Suicide and Other Causes of Death in Electrical Utility Workers; Their Association with Exposure to Electric and Magnetic Fields

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1.Table of contents

2. Abstract

This dissertation comprises three related papers.

The first paper reports a historical cohort mortality study which was carried out among 21,744 electrical utility workers in the province of Québec. A total of 1582 deaths were observed at the end of follow-up (1970-1988). A job exposure matrix (JEM) was used to estimate the exposure to 60 Hz electric, magnetic, and pulsed electromagnetic fields (PEMF) from the code of the last job held by each worker. The results showed no evidence of excess of cause specific or general mortality relative to provincial death rates in the cohort overall. The ratios of Standardized Mortality Ratios (SMRs) as estimates of rate ratio (RR) in the exposed relative to the background group were also calculated. Statistically significant RRs were found for pancreatic cancer for electric fields (RR=2.8, 95% Confidence intervals (CI) 1.13-7.01) and for lung cancer for PEMF (RR=1.56, 95% CI 1.05-2.25). Deaths caused by accidents and violence showed significant RRs for electric fields (RR=2.16, 95% CI 1.59-2.92), magnetic fields (RR=1.76, 95% CI 1.29-2.39) and for PEMF (RR=1.96, 95% CI, 1.40-2.71). Occupational accidents related to power lines explain some of the excess of deaths from accidents and violence. There was a small non-significant association with magnetic fields for leukaemia (RR=1.52, 95 % CI 0.45-4.47) and brain cancer (RR=1.59, 95 % CI 0.57- 4.31), but the results for these two sites were based on small numbers.

The second paper reports a case-cohort study to investigate a previously suggested association between exposure to electric and magnetic fields and suicide. Forty-nine deaths from suicide between 1970 and 1988 were identified in the above-mentioned cohort and a sub-cohort comprising a one per cent random sample was selected from it. Cumulative and current

exposures to electric fields, magnetic fields and PEMF were estimated for the sub-cohort and cases through the JEM. For cumulative exposure, rate ratios (RR) for all three fields showed mostly small non-significant increases in the medium and high exposure groups. The most elevated risk was found in the medium exposure group for electric field-geometric mean (RR=2.76, 95% CI 1.15-6.62). The results did not differ after adjusting for socioeconomic status (SES), alcohol use, marital status and mental disorders. There was little evidence for an association of risk with exposure immediately prior to the suicide. Small sample size (deaths from suicide) and inability to control for all potential confounding factors were the main limitations of this study.

The third paper reports a study of validity attributing magnetic field exposure by using a worker's last job. This was done by comparing, in a sample of the cohort, estimates obtained using last job with those obtained using full work histories. The correlation between indices based on last job and those based on all jobs varied between 0.75 and 0.78. The study showed that the last job was particularly good in identifying the highest exposed individuals. The results are most likely to be generalizable to other industries in which highest exposed jobs are also skilled jobs.

2. Résumé

Cette thèse de doctorat comprend trois articles connexes.

Le premier article rapporte une étude de mortalité de type prospective historique qui a été réalisée auprès de 21,744 travailleurs dans le secteur électrique de la Province du Québec. L'analyse des dossiers des membres de la cohorte a révélé 1582 décès durant la période 1970 - 1988. L'exposition aux champs électriques de 60 Hz, magnétiques et electromagnétiques à pulsations rythmiques (CEMPR) a été estimée par l'utilisation d'une matrice d'exposition au travail (MET) développée à partir des codes de statut du dernier emploi des travailleurs. Les résultats ont montré qu'il n'y avait aucun exces mortalité total ou spécifique par cause dans la cohorte par rapport aux taux de mortalité dans la population general. Nous avons aussi calculé les rapports standardisés de mortalité (RSM) [Standardized Mortality Ratios] pour une estimation indirecte des rapports de taux [Rate Ratios ou RR]. Les RRs pour le cancer du pancréas et l'exposition aux champs électriques [RR=2.8; Intervalle de confiance 95% (IC) 1.13-7.01] et pour le cancer du poumon et l'exposition aux CEMPR [RR=1.56; IC 95% 1.05-2.25] étaient statistiquement significatifs. Les décès dûs aux accidents et à la violence avaient aussi une association statistiquement significative avec les champs électriques (RR=2.16; IC 95% 1.59-2.92), magnétiques (RR=1.76; IC 95% 1.29-2.39) et avec les CEMPR (RR=1.96; IC 95% 1.40-2.71). Les accidents de travail liés aux lignes électriques à haut voltage expliquent une certaine proportion de la surmortalité due aux accidents et à la violence. Nous avons aussi trouvé une faible association non-significative entre l'exposition aux champs magnétiques et la mortalité par la leucémie (RR=1.52; IC 95% 0.45-4.47) et le cancer du cerveau (RR=1.59; IC 95% 0.57-4.31). Toutefois, ces derniers résultats proviennent d'un échantillon de taille insuffisante.

Le deuxième article présente une étude de type cas-cohorte qui avait comme

but d'étudier la relation suggérée antérieurement entre l'exposition aux champs électriques et magnétiques et le suicide. Nous avons pu identifier 49 décès dûs au suicide dans la cohorte ci-haut mentionnée durant la même période d'observation. La sous-cohorte pour cette étude a été constituée par un échantillonage aléatoire (fraction échantillonale = 1%) de la cohorte originale. Ensuite nous avons estimé l'exposition actuelle et cumulée aux champs électriques, magnétiques et aux CEMPR à la fois pour le sous-cohorte et les cas de décès en se servant de la matrice d'exposition au travail. Pour ce qui est de l'exposition cumulée, les RRs pour tous les trois champs ont révélé une légère augmentation non-significative dans les groupes d'exposition moyenne ou forte. Le rapport le plus élevé a été observée dans le groupe à exposition moyenne aux champs électriques (RR=2.76, IC 95% 1.15-6.62). L'ajustement par le statut socioéconomique, par l'usage d'alcool, par le statut marital et par les troubles psychiques n'a pas affecté les résultats. D'autre part, l'évidence pour une association entre l'exposition immediatement précédante et le suicide subséquent s'est averée faible. Le nombre insuffisant de décès dus au suicide et l'incapacité de pouvoir contrôler l'effet potentiel de tous les facteurs de confusion étaient les faiblesses méthodologiques de la présente étude.

Le troisième article rend compte d'une étude portant sur la validité de l'utilisation du dernier emploi comme une mesure indirecte de l'exposition aux champs magnétiques. Pour ce faire, nous avons comparé les indices de l'exposition estimés en fonction du dernier emploi et d'un compte rendu complet de l'historique de travail de l'individu dans un sous-échantillon du cohorte des travailleurs. La corrélation entre les deux indices a été de l'ordre de 0.75 et 0.78; le dernier emploi étant un meilleur indicateur pour identifier ceux ayant eu une forte exposition. Nous croyons que l'on pourrait généraliser ces résultats aux autres industries où il existe un certain rapport entre l'exposition forte et le degré de compétence du travailleur.

3. Preface

This dissertation includes three papers (submitted for publication). Each paper has its own abstract, introduction, methods, results and discussion sections, list of references and tables.

Faculty regulations concerning the option of including copies of the papers as part of the thesis are cited below to inform the external reader.

"Candidates have the option, subject to the approval of their Department, of including, as part of their thesis, copies of the text of a paper(s) submitted for publication, or clearly-duplicated text of a published paper(s), provided that these copies are bound as an integral part of the thesis. If this option is chosen, connecting texts, providing logical bridges between the different papers, are mandatory.

