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**Field Report**

# Occupational Exposures of Pharmacists and Pharmaceutical Assistants to 60 Hz Magnetic Fields

**Chung-Yi LI[1]*, Ruey-Shiung LIN[2], Chia-Hsing WU[1] and Fung-Chang SUNG[3]**

[1] Department of Public Health, College of Medicine, Fu Jen Catholic University, Taipei Hsien, Taiwan, ROC
[2] Graduate Institute of Epidemiology, College of Public Health, National Taiwan University, Taipei, Taiwan, ROC
[3] Graduate Institute of Environmental Health, College of Public Health, National Taiwan University, Taipei, Taiwan, ROC

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**Abstract: We carried out the study to assess, using field surveys and personal dosimetry, the potential exposure of pharmacists and pharmaceutical assistants to 60 Hz magnetic fields in a medical center of Taiwan. Field surveys were conducted twice in the pharmacy where two workers were randomly selected and solicited to wear personal dosimetry instruments for a full-shift assessment of personal exposure. We used an EMDEX II for on site measurements and did not consider any specific instrument or equipment for health care services as potential sources of magnetic field. The results showed that the average magnetic flux densities for the selected areas were between 0.63 mill-Gauss (mG) and 2.23 mG, while the full-shift time-weighted-average exposure for the two selected workers was 4.98 mG and 6.54 mG, respectively. Both inadequate consideration for the field survey of the temporal variability in magnetic flux densities over the workday and that the monitored workers spent almost half of the full-shift working in places outside of the study areas may have contributed to such discrepancy in results between field survey and personal dosimetry. This study suggests that the potential for elevated exposure to 60 Hz magnetic fields in health care settings does exist, and that using job title as a surrogate for magnetic fields exposure classification might entail certain degrees of misclassification. Although limited in its scope and sample size, the study presented here seems to demonstrate the inadequacy of using stationary workplace measurements for the assessment of personal occupational exposure to 60 Hz magnetic fields.**

**Key words:** Magnetic fields, Dosimetry, Survey, Occupational exposure

## Introduction

Power-frequency (PF) (50/60 Hertz (Hz)) electric and magnetic fields are ubiquitous in modern life. The exposure to PF electric and magnetic fields has been one of the environmental exposures that are important in indoor environment[1)], in particular for residents living near high-voltage power lines[2)] and workers employed as "electrical" occupations[3, 4)]. Because PF magnetic fields can easily penetrate trees and buildings, most of the studies have been focused on the possible causal link between elevated magnetic fields, rather than electric fields, exposure and adverse health outcomes in particularly cancers such as leukemia or brain cancer[5, 6)]. Previous studies considered a wide range of occupations as "electrical" occupations. These "electrical" occupations are usually involved in motor driven tools (e.g., electric drill) or equipment with a consumption of high current (e.g., streetcar and subway motorcar). On site measurements of the magnetic fields intensity for some of these occupations such as workers from electrical utilities were also reported in the literature[7–9)]. Nonetheless, the magnetic fields exposures for most of the "electrical" occupations were still so classified based on analogy or the experience of the industrial hygienist[10)]. Additionally, the information on the

*To whom correspondence should be addressed.

direct measurements showed a huge discrepancy in magnetic fields intensity between "electrical" occupations. For example, the magnetic fields intensity close to the handle of an electric drill can be as high as 5,000 mili-Gauss (mG)[10], whereas many electric utility employees experienced an exposure level of less than 2 mG[9], an intensity of background exposure in most parts of the world[11]. Unlike "electrical" occupations most of which are blue-collar workers, white-collar office workers have been considered background exposed in most studies. Although office workers generally experience a lower level of exposure than "electrical" workers, the potential for overexposure to magnetic fields in offices can't be ignored. Recent studies have demonstrated that white-collar office workers may have an intermittent exposure of more than 100 mG as they were close to some office equipment such as photocopier[12]. Such elevated exposure might last for a full-shift if the sitting position was near some major source of magnetic fields.

There were very few studies to date conducted to assess the health workers' exposure to magnetic fields in the power frequency range, i.e., 50/60 Hz[13]. The purpose of the study was to assess the potential exposure of pharmacists and pharmaceutical assistants to 60 Hz magnetic fields. In doing so, we conducted surveys of magnetic fields intensities in two areas of a medical center in Taipei, Taiwan. We also compared the surveyed data with the data of personal dosimetry to assess the adequacy of using data from field surveys to estimate the personal exposure to magnetic fields in hospitals.

