over brief periods, the result of working with electrical equipment such as copying machines.

The OE of Secretarial staff No. 6 ranged up to 17 mG while she worked on a computer. Her overall NOE was generally low, ranging up to 2 mG. In contrast, Secretarial staff No. 7 had significantly higher NOE than OE. According to the log sheet, there were several electrical appliances such as a clock radio and a waterbed in the subject's house. This subject also experienced a reading of 10 to 12 mG over a one-hour period while working on the computer.

Several factors might have impacted the personal monitoring process. Some participants mentioned that the dosimeter was removed occasionally because it caused some discomfort. The monitor was temporarily placed near a work surface during one particular activity and was reattached when the person started a new activity. For example, one of the subjects, who had an average exposure of 7 mG of NOE, recorded a continuous 12 mG exposure over a six-hour period. The log sheet indicated that the person left the dosimeter near a clock radio before going to sleep that night.

Accurate account of time, activity and the sources of exposure may have been compromised because the subjects provided a general description of these parameters. Most log sheets recorded a description of the activity on a half-hour or even occasionally on an hourly basis. Sources of NOE were particularly difficult to isolate due to the frequent movements of the subjects in their houses.

Area MF measurements

Table III summarizes the magnetic flux density determined in different areas of the schools. In general, the mechanical rooms (which contain pumps, valves, air handling and ventilating units, water softeners, water heaters and boilers) had the highest overall readings followed by offices, classrooms and hallways. The readings of magnetic flux densities generally increased with the increase in the elevation from the floor. A possible explanation for this trend is the existence of overhead fluorescent lighting in many places throughout the schools.

Previous results of area monitoring in different schools are generally comparable with those obtained in this study. For example, in a study conducted by Sun et al.,⁶ the mean measurement in the hallways and in a typical classroom were 0.10 mG and 0.06 mG, respectively. A study performed by the Electric Power Research Institute¹¹ reported a mean of 0.11 mG, based on many samples taken in schools.

Comparison with exposure guidelines

The American Conference of Governmental Industrial Hygienists¹² has recommended a threshold limit value-ceiling (TLV-C) for occupational exposure to MFs in the frequencies ranging from 1 to 300 Hz. This is given by $B = 600/f$, where B is magnetic flux density in G and f is the frequency in Hz. Thus, for the common power-line frequency of 60 Hz, the TLV-C will be 10 G. The International Non-Ionizing Radiation Committee¹³ recommended values ranging from 5 to 50 G for MFs with a limit of 250 G for limbs. These and other guidelines for controlling OE to MFs are summarized and evaluated by Baily et al.¹⁴

The results of this study show that the exposures of the school employees to MFs are well below the recommended values. Existing guidelines are designed to prevent only short-term adverse health effects by maintaining bulk-tissue current densities below 10 mA·m⁻²(rms). Compliance with these recommendations does not necessarily mean that workers are fully protected against possible chronic diseases such as cancer. Some recent data confirm earlier reports that MFs cause changes in certain

biological systems,¹⁵ but the basis for those effects and underlying mechanisms of interaction remain largely unknown, and the long-term health implications for humans and animals have yet to be fully determined.¹⁶ Permissible exposure limits should, therefore, be set well below the existing recommended values as indicated by the emerging scientific data.¹⁷

ACKNOWLEDGEMENTS

The authors' appreciation is extended to Sadik A. Khuder, PhD, for assisting in statistical analysis, to Waterloo Catholic District School Board for facilities provided, and to the subjects for their participation in this study.

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Received: April 19, 1999

Accepted: September 17, 1999

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