The thesis must still conform to all other requirements of the "Guidelines Concerning Thesis Preparation" and should be in a literary form that is more than a mere collection of manuscripts published or to be published. The thesis, must include, as separate chapters or sections: (1) a Table of Contents, (2) a general abstract in French and in English, (3) an introduction which clearly states the rationale and objectives of the study, (4) a comprehensive general review of the background literature to the subject of the thesis, when this review is appropriate, and (5) a final overall conclusion and/or summary.

Additional material (procedural and design data, as well as descriptions of equipment used) must be provided where appropriate and in sufficient detail (eg. in appendices) to allow a clear and precise judgment to be made of the importance and originality of the research reported in the *thesis.*

In the case of manuscripts co-authored by the candidate and others, the candidate is required to make an explicit statement in the thesis who contributed to such work and to what extent; supervisors must attest to the accuracy of such claims at the Ph.D Oral Defense. Since the task of the examiners is made more difficult in these cases, it is in the candidate's interest to make perfectly clear the responsibilities of the different authors of co-authored papers."

An explicit statement on who contributed to this thesis work and to what extent is given in Chapter 5: Statement of originality, contribution and co-authorship.

4. Introduction

If exposure to electric and magnetic fields are associated with cancer or other health effects there will be major consequences for public and occupational health, because almost everybody is exposed. The recent studies of cancer in human populations show some consistency suggesting that there may be an elevated risk of certain types of cancer as a result of such exposure. The data, however, are not conclusive. Information on the relationship between EMF exposure and causes of deaths other than cancer is very limited because nearly all epidemiological studies have exclusively focused on cancer.

In fall 1988, to investigate possible occupational cancer risk, a "nested" case-control study of cancer among electrical utility workers in Québec, Ontario, and France (referred to as the "Canada-France Study") was initiated by Dr. G. Thériault, Director of the Department of Occupational Health, McGill University. The study was funded by the utilities. For the Canada-France case-control study a complete cohort of male workers from the Hydro-Quebec utility company were identified, and was traced until death or the end of the study as one means of identifying cancer cases, and to allow simple selection of controls. A job exposure matrix (JEM) linking job titles to exposure to electric and magnetic fields was established in a survey of current employees.

The existence of this data in Québec for the Canada-France cancer study allowed economical investigation of mortality more generally in the Québec cohort. Suicide was a particular interest. The concern for suicide was based on the evidence that 1)exposure to electric and magnetic fields alters the circadian melatonin rhythms (from animal studies) 2)disruptions in the normal circadian rhythm of pineal melatonin secretion are associated with depression 3)depressive illness is strongly related with suicide.

A study proposal (Appendix 2) was submitted to Health Canada (formerly Health and Welfare Canada). The study was initiated following funding and permission from the utility (Appendix 1).

The objective and rationale for each of the three papers resulting from this study are given below.

Paper 1: A mortality study of electrical utility workers in Quebec.

Objective: to investigate the mortality in electric utility workers, and specifically in workers exposed to electric and magnetic fields

Rationale:

1. Although nearly all cancer cases included in this study were included in the Canada-France study also, the use of an alternative (cohort) design allowed a partially independent verification of the results of that study; in particular by making external comparisons of mortality with the Quebec reference population.

2. Although no a priori hypotheses of association between exposure to electric and magnetic fields and causes of death other than cancer were strongly suggested by previous work, we believed that examining them (if the results were negative) would allay fears that hitherto unsuspected risks exist, or (if the results were positive) would identify associations which should be studied further.

Paper 2: A case-control study of suicide in relation to exposure to electric and magnetic fields among electrical utility workers.

Objective: to investigate, from a sample of the cohort, the relationship between risk of suicide and more refined exposure indices, after accounting for potential confounders.

Rationale:

1. Suicide currently takes over 6000 lives per year in Canada. Because of the relatively young age of suicide victims, the years of life lost are enormous, second only to heart disease among other causes of death (National Task Force on Suicide in Canada, Health and Welfare Canada 1987. Knowledge on the etiology of suicide is a precondition for successful preventive measures.

2. Suspicions have been raised that exposure to electric and magnetic fields may cause suicides. Certain utility workers have high exposures. This group was thus convenient for studying the effect of such an exposure and would benefit assuming preventive measures were possible if an association was found. However, the implications of prevention of suicide, if effects were found, would go beyond utility workers to all persons exposed environmentally, and in particular, domestically.

Paper 3: Using "last job held" to estimate exposure to electric and magnetic fields: a validation study.

Objective: to investigate the validity of attributing magnetic field exposure by using the "last job held".

The third paper was not included in the proposal.

Rationale:

1. It is desirable to obtain the most accurate estimate of exposure in occupational epidemiological studies. In large cohort studies, complete work histories may not be readily available. Quite frequently the "last job held" is the only information that investigators can obtain as in the cohort mortality study described above. In this and other cases, it was not feasible to abstract the complete occupational histories for all the members of the cohort. Therefore, it was important to validate the use of the last job held for assessing exposure.

5. Statement of originality, contribution and co-authorship

The cohort of 21,744 workers from which the cases and controls were selected, was constructed for the Quebec part of the "Canada-France study". Thus, I had at my disposal a cohort of electrical utility workers in Quebec.

Following a literature review, I identified suicide as the cause of death other than cancer most likely to be related with EMF. I wrote, with Dr. Armstrong, a research proposal to investigate suicide and other causes of death and their relation to electric and magnetic fields among Hydro Quebec workers (Appendix 2). The proposed study had two phases;

i) a historical cohort mortality study,

ii) a case-cohort study of suicide.

We submitted the proposal for funding to the National Health Research and Development Program, Health and Welfare Canada (now Health Canada). The funding was approved in February 1991. After obtaining the necessary permissions, my research assistant and I began the data collection.

I was responsible for the execution and writing up of the study. In particular, I was responsible for obtaining ethical approval from McGill University, and permission from La Commission de l'accèss de l'information du Quebèc. I was also responsible for the budget, personnel, and all data processing and analysis.

For workers who were active at the study start date, the company computer files contained the last job title of each cohort member. For the rest, approximately 8,000 workers, the information on the "last job held" was abstracted manually from the company records under my supervision.

Identification of the vital status of cohort members, and abstracting the cause of death from the provincial death registration records were carried out for the "Canada-France" study. I participated in this work but was not responsible for it.

For the cases of suicide and the members of the sub-cohort, the complete job histories and the data related to the potential confounding factors were collected from the company personnel records and medical files by myself and my research assistant.

The job exposure matrix (JEM) was developed for the "Canada-France" case-control study. I applied the JEM to the last job held of members of the complete cohort and to the complete work histories of the cases and the members of the sub-cohort, to estimate the exposures.

I carried out all statistical analysis, including

i) computing SMRs using the Person-Years Analysis Program prepared by IARC for the mortality study,

ii) carrying out the relative risk (Cox) regression analysis using EPICURE for the case-cohort study of suicide,

iii) carrying out the relevant analysis for the validity study.

I carried out the literature review and wrote the three papers. The papers were co-authored by Dr. B. Armstrong (1,2, and 3), Dr. G. Thériault(1 and 2) and Mr. J. Deadman (1 and 2) for their following contributions:

Dr. B. Armstrong, as my thesis supervisor, continuously followed my progress, reviewed the manuscripts and made many comments.

Dr. G Thériault as the principal investigator of the "Canada France" study, obtained the permission from Hydro Québec, and allowed me to use his data. He reviewed and commented on the papers.