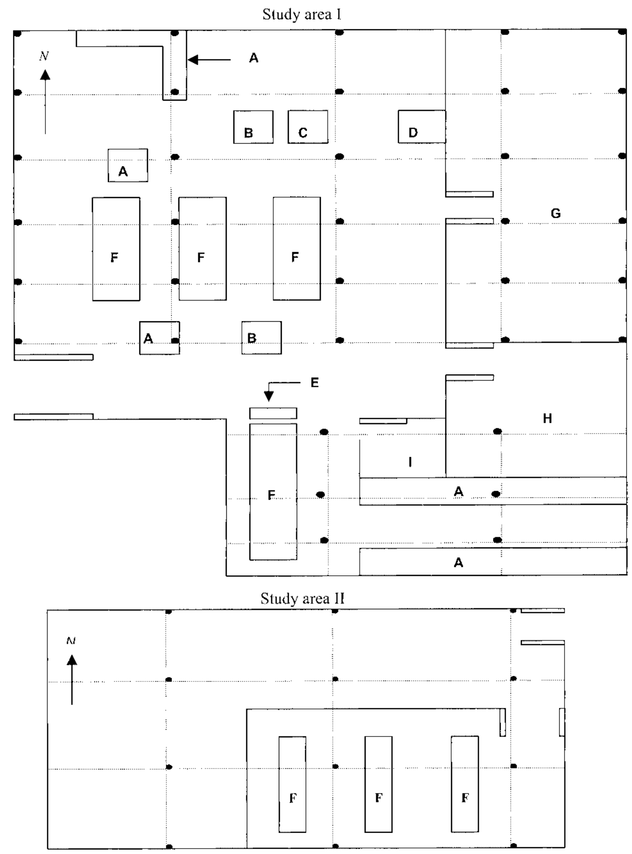


**Fig. 1. Scheme of the study area I and the study area II (not to scale)**
A: visual display terminal and printer; B: elevator; C: air conditioner; D: power room, control panel, and transformer; E: photocopier; F: work tables, closets for drug storage; G: meeting room; H: drug storage room; I: Director's office; •: site where measurement was taken.

## Materials and Methods

*Depiction of the study areas and the monitored pharmacists and pharmaceutical assistants*

This study was conducted at the pharmacy of a medical center in the city of Taipei. The pharmacy comprises two work areas located on the ground floor of a 16-floor building. More than 30 employees worked in the selected areas, most of whom were either pharmacists or pharmaceutical assistants; some others were office clerks. Figure 1 illustrated the scheme of the two study areas. The major sources of 60 Hz magnetic fields in the study areas included visual display terminal, elevator, transformer, photocopier, and air-conditioner. Most of the pharmacists and pharmaceutical assistants spent more than half of their full-shift working in the study areas. However, they must go on other responsibilities if necessary in different places of the hospital. The time that pharmacists and pharmaceutical assistants spent in places other than the study areas varied from day to day as well as from person to person. For office clerks, they stayed in the study areas for nearly the entire full-shift.

*Measurements*

The instruments used for field survey and personal dosimetry were an EMDEX II (*the EMDEX Electric and Magnetic Field Digital Exposure System, Enertech Consultants, Cambell, California*). Both field survey and personal dosimetry were carried out on October 26, 1999. The EMDEX II measures magnetic flux densities in the frequency of 40–800 Hz frequency (broadband) using three orthogonally mounted sensors and reported the individual components and resultant field magnitude over the sampling interval[14]. We reported the resultant field root mean square (rms) in this study.

Because the magnetic flux densities are not likely to be homogeneous in the study areas, we attempted to select a number of sites in the study areas for exposure measurement in order to obtain a representative estimate of the overall exposure in the study areas. A total of 36 sites in the study area I; and 12 sites in the study area II were selected for field survey (Fig. 1). In considering the temporal variability of magnetic flux density, the field survey was conducted twice at the time interval of 10:00–11:00 AM and 3:00–4:00 PM, respectively. For each selected site, measurements were taken at a one-meter high spatial placement over six minutes with a sampling time interval of 30 seconds. As a result, a total of some 12 readings were recorded in the dosimeters for each measured site. For each site, we further calculated the average of some 12 readings of rms as a site-specific magnetic flux density. The overall exposure in each study area was represented by the arithmetic mean or geometric mean of all site-specific magnetic flux densities.