Mr. J. Deadman carried out the field work and prepared the job exposure matrix (JEM), and reviewed those parts of the papers pertaining to this.

6. The health effects of electric and magnetic fields (EMF): Literature Review

(the references for the literature review are listed on pages 27 to 37)

Sources and characteristics of electric and magnetic fields

The orderly arrangement of radiation according to wavelength or frequency is called the electromagnetic spectrum. This spectrum ranges from extremely low frequency(10-300 Hz) through radiofrequencies(10^4-10^{10} Hz), microwaves(10^8-10^{11} Hz), infrared(10^{12}-10^{14} Hz), visible light(10^{15} Hz), ultraviolet(10^{15}-10^{17} Hz), to x rays(10^{16}-10^{21} Hz) and gamma rays(10^{19}-10^{22} Hz)(Figure 1, pp.38). The various frequency ranges have different characteristics of emission, transmission and absorption in matter, and in particular interact with the biological systems differently[1].

Electric fields are produced by electric charge on the surface of a conductor, which is related to the conductor's voltage. The intensity or "strength" of an electric field (E) is expressed in units of volts/meter. It varies directly with the potential difference (voltage) of the source creating it and inversely with the distance from the source. An electric field exits near a voltage source irrespective of whether an electrical current is flowing through it.

A magnetic field (H) exists near a voltage source only when electrical charge flows through the source to constitute an electrical current. The magnetic field intensity near the source is expressed in units of amperes/meter. The force exerted by the magnetic field on a magnet or on a moving electric charge is proportional to the magnetic flux density (B), which is related to the magnetic field strength, H, through the permeability, μ, of the material:

$$B=\mu H$$

The unit of measurement of the magnetic flux density is Gauss(G) or tesla (T), where 1T=1000 G, varies directly with the amount of current and inversely with the distance from the source.

The human body is a good conductor of electricity. Electric current enters the body and leaves it through the parts that are in contact with the ground. Magnetic fields induce a secondary electric current which remains within the body and travels in a circular pattern.

Everyone is exposed to the static magnetic field arising from current flow in the Earths' core. This gives rise to a magnetic flux density of 30-70 μT on the surface of the planet, depending on location. The earth's static electric field strength changes with weather conditions. In quiescent periods it is 100-200 volts/metre, in stormy conditions it can be 10,000 V/m.

The most common man-made time varying fields to which people are continuously exposed are those arising from the use of 50/60 Hz electric power transmission and distribution, the use of home electrical appliances, medical diagnostic and therapeutic equipment and various radio and TV transmitters. Examples of fields to which people are exposed are given in Table 1(pp.39). High voltage power lines give rise to the highest electric field strengths that are likely to be encountered by people. The intensity of those fields is proportional to the amount of electricity that circulate in the lines. Electric fields can reach 10 kV/m for wires that transport 765 kV. Magnetic fields are also highest under these lines and can reach 25μT.[2] Although electric and magnetic fields can occur separately they are generally correlated.

Early studies: Non-specific health effects

The first reports of symptoms in workers occupationally exposed to EMF came from the former Soviet Union[3,4,5]. They reported non-specific symptoms such as fatigue, headache, nausea, cardiovascular effects, sleep disturbances, anxiety, change in blood cell concentrations and blood chemistry. Although these early cross-sectional reports were limited because of the methodological weaknesses (i.e. small number of subjects, lack of comparison group, subjective reporting, self-selected study subjects), they succeeded in starting considerable public and scientific debate over the adverse effects of occupational exposure to electric fields.

The results of these studies prompted similar investigations outside the former Soviet Union. However, with the exception of a Spanish study of switchyard workers[6], comparable health surveys on occupationally exposed workers carried out in the USA[7,8], Canada[9,10], Sweden[11], and Italy[12] have failed to confirm the health effects reported in the former Soviet Union.

In 1985 in UK, Broadbent et al.[13] made an attempt to measure non-specific health effects in electric power transmission and distribution workers. The data were collected from the hospital questionnaires on the self-reported health events. Unlike most other studies, objective measurement of exposures were made with personal dosimeters but only for electric field exposure. The dosimeters were worn for 2 weeks by 287 subjects. There were no adverse health effects found to be associated with higher exposure levels.

Several explanations were suggested to the question of why the effects observed in the earlier studies were not reproduced in more recent investigations. It was suggested that the non-specific symptoms found in earlier studies might have been caused by other agents in the work environment. The methodological problems of the earlier studies constitute severe limitations to the interpretability of the results in term of causal relationships.

The controversial results from these early epidemiological results stimulated a series of carefully controlled experiments by Hauf et al[14,15]. In Hauf's experiments volunteers were exposed to 50 Hz electric field strengths up to 20 kV/m for 5 hours. Except for a decrease in heart rate, no effect on the patterns of electroencephalogram(EEC) and electrocardiogram (ECG) record, blood pressure, blood chemistry and concentrations of biochemicals in urine was found. Other experimental studies[16,17] failed to show any effect of exposure to electric fields and magnetic fields at 50-60 Hz at strengths up to 5mT, however, following exposure at about 60 mT at 50 Hz the subjects complained of headache and feeling unwell[18,19].

Experimental research on biological effects of EMF has been carried out primarily with small rodents, but a variety of other animal species have also been used. These experiments were undertaken to investigate the effect of 50-60 Hz EMF exposure on development, and reproduction, as well as endocrine, immune, mutagenic and other physiologic responses.

Gann[20] found a decrease in heart rate and cardiac output in dogs exposed to 15 kV/m electric fields. Hilton and Phillips[21] however reported no changes in ECGs of rats exposed to similar electric fields. Several studies showed alterations in blood chemistry such as increased lipid and protein levels with magnetic field exposure[23]. Craig[23] and Adey[24] showed possible cancer-promoting effects of EMF through stimulation of ornithine decarboxylase, an essential enzyme for cell growth and DNA synthesis. Free[25] reported suppressed testosterone levels in rats exposed to 60 Hz electric fields. Lymangrover[26] reported elevation in steroid hormones of rat adrenal tissue exposed to 10 kV/m electric fields. Results from these experimental studies should not be extrapolated without great caution to humans. That there is an interaction between EMF exposure and biological systems can however be considered established. Furthermore, there is a generally accepted mechanism for interaction with EMF fields and biological systems. The EMF produce electrochemical alterations in the properties of the cell membranes, change their transport characteristics as well as their molecular structure and thus alter the physiological functions of the cell[27].

Cancer

(This section is brief because cancer was the main subject of the Canada-France study but not our cohort mortality study.)

A number of epidemiologic studies have suggested possible carcinogenic effects (in particular childhood leukaemia) of residential exposure to these fields[28,29].

Also, several analyses of occupational data from death certificates considered occupational exposure to EMF and cancer[30,31,32,33,34]. Savitz and Colle[35] calculated a summary estimate of the relative risk of all leukaemia in exposed occupations across ten occupational studies of 1.2 with 95 %CI 1.1-1.3. The relative risk for acute myeloid leukaemia for electrical workers in five studies ranged from 1.1 to 2.9 with an average estimate 1.5 (95% CI 1.2-1.8)[36]. Milham[38], Lin et al.[39] and Spears et al.[40] showed also significantly increased risk among electrical workers for deaths from brain tumours. However, the studies by Juutilainen et al.[41], Garland et al.[42], Tynes et al.[43], and Sahl et al.[44] provided only weak support overall for a relationship between cancer and EMF exposure.

In 1992, a Swedish study[45] suggested increased risk of chronic lymphoid leukaemia, especially among workers occupationally exposed to EMF, in the highest exposure category (OR=4.84, 95% CI 1.69-13.84).

In a more recent study, Thériault et al.[46] showed increased risk for acute non-lymphoid leukaemia (OR=2.41, 95% CI 1.07-5.44) and acute myeloid leukaemia (OR=3.15 95% CI 1.20-8.27) among electrical utility workers in Quebec.

Authors of review papers which have discussed association between EMF exposure and cancer[35,37,47,48,49,50] have agreed that no firm conclusion can be drawn from the current data and more studies are needed. However, in the most recent review, Carpenter[51] pointed out the high proportion of positive studies to negative ones, and concluded that the evidence, based on the overall picture, was "strong" for an association between EMF exposure and leukaemia and brain cancer.

Depression and electric and magnetic field exposure; experimental studies and biological plausibility

A number of reports indicate that EMF may affect the nervous system and neuroendocrine function in animals and humans. Observed effects include alterations in EEG patterns[52], and alterations in neuromuscular transmission[53]. Wilson et al.[54,55,56,57], demonstrated that exposure of rats to electric fields reduces melatonin production by the pineal gland. Work by Welker[58], Samm[80] and others has also demonstrated the pineal gland's sensitivity to low strength magnetic fields. A recent experiment in 42 volunteers showed that the urinary excretion of melatonin metabolites changed in some individuals with use of electric blankets[59]. Melatonin is known as a neuroendocrine transmitter. Its levels in the pineal gland and circulation are low in the day time and rise during the hours of darkness normally reaching a peak around 2 am. It thus provides the body with hormonal information on external light and helps maintain a number of circadian rhythms. One consequence of EMF exposure may thus be a "functional pinealectomy" that causes a disruption in circadian rhythms and leads to other physiologic and behavioral alterations. Rogers[60,61] found that exposure to EMF fields produces behavioral alteration in nonhuman primates. Coelho[62] and Orr[63] also reported behavioral changes in baboons following exposure to 60 Hz EMF.

There is substantial evidence that disruptions in the normal circadian rhythm of pineal melatonin secretion are associated with depression. Such disruptions may be in the phase or amplitude of melatonin signal, or both.

Breck-Friis et al.[64] showed low melatonin level in clinically depressed patients. Wetteberg[65], Lewy et al.[66], Claustrat et al.[67] , and Nair et al.[68] found that low melatonin (or its metabolites) in blood and urine are correlated with depressive illness. In addition to that, tricylic antidepressant drugs increase the melatonin in human beings[69]. Wehr et al.[70] and Lewy et al.[66] showed that some depressive symptoms may be relieved by inducing phase alterations in the circadian rhythm.

Mechanisms for the possible effect of melatonin in the etiology of depression are not well understood. Melatonin is inhibitory of most other endocrine glands. The night peak of melatonin maintains the circadian rhythm in gonads, pituitary and hypothalamus for example. Loss of synchronization in these glands may lead to inappropriate release of synthesis of mood altering steroidal hormones or neurotransmitters.

Finally there is firm evidence that depressive illness is strongly related with suicide[71].

Suicide, depression and electric and magnetic field exposure; epidemiologic studies

Reichmanis[72] examined the association between the act of suicide with EMF arising from 50 Hz over-head high voltage transmission lines (OH-HV lines) at the domicile of 598 suicide victims and controls in the Midlands, England. The addresses of cases and controls were plotted on planimetric maps together with OH-HV transmission lines. The total electric and magnetic fields attributable to OH-HV lines were computed from this information for each case and control. On this basis cases had significantly higher exposure than controls ($p < 0.05$).

Later, Perry[73] conducted a study using the same 598 cases of suicide. New controls were selected randomly from voter registration lists of the area. Measurements of magnetic fields were made at suicide and control addresses, 0.5 m away from the front door. More suicide than control measurements were above the median (278 suicides 232 controls, $p<0.01$) and, the mean value of measured EMF for the suicide addresses (0.087 μT) was significantly higher than that of the controls (0.071 μT) ($p<0.05$). The authors argued that confounding by socio-economic factors was unlikely, since the distribution of type of residence was not significantly different in cases and controls ($p>0.20$).

These two studies were criticised by Bonnell[74] for not using orthodox epidemiological approaches and inadequate control for confounding.

Perry[75] found, in residents of high rise apartments in Wolverhampton, England, significantly ($p=0.03$) more people suffering from depressive illness than controls had been living close to electric cables and hence exposed to EMF.

McDowell[76] followed up 8000 persons in England who were living within 30 meters of electric transmission facilities in 1971. The subjects were traced to 1983 and death certificates were obtained from national records. They found an SMR of 0.75 (8 observed) (95% CI 0.32-1.47) for suicide (5) and "undetermined" deaths (3) combined. For those cases resident less than 15 meters from the lines, the SMR was 1.43 (2 observed) (95% CI 0.16-5.16). This study thus provided no support for an association between EMF and suicide but was limited by small sample size.

Later, Baris and Armstrong[77] found that men described as electrical workers on their death certificates did not have an elevated rate of suicide.

Poole et al.[78] conducted a telephone survey to assess the prevalence of depressive symptoms in relation to proximity of residence to an alternating-current transmission line in the United States. They found greater depressive symptomatology in people who live near the transmission lines as compared with those who live farther. The estimated prevalence odds ratio was 2.8 (95%CI 1.6-5.1). The association was not explained by demographic variables associated with depression or with attitudes about power lines.

More recently, MacMahan[79] investigated the depressive symptomatology in 152 female residents living close to overhead transmission lines in Orange County, California. No significant difference was found in depressive scores in residents adjacent to overhead transmission lines compared to residents one block away. Spot measurements taken at front doors were used to assess the magnetic field exposure.

Summary and conclusion

A number of epidemiologic studies have suggested the carcinogenic effects (in particular leukaemia and brain cancer) of residential and occupational exposure to EMF but the data are not conclusive. Experimental studies have shown some evidence of an association between EMF exposure and decreased pineal function and between decreased pineal function and depression. Some epidemiologic studies have suggested an association between residential exposure to EMF and suicide, but weaknesses in measures of exposure and control for confounding preclude confident conclusions being drawn from these studies.

Apart from suicide and cancer, some evidence from animal studies exists for effects of EMF on endocrine and physiological functions of organ systems, so that there is some plausibility for an association with deaths due to endocrine diseases, but there is no direct evidence for this.