In addition to the measurement of the study areas, we randomly selected two pharmacists and pharmaceutical assistants solicited to simultaneously wear EMDEX II for personal full-shift exposure assessment. The EMDEX II was worn in a belted pouch around the waist, a body part considered to have the highest level of exposure[12]. The two workers were asked to wear the dosimeter for a full-shift of some 8 hours during which the EMDEX II performed spot measurements of magnetic fields with a time interval of 5 minutes between neighboring measurements, which gave rise to a total of some 100 spot measurements for each monitored worker. They were asked not to leave the building during measurements. They were also asked to record the time period that they were not in the study areas and to document every 60 minutes the activities that they participated in. The full-shift time-weighted-average (TWA) exposure to magnetic flux density was reported for personal exposure.

*Data analysis*

For field surveys, we presented the minimum, maximum, and median densities for the two time periods of measurement in each study area; and calculated the average and geometric mean of all site-specific exposure to estimate the overall exposure for each study area. Information on personal monitoring was retrieved from the EMDEX II with software that has both statistical and graphing options. The statistical option provides the high, low, median, and mean magnetic flux density, and the cumulative percent of time at discrete flux densities over the sampling period[12].

## Results

Table 1 presents the magnetic flux densities in the two study areas. For the study area I, the magnetic flux densities measured in the morning ranged from 0.27 to 5.09 mG with an average of 1.78 mG and a geometric mean of 1.37 mG. The magnetic flux densities measured in the afternoon tended to be greater than those measured in the morning. Similar pattern of temporal variability in magnetic flux density was shown for the study area II. The magnetic flux densities for the study area II were consistently lower than those for the study area I. The lowest and highest exposure for the study area II was 0.23 mG recorded in the morning and 2.01 mG recorded in the afternoon.

One of the two monitored workers was a pharmacist and the other one was a pharmaceutical assistant. The full-shift TWA exposure and the maximum reading for the two monitored workers were shown in Table 2. The highest exposure experienced by the two monitored workers was 17.9 mG and 44.7 mG, respectively; both readings were recorded as they were in the study areas. The full-shift TWA exposure for the two workers was 4.98 mG and 6.54 mG, respectively; both were higher than the exposure presented by the field survey. As the exposure was restricted to those readings recorded in the study areas, the corresponding TWA exposure was declined to 3.24 mG and 4.65 mG, still higher than the field exposure. Figure 2 illustrates the temporal variability of exposure for the two workers. Exposure variability was greater for worker II than for worker I mainly because a notably higher exposure was recorded in the

**Table 1. 60 Hz magnetic flux densities (mG) in the study areas**

| Study areas and time of measurements | | No. of spatial sites measured | Min. | Max. | Median | AM ± STD | GM ± GSTD |
|---|---|---|---|---|---|---|---|
| Area I | 10–11 am | 36 | 0.27 | 5.09 | 1.27 | 1.78 ± 1.31 | 1.37 ± 0.03 |
| | 3–4 pm | 36 | 0.35 | 6.52 | 1.40 | 2.23 ± 2.10 | 1.50 ± 0.03 |
| Area II | 10–11 am | 12 | 0.23 | 1.62 | 0.51 | 0.63 ± 0.44 | 0.58 ± 0.02 |
| | 3–4 pm | 12 | 0.29 | 2.01 | 0.59 | 0.75 ± 0.02 | 0.68 ± 0.51 |

AM=arithmetic mean; STD=standard deviation; GM=geometric mean; GSTD=geometric standard deviation.

**Table 2. 60 Hz magnetic flux densities (mG) exposure of the two monitored pharmacists and pharmaceutical assistants**

| ID | Time period of measurement | No. of measurement | Min. | Max. | Median | AM ± STD | GM ± GSTD |
|---|---|---|---|---|---|---|---|
| 1 | 10:04 AM to 05:59 PM | 96 | 0.26 | 17.9 | 3.69 | 4.98 ± 4.01 | 3.59 ± 2.34 |
| 2 | 09:45 AM to 06:10 PM | 102 | 0.26 | 44.7 | 5.04 | 6.54 ± 8.38 | 3.13 ± 4.02 |

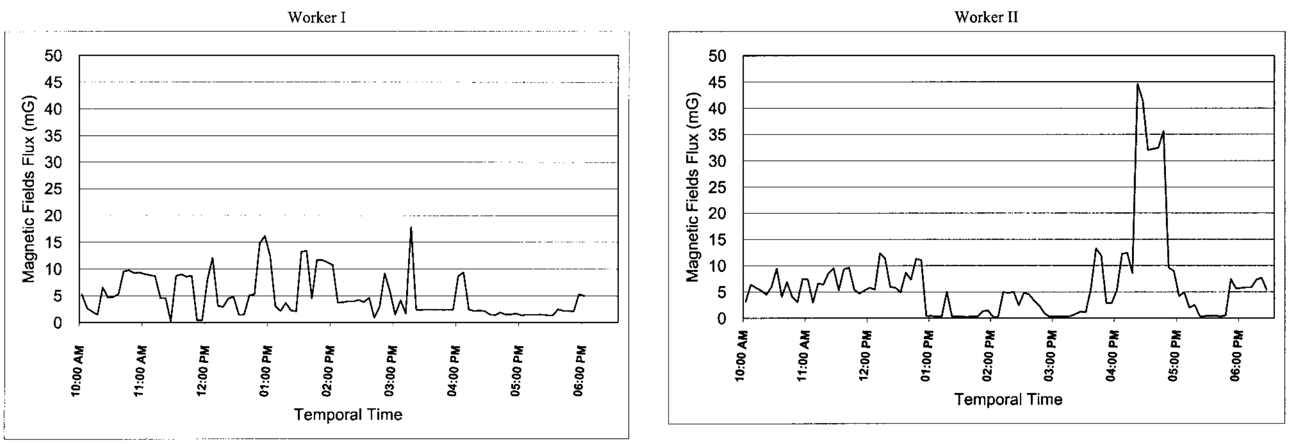


**Fig. 2. Temporal variability of magnetic field flux for the two monitored pharmacists and pharmaceutical assistants.**

**Table 3. Exposure time integrals for the two monitored pharmacists and pharmaceutical assistants over the sampling interval**

| Exposure Level (mG) | Worker I | | | Worker II | | |
|---|---|---|---|---|---|---|
| | No. of observation | % of time | Cumulative exposure (mG-h) | No. of observation | % of time | Cumulative exposure (mG-h) |
| 0–≤2 | 22 | 22.9 | 2.44 | 30 | 29.4 | 1.4 |
| >2–≤4 | 31 | 32.3 | 6.99 | 9 | 8.8 | 2.13 |
| >4–≤6 | 16 | 16.7 | 6.46 | 30 | 29.4 | 13.02 |
| >6–≤8 | 1 | 1.0 | 0.55 | 10 | 9.8 | 5.91 |
| >8–≤10 | 15 | 15.6 | 11.24 | 9 | 8.8 | 6.87 |
| >10–≤12 | 4 | 4.2 | 3.78 | 4 | 3.9 | 3.80 |
| >12–≤14 | 4 | 4.2 | 4.29 | 4 | 3.9 | 4.19 |
| >14–≥16 | 1 | 1.0 | 1.24 | 0 | 0.0 | 0.00 |
| Total | 96 | 100 | 39.84 | 102 | 100 | 55.56 |

afternoon for worker II. Recorded data from personal dosimetry also showed that the cumulative percent of time with exposure greater than 6 mG (a density similar to the maximum reading from field surveys) over the sampling period was around 26% for both workers; and the full shift cumulative exposure of the two workers was 39.84 mG-h and 55.56 mG-h, respectively (Table 3). Table 4 shows the activities and the corresponding magnetic flux densities. According the workers' diary, both workers spent some 45% of workday working outside of the study areas where both workers tended to experience an even higher level of exposure to magnetic flux density.

## Discussions

There has been considerable controversy about the possible

**Table 4. Activities and the corresponding magnetic flux densities (mG) for the two monitored pharmacists and pharmaceutical assistants**

| Event | Worker I | | | | Worker II | | | |
|---|---|---|---|---|---|---|---|---|
| | Time | Activities | Magnetic flux densities | In the study areas | Time | Activities | Magnetic flux densities | In the study areas |
| 1 | 10:55 | Near by copier | 9.32 | Yes | 10:05 | In Chief's office | 6.26 | Yes |
| 2 | 11:55 | Near by computer | 0.46 | Yes | 11:05 | Near by computer | 2.97 | Yes |
| 3 | 12:55 | Pharmaceutical preparation | 16.20 | No | 12:05 | Near by computer | 5.46 | Yes |
| 4 | 14:00 | Pharmaceutical preparation | 10.77 | No | 12:50 | Near by computer | 11.06 | No |
| 5 | 14:55 | Near by counter | 5.76 | Yes | 13:35 | Pharmaceutical preparation | 0.25 | Yes |
| 6 | 15:55 | Near the bench (lab.) | 2.41 | No | 14:25 | Lunch at office | 2.45 | Yes |
| 7 | 16:50 | Pharmaceutical preparation | 1.54 | Yes | 15:25 | Near by computer | 1.23 | No |
| 8 | 17:50 | In Chief's office | 2.13 | Yes | 16:15 | In Chief's office | 8.56 | Yes |
| 9 | | | | | 17:20 | Near by counter | 0.38 | Yes |