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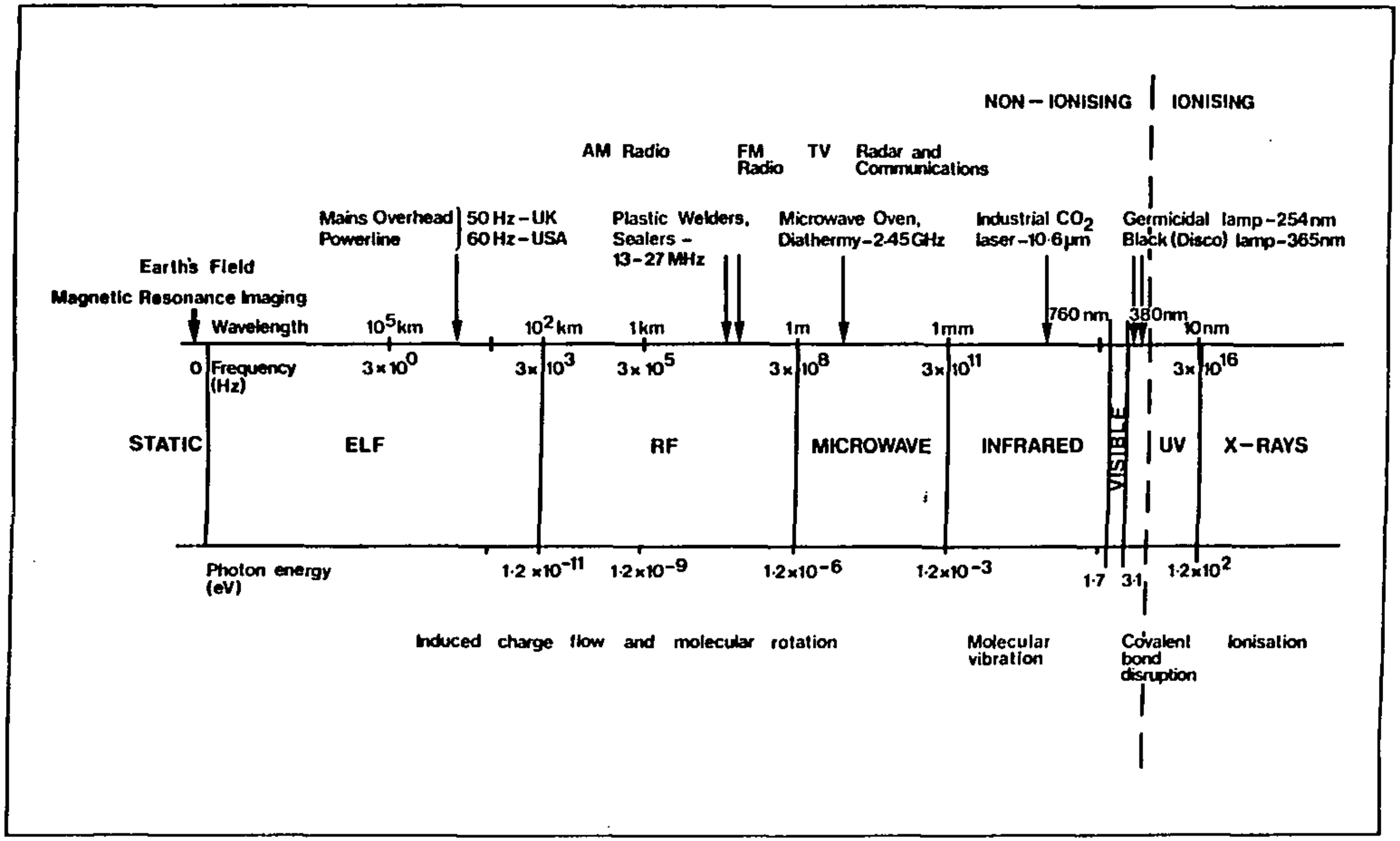
Figure 1



Source: Electromagnetic Fields and the Risk of Cancer, Report of an Advisory Group on Non-Ionizing Radiation NRPB, Volume 3 No. 1, 1992.

*** Table 1: Reported levels of extremely low electric and magnetic fields measurements**

		E field (Volts/meter)	B field (μTesla)
Natural EMF fields			
Earth's natural fields	50-60 Hz	10^{-6}	10^{-6}
Home appliances			
(60 Hz, 30 cm away from the source)			
Electric blanket		250	
Broiler		130	
Stereo		90	
Refrigerator		60	0.01-0.25
Electric iron		50	0.12-0.30
Hand mixer		50	0.60-0.10
Toaster		40	
Hair dryer		40	0.01-7.00
Colour TV		30	0.04-2.00
Coffee maker		16	0.08-0.15
Can opener			0.08-9.00
Drills			2.50-3.00
Industrial equipment			
Arc welder			
Induction motors			$8x10^3$
Heating devices			$70x10^3$
Medical diagnostic equipment			
Nuclear magnetic resonance (NMR)			$2x10^3$

High voltage power lines	**E field (V/m)**			**B field (μT)**		
(60 Hz)	**Max ****	**30m**	**60 m**	**Max****	**30m**	**60m**
115 kV	1500	70	10	3.50	0.20	0.05
230 kV	3300	200	30	9.70	0.90	0.20
500 kV	7500	1000	30	17.60	2.50	0.60

Source: WHO 1984, Lovsund 1982, Tenforde and Kaune 1987

* These fields levels are approximate. Actual field levels will depend on design and operating conditions

** Maximum on the ground level

5. A mortality study of electrical utility workers in Quebec

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Jan Deadman[1], Gilles Thériault[1]

Abbreviations

EMF, Extremely low frequency electric and magnetic fields; PEMF, pulsed electromagnetic fields; JEM, job exposure matrix; SMR, standardized mortality ratio; RR, rate ratio; 95 % CI, 95 percent confidence intervals; V/m, volts per meter; μT, microTesla; ppm, parts per million.

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Abstract

A historical cohort mortality study was carried out on workers who were employed in an electrical utility in the province of Québec, between 1970 and 1988. The study population consisted of 21,744 men and a total of 1582 deaths were observed at the end of follow up. A job exposure matrix (JEM) was used to estimate the exposure to 60 Hz electric, magnetic, and pulsed electromagnetic fields (PEMF). There was no evidence of excess of cause specific or general mortality relative to provincial death rates in the cohort overall. Standardized mortality ratios (SMRs) were in general below one. We also calculated ratios of SMRs as estimates of rate ratio (RR) in the exposed relative to the comparison group with background exposure. We found significant RR of 2.8 (95% Confidence intervals (CI) 1.13-7.01) for pancreatic cancer for electric fields and RR of 1.56 (95% CI 1.05-2.25) for lung cancer for PEMF. Deaths caused by accidents and violence showed significant RRs for electric fields (RR=2.16, 95% CI 1.59-2.92), magnetic fields (RR=1.76, 95% CI 1.29-2.39) and for PEMF (RR=1.96, 95% CI, 1.40-2.71). Occupational accidents related to power lines explain some of the excess of deaths from accidents and violence. We observed a small non-significant association with magnetic fields for leukaemia (RR=1.52, 95 % CI 0.45-4.47) and brain cancer (RR=1.59, 95 % CI 0.57- 4.31), but the results for these two sites were based on small numbers.

Key words: electromagnetic fields, occupational exposure, mortality.

Introduction

Reports of symptoms such as headache, fatigue and disruption of sleep patterns in high-voltage switchyard workers occupationally exposed to extremely low frequency electric and magnetic fields (EMF) appeared in the late 1960s[1-3]. Although these early cross-sectional reports had methodological weaknesses, they created considerable public and scientific debate over the adverse health effects of occupational exposure to EMF. Later, a number of epidemiological studies have suggested possible carcinogenic effects of such an exposure. In particular, increased risks of leukaemia[4-10] and brain tumours[11-13] have been reported. Several review papers have been published on the association between exposure to electric and magnetic fields and cancer[14-16]. The majority of these studies have been questioned for their design limitations, mainly because of crudeness of exposure assessments and small sample size. Recently, a large study with extensive exposure assessments[17] showed an increased risk for acute myeloid leukaemia. No increase was observed for 29 other types of cancer studied. However, the evidence for the association still remains inconclusive.

Information on the relationship between EMF exposure and causes of deaths other than cancer is very limited. Nearly all epidemiological studies have focused on cancer and no attention has been given to other causes of deaths.

Here we report the mortality of men who worked in a electrical utility company in Québec, Canada. This cohort was one of three cohorts in which cancer incidence was investigated in the "Canada-France" case-control study[17]. Thus deaths from cancer in this study were included in the earlier study but deaths from other causes have not been included in any previous study.