link between exposure to PF magnetic fields and various adverse health outcomes, in particular human cancer. In a recent report[15], the U.S. National Institute of Environmental Health Science (NIEHS) suggested that the level and strength of evidence supporting PF electric and magnetic fields exposure as a human health hazard are insufficient to warrant aggressive regulatory actions. However, the NIEHS also concludes that exposure to PF electric and magnetic fields cannot be recognized as entirely safe because of weak scientific evidence that exposure may pose a leukemia hazard. Apart from an inconsistency between epidemiological findings and laboratory evidence, the most problematic methodology in epidemiological studies is related to exposure assessment. The parameters by which to assess exposure to magnetic fields remained undefined mainly because of lacking a widely accepted mechanism that could explain the observed associations. Various parameters of magnetic fields exposure were explored in previous studies in relation to risks of adverse outcomes. These parameters included TWA magnetic flux density, specific frequency, temporal and spatial patterns of variability, the percentage of time spent above a certain discrete level, peak exposure, etc.[12, 16]. The exposure measure that is an appropriate metric of exposure remains to be defined. Occupational studies frequently used job title as a surrogate for exposure assessment, and rarely considered the extent to which misclassification of real exposure might result from such methodology[7–9]. Our results showed that pharmacists and pharmaceutical assistants, conventionally regarded as "non-electrical" occupations, were likely to experience an exposure level of magnetic fields similar to certain "electrical" occupations. Although limited in its scope and sample size, our study may have demonstrated that the exposure level measured from the field might underestimate the personal exposure to a significant extent. These observations suggested a potential for exposure misclassification by using job title as a surrogate for magnetic fields exposure classification and an inadequacy of using stationary workplace measurements for the assessment of personal exposure.

The remarkable discrepancy in exposure level between field survey and personal dosimetry can be explained by the following. Firstly, the level of personal exposure to magnetic flux densities can be strongly affected by certain office equipments. A study[17] compared personal exposure to 60 Hz magnetic fields and stationary home measurements for people living away from high-voltage power lines (assuming with a low exposure at home). Results from that study showed an obvious impact of residential activities on magnetic fields exposure level; the percentage of time with exposure above 7.8 mG was averaged to 40% for personal dosimetry compared to 0% for stationary home measurements[17]. Although hospital workers were not "electrical" occupation, they are likely to use a variety of medical instrument (e.g., therapeutic, diagnostic, monitoring equipment, etc.) or office equipment (e.g., visual display terminal, photocopier, etc.); all these facilities may generate high magnetic fields. A previous study reported an average daily highest exposure to magnetic fields of 97.5 mG for 23 "non-electrical" white-collar workers[16]. On site measurements showed that some commonly used facilities in hospitals such as computer/visual display terminal (3–29 mG), printer (25 mG), and work station monitor (5 mG) may generate magnetic fields much higher than background exposure. Secondly, we inadequately considered the temporal variability of magnetic flux densities in the study areas. Because of the shortage of dosimeters, we were unable to monitor the magnetic flux densities in the study areas for the entire workday. Rather, we performed only two times of short-term measurements; one in the morning and the other in the afternoon. Our data did reveal a temporal variability during a workday (higher magnetic flux densities in the afternoon). Inadequate management of the temporal variability might have affected our results. Additionally, we selected some 50 sites for measurements in the study areas and calculated the average as a summary exposure index for the study areas. This way of doing tended to dilute the higher densities encountered in some locations of the study areas. For example, the highest exposure (6.52 mG) recorded in the field surveys was taken at a site near power room; this density was much higher than the average. As a worker sitting near this site for a longer time, his/her personal exposure was expected to be much higher than the average. Finally, we selected only two workers for personal dosimetry. Bias due to selecting a non-representative sample might be introduced to this study because of a small sample size. According to the diary, both monitored workers spent 45% of their full-shifts outside of the study areas where there was an even higher level of exposure, which further enlarged the gap in results between field surveys and personal dosimetry.

Guidelines for occupational exposure to PF magnetic fields have been available from some institutions[18–20]. The ICNIRP suggested a whole body exposure level of higher than 4.2G[20]. The U.K. NRPB[18] and the U.S. ACGIH[19] suggested even higher exposure limits of 13.3 G and 10 G, respectively. These exposure guidelines are hundreds times higher than the exposure levels that are normally encountered in the occupational settings. Despite that, one should be noted that these guidelines were established primarily for protecting workers from harmful thermal effects (such as cataracts)[18–20] rather than from the non-thermal effects (such as cancer or adverse reproductive outcomes) for which the association with exposure to PF magnetic fields has been investigated for more than twenty years.

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