Methods

Study population

The study population consists of 21,744 male electrical utility workers who were employed at Hydro Québec, a state-owned utility company covering the Canadian Province of Québec. To qualify, workers must have been employed between January 1st 1970 and December 31st 1988 and have worked at least one continuous year. Name, Social Insurance Number, date of birth, date of hire and date of departure and the title of the last job were obtained for each individual. For workers who were active at the study start date, the company computer files contained the above information. For the rest, the information was abstracted manually.

From the company records of current employees and pensioners, 16,834 of the study subjects were known to be alive at the end of 1988. In addition, from the company benefits records, 1539 men were known to have died prior to 1988. The remaining 3,371 who had left the company during the follow-up period were checked against Provincial sources (Regie de Rentes du Quèbec) and vital status was identified. Nine subjects had unknown vital status. For those found to have died, the cause of death (ICD codes) was abstracted from the provincial death registration records. All codes from earlier revisions of the ICD were converted to those corresponding to the ninth revision.

Estimating exposure

We used a job exposure matrix (JEM) to dichotomize jobs into "background" and "above background" exposure groups, and to categorize the above-background jobs into medium, high and very high exposure categories. The JEM was developed for a large case-control study of cancer in utility employees[17]. The matrix rows consisted of grouped job titles with similar expected exposure. The grouping of job titles was done a priori in consultation with utility hygienists, an occupational physician and health and safety committees. Exposures to 60-Hz electric and magnetic fields and pulsed electromagnetic fields(PEMF) were assessed for the grouped job titles from current exposure measurements made with the POSITRON exposure monitor (Positron Industries, Montreal, Québec Canada) worn over a work-week by a stratified random sample (n=466) of workers. The entry in each row of the matrix category was the arithmetic mean of the weekly arithmetic means of all workers within the job category.

As the full work histories were not readily available, we applied the JEM to the last job held. In this way, we classified workers into two exposure groups: background and above background. This was done separately for magnetic, and electric fields, and PEMF. The background exposed group included all subjects in the two categories of jobs identified a priori as background (blue collar background, white collar background) and also others with mean measured exposure less than or equal to the mean of the highest of the two background categories.

SMRs were computed using the Person-Years Analysis Program prepared by IARC[18]. Age-, year- and cause-specific mortality rates of Québec men were applied to the person years of the cohort to obtain expected deaths.

Results

Of all 21744 men in the cohort, 1582 (7.28 %) had died by the end of follow-up (December 31st 1988). Only 9 (0.04 %) were lost to follow-up. The mean length of follow-up was 12.9 years. The mean age at hire was 26.2 years, the mean age at death or end of follow-up was 46.1 years.

The mean exposures of each job category in the JEM and also the classification of each job category to the background or above background groups are presented in Table 1. The mean exposures for electric and magnetic fields, and PEMF overall among workers in the background groups were 5.42 V/m, 0.15 μT and 3.66 ppm and overall among the above background groups were 38.57 V/m, 0.94 μT and 64.23 ppm respectively.

Tables 2-4 show SMRs for selected major causes of death overall and by level of each of magnetic and electric fields, and PEMF (background and above background). Overall SMRs were generally less than one, most likely resulting from factors related to the healthy worker effect. None was close to being significantly elevated. The SMRs in the above background groups were also in general less than one, and none of these was significantly elevated either.

Despite the low SMRs, in some cases those in the above background groups were substantially higher than those in the background groups. We calculated ratios of SMRs as estimates of rate ratio (RR) in the exposed relative to the background group and 95 % confidence intervals for the RR. The causes of death for which the SMR in the above background group were significantly higher (at $p<0.05$, two-sided) than the SMRs in the background group were as follows:

1) pancreatic cancer: RR =2.8 (95% CI 1.13-7.01) for electric fields:
2) lung cancer: RR=1.56 (95% CI 1.05- 2.28) for PEMF;
3) deaths due to accidents and violence: RR =2.16 (95% CI 1.59-2.92) for magnetic fields, RR= 1.76 (95% CI 1.29-2.39) for electric fields, RR=1.96 (95% CI 1.40-2.71) for PEMF.

RRs for leukaemia (1.52, 95% CI 0.45-4.47) and brain cancer (1.59, 95% CI 0.57-4.31) were elevated but not significantly so. Other non-significant RRs are not reported.

Fifteen out of the 191 total deaths due to accidents and violence were accidents caused by electrocution (ICD-9, E925). All deaths (n=15) in this group held a last job classified as exposed above background level for magnetic fields. Nine of them were coded as E925.1: "electrical accidents related to power lines in electrical power generating plants and distribution stations". The other six deaths may also have been due to occupational electrocution even though not coded as such. For electric fields, 13 deaths out of 15 and for PEMF , 12 out of 15 worked in the occupations with exposures above background. Thus electrocutions explain some but not all the excess in the above background groups from deaths due to accidents and violence.

We examined the association with significant RRs ($p<0.05$), further sub-dividing subjects into four categories by exposure (Table 5). These causes of deaths were the ones for which the SMRs in the above background group were significantly higher at $p<0.05$ (two-sided) than the SMRs in the background. We used the median and 75th percentiles of the above background values as cut-off points to define the exposure groups. Leukaemia and brain cancer were also included in the analysis with four groups of exposure because of the special interests for these two cancer sites.

For pancreatic cancer and electric fields, we observed the highest risk among subjects exposed to levels below the 75th percentiles but above median (SMR=2.13, 95% CI 0.58-5.46). There was a significant trend with increasing level of exposure ($X^2=6.62$, $p<0.05$).

For lung cancer in relation to PEMF, the highest risk was observed among exposed subjects to levels above 75th percentiles (SMR=1.47, 95% CI, 0.84-2.38). The analysis with four exposure groups showed a significant trend with increasing level of exposure ($X^2=5.51$, $p<0.05$).

We have observed that SMRs for leukaemia was highest among workers exposed to levels above 75th percentile for magnetic fields (2.37, 95% CI 0.29-8.55). However, the numbers were small, and there was no significant trend with increasing level of exposure(X^2=1.15, p>0.05)(Table 5). Brain cancer results were similar to those of leukaemia. SMR was highest among workers exposed to levels above median and below the 75th percentiles (2.18, 95% 0.45-6.39) but with a non-significant trend (X^2=0.20, p>0.05).

Exposure was largely limited to blue collar jobs. To control for a possible confounding effect by socio-economic status, we report below RRs for blue collar workers only, for causes of deaths which showed significant RRs for the entire cohort.

1) pancreatic cancer: RR=3.60 (95% CI 1.06-13.39) for electric fields;
2) lung cancer: RR=1.37 (95% CI 0.89-2.01) for PEMF ;
3) deaths due to accidents and violence: RR=1.71 (95% CI 1.15-2.07) for magnetic fields, RR=1.41, (95% CI 0.97-2.08) for electric fields, RR=1.63 (95% CI 1.12-2.36) for PEMF.

Discussion

Analysis of mortality of 21,744 electrical utility workers provided no evidence of increased mortality overall. Death rates were substantially below the Québec male population, with an SMR of 75 % for all causes and 83% for all cancers. SMRs for major causes of death and for the site specific cancers were also less than one.

These low SMRs probably resulted from a " healthy worker effect"[19], as these men were all fit enough to work in 1970 and later. Similar results have been reported in other studies of occupational cohorts, especially with the limited duration of follow-up.

The low SMRs might have also resulted from the under-ascertainment of mortality. We would expect ascertainment to be poorest in men leaving the company without pension rights. Thus, we investigated this possible source of bias further by calculating SMRs by three categories of activity status: active, retired and leavers. The SMRs and 95% CI were 0.62 (0.57-0.66), 0.92(0.87-1.00) and 0.64 (0.46-0.85) respectively. The low SMR in active workers could be explained by healthy worker effect. The SMR of 0.64 among leavers suggests a possible under-ascertainment of mortality in this group, but the total number of workers was small in this group (observed deaths=41, expected deaths=65.65), so that resulting bias would have been very small.

To obtain complete job histories for the entire cohort was not feasible in this study. Obviously, the last job does not represent the total work experience of a worker. Non-differential misclassification, biasing the results toward the null value, might have been produced from using the last job only to classify workers into exposure categories. A recent case-control study of leukaemia in telephone linemen[20] demonstrated 85% agreement between last job and longest job. We had similar findings in our validation study[22]. The results of the validation study suggested that although not all workers starting in highly exposed jobs stayed in them, it seemed that the workers who ended their working life in highly exposed jobs had stayed in these jobs throughout their working life. Last job was particularly good for identifying the highest exposed individuals. Thus, our results for the high and very high groups are likely to be the least affected by exposure misclassification.

Other possible sources of errors would be the errors in estimating means in the JEM and the misclassifications of individuals due to the inter-worker variations in the same row of the JEM. Again, the effect of these misclassifications would be to bias the risk estimates toward the null value. Nevertheless, the difference between mean exposure levels of the background and above background was substantial, so that even allowing for some misclassification, the exposure contrast between groups was probably quite large.

There was no prior evidence for the association between pancreatic cancer and EMF exposure in the literature. It is possible that the observed excess may be a chance finding that must be expected to occur when many outcomes are examined. Our findings do not allow a conclusion for a causal association to be drawn but they justify further investigation into the possibility that electric field exposure may be associated with pancreatic cancer.

In relation to the observed association for lung cancer, the evidence is too limited to conclude whether the observed association is causal. Beside the limitations of the exposure assessment, our study had no ability to control for the possible confounding effect of smoking and other occupational exposures. Analysis of the same cases in the case-control study based on this cohort and others also showed an association between lung cancer and PEMF[21]. In that study, an elevated odds ratio of 3.11 (95% CI 1.60-6.04) was observed among the highest exposed workers after controlling for smoking or other occupational exposures.

The evidence for an elevated risk for leukaemia and brain cancer is weak in our study. The main limitation of the study was the small number of observed deaths in the high exposure categories (Table 5).

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Table 1: Job Exposure Matrix ; mean exposure to 60 Hz magnetic, electric and PEMF

		Magnetic fields µT		Electric fields (Volt/meter)		PEMF (ppm)	
	N[a]	Mean	Exposure gr.	Mean	Exposure gr.	Mean	Exposure gr.
Row code & Job group							
Matrix							
Jobs considered a priori to have background exposure							
Blue collar jobs [b]	2225	0.15	B[d]	5.02	B	23.70	B
White collar jobs [c]	10661	0.16	B	5.76	B	0.00	B
Hydroelectric generation							
Equipment electricians	56	0.99	AB[d]	18.21	AB	2.47	B
Equipment mechanics	471	0.77	AB	14.46	AB	4.06	B
Foremen, operations&others.	377	0.50	AB	12.42	AB	22.46	B
Operator	295	1.56	AB	6.34	AB	0.27	B
Nuclear generation							
Equipment electricians	144	0.19	AB	2.82	B	0.00	B
Operator, nuclear station	1	0.13	B	2.52	B	0.00	B
Diesel generation							
Operator, autononous network	43	0.32	AB	4.82	B	9.38	B
Transmission							
Transmission splicer	185	1.79	AB	15.79	AB	63.12	AB
Transmission linemen <=735 kV	168	0.60	AB	57.99	AB	63.22	AB
Substation							
Equipment electrician <= 735 kV	787	2.36	AB	52.13	AB	39.65	AB
Maintenance worker, civil & mech. eng	620	1.05	AB	31.75	AB	0.01	B
Operator mobile	233	1.17	AB	12.04	AB	3.90	B
Operator, 735kV substation	36	1.78	AB	36.89	AB	3.56	B
Technician	338	1.60	AB	8.63	AB	0.03	B
Distribution							
Emergency men	125	0.50	AB	12.71	AB	201.73	AB
Foremen, overhead lines	537	0.16	B	5.77	AB	35.44	AB
Foremen, underground lines	57	0.14	B	3.02	AB	417.95	AB
Linemen (contact & hotstic)	1918	0.37	AB	83.18	AB	74.76	AB
Meter installer	263	0.42	AB	5.47	B	0.14	B
Meter reader	337	0.17	AB	10.03	AB	0.00	B
Splicer, distribution	300	1.87	AB	9.73	AB	20.03	AB
Tree trimmer	33	0.34	AB	37.51	AB	35.46	AB
Others							
Estimator	315	0.13	B	4.31	B	0.00	B
Instructor	172	0.17	AB	2.83	B	0.00	B
Licensed electricians	50	0.87	AB	12.52	AB	0.46	B
Operator, dispatcher	534	0.09	B	3.16	B	0.03	B
Technician, telecommunication	184	0.44	AB	5.12	B	24.44	AB
Total	21465[e]						

Regrouping for this study

	N	Mean	Exposure gr.	N	Mean	Exposure gr.	N	Mean	Exposure gr.
All background	14291	0.15	B	14554	5.42	B	17271	3.66	B
All above background	7174	0.94	AB	6911	38.57	AB	4194	64.23	AB

[a] N= number workers
[b] Blue collar jobs (vechile and general mechanics, stockkeeper, toolkeeper)
[c] White collar jobs (office workers)
[d] B = Background
AB= Above background
[e] Total number of subjects in the cohort is 21,744. The difference is due to 279 workers who had no information on the last job held.

Table 2: Standardized mortality ratios (SMR) and 95 % Confidence intervals (95 % CI) for major causes of death for male electrical utility workers:1970-1988, overall and by level of magnetic fields

Cause of death[b] ICD-9	Exposure level (magnetic fields): Background[a] <=0.16 μT			Above background > 0.16 μT			Total[c]		
	Observed	SMR	95 % CI	Observed	SMR	95 % CI	Observed	SMR	95 % CI
All causes	1033	0.68	0.64-.0.73	429	0.81	0.73-0.89	1582	0.75	0.71-0.79
Major causes									
Neoplasms	307	0.76	0.68-0.85	133	0.95	0.80-1.33	466	0.83	0.76-0.91
Stomach	14	0.56	0.30-0.93	6	0.71	0.26-1.54	23	0.66	0.42-0.99
Large intestine rectum	38	0.84	0.60-1.13	11	0.72	0.36-1.28	56	0.83	0.63-1.10
Liver and gallbladder	6	0.66	0.24-1.43	5	1.59	0.52-3.72	11	0.87	0.43-1.56
Pancreas	13	0.60	0.32-1.02	10	1.33	0.64-2.45	23	0.76	0.48-1.14
Trachea bronchus/lung	124	0.80	0.67-0.96	51	0.96	0.71-1.26	183	0.85	0.74-0.99
Male genitalia	10	0.50	0.24-0.92	5	0.79	0.25-1.84	15	0.54	0.30-0.89
Urinary	19	1.06	0.64-1.65	6	0.99	0.03-6.23	26	1.04	0.68-1.53
Brain	12	0.95	0.49-1.67	7	1.51	0.61-3.11	20	1.13	0.69-1.75
Non-Hodgkin's lymphoma	15	1.19	0.67-1.97	3	0.67	0.14-1.96	18	1.02	0.61-1.63
Leukaemia	11	0.81	0.40-1.45	6	1.22	0.45-2.66	20	1.05	0.64-1.62
Endocrine & nutritional	11	0.34	0.17-0.62	7	0.65	0.26-1.33	24	0.57	0.35-0.81
Nervous system diseases	16	0.86	0.49-1.40	2	0.29	0.03-1.04	18	0.69	0.41-1.08
Circulatory diseases	439	0.70	0.62-0.76	133	0.62	0.52-0.74	625	0.71	0.66-0.77
Respiratory diseases	45	0.55	0.41-0.74	13	0.49	0.26-0.83	68	0.60	0.47-0.77
Digestive diseases	44	0.60	0.44-0.81	20	0.78	0.48-1.20	68	0.67	0.52-0.85
Genitourinary diseases	5	0.39	0.13-0.92	5	1.20	0.39-2.80	12	0.68	0.35-1.19
Deaths due to accidents and violence	95	0.45	0.37-0.56	85	0.97	0.78-1.20	191	0.64	0.55-0.73
Suicide	29	0.48	0.32-0.69	20	0.75	0.46-1.17	49	0.56	0.41-0.71
Motor vehicle accidents	31	0.47	0.32-0.67	24	0.84	0.54-1.25	60	0.63	0.48-0.81

[a] Value of the background blue or white collar whichever is greater

[b] Cause of death included in the table if the total number of observed deaths > 5

[c] Includes 120 observed deaths with no information on the last job held, therefore the total number of observed deaths in this column are sometimes greater than the total number of observed deaths from the columns of the background and above background groups

Table 3: Standardized mortality ratios (SMRs) and 95 % Confidence intervals (95 % CI) for major causes of death for male electrical utility workers:1970-1988, overall and by level of electric fields

Cause of death[b] ICD-9	Exposure level (electric fields) Background[a] <= 5.76 volts/meter			Above background >5.76 volts/meter			Total[c]		
	Observed	SMR	95 % CI	Observed	SMR	95 % CI	Observed	SMR	95 % CI
All causes	1080	0.70	0.66-0.75	382	0.74	0.67-0.83	1582	0.75	0.71-0.79
Major causes									
Neoplasms	312	0.76	0.68-0.85	128	0.95	0.80-1.14	466	0.83	0.76-0.91
Stomach	15	0.59	0.33-0.97	5	0.20	0.26-1.44	23	0.66	0.42-0.99
Large intestine and rectum	38	0.83	0.59-1.12	12	0.81	0.42-1.42	56	0.90	0.63-1.10
Liver and gallbladder	7	0.76	0.30-1.56	4	1.33	0.36-3.40	11	0.87	0.43-1.56
Pancreas	12	0.54	0.28-0.95	11	1.53	0.76-2.73	23	0.76	0.48-1.14
Trachea/bronchus/lung	121	0.77	0.64-0.93	54	1.04	0.79-1.37	183	0.85	0.74-0.99
Male genitalia	11	0.54	0.27-0.96	4	0.84	0.18-1.73	15	0.54	0.30-0.89
Urinary	19	1.04	0.63-1.63	6	1.03	0.38-2.25	26	1.04	0.68-1.53
Brain	15	1.18	0.66-1.95	4	0.86	0.24-2.27	20	1.13	0.69-1.75
Non-Hodgkin lymphoma	14	1.10	0.60-1.85	4	0.93	0.25-2.38	18	1.02	0.61-1.63
Leukaemia	12	0.87	0.45-1.52	5	1.06	0.34-2.47	20	1.05	0.64-1.62
Endocrine & nutritional	13	0.41	0.22-0.69	5	0.98	0.16-1.13	24	0.56	0.35-0.81
Nervous system diseases	15	0.79	0.44-1.30	3	0.46	0.09-1.34	18	0.69	0.41-1.08
Circulatory diseases	464	0.72	0.66-0.79	108	0.53	0.43-0.64	625	0.71	0.66-0.77
Respiratory diseases	45	0.54	0.40-0.73	13	0.51	0.27-0.88	68	0.60	0.47-0.77
Digestive diseases	47	0.64	0.47-0.85	17	0.68	0.40-1.09	68	0.67	0.52-0.85
Genitourinary diseases	5	0.39	0.12-0.90	5	1.26	0.41-2.95	12	0.94	0.35-1.19
Deaths due to accidents and violence	105	0.50	0.41-0.60	75	0.88	0.70-1.11	191	0.63	0.55-0.73
Suicide	31	0.50	0.35-0.72	18	0.70	0.42-1.11	49	0.56	0.41-0.74
Motor vehicle accidents	32	0.48	0.33-0.68	23	0.84	0.53-1.25	60	0.63	0.48-0.81

[a] Value of the background blue or white collar whichever is greater

[b] Cause of death included in the table if the total number of observed deaths > 5

[c] Includes 120 observed deaths with no information on the last job held, therefore the total number of observed deaths in this column are sometimes greater than the total number of observed deaths from the columns of the background and above background groups

Table 4: Standardized mortality ratios (SMRs) and 95 % Confidence intervals (95 %) for major causes of death for male electrical utility workers:1970-1988, overall and by level PEMF

Cause of death[b] ICD-9	Exposure level (PEMF) Background[a] <= 23.70 ppm			Above background >23.70 ppm			Total[c]		
	Observed	SMR	95 % CI	Observed	SMR	95 % CI	Observed	SMR	95 % CI
All causes	1249	0.71	0.67-0.75	213	0.74	0.64-0.85	1582	0.75	0.71-0.79
Major causes									
Neoplasms	373	0.80	0.72-0.88	67	0.90	0.70-1.15	466	0.83	0.76-0.91
Stomach	19	0.65	0.39-1.01	1	0.99	0.01-1.26	23	0.66	0.42-0.99
Large intestine and rectum	44	0.84	0.61-1.10	7	0.86	0.35-1.78	56	0.90	0.63-1.10
Liver and gallbladder	11	1.04	0.52-1.86	0	0.00	0.30-9.35	11	0.87	0.43-1.56
Pancreas	17	0.67	0.39-1.07	6	1.51	0.55-3.29	23	0.76	0.48-1.14
Trachea/bronchus/lung	140	0.78	0.66-0.92	35	1.22	0.86-1.72	183	0.85	0.74-0.99
Male genitalia	13	0.56	0.30-0.95	2	0.66	0.08-2.39	15	0.54	0.30-0.89
Urinary	22	1.05	0.66-1.59	3	0.95	0.20-2.78	26	1.04	0.68-1.53
Brain	18	1.24	0.73-1.95	1	0.38	0.01-2.10	20	1.13	0.69-1.75
Non-Hodgkin lymphoma	15	1.03	0.58-1.70	3	1.21	0.25-3.55	18	1.02	0.61-1.63
Leukaemia	15	0.95	0.53-1.57	2	0.73	0.53-1.57	20	1.05	0.64-1.62
Endocrine & nutritional	16	0.44	0.25-0.71	2	0.35	0.04-1.2[illegible]	24	0.55	0.35-0.81
Nervous system diseases	16	0.73	0.42-1.19	2	0.88	0.06-1.93	18	0.69	0.41-1.08
Circulatory diseases	507	0.69	0.63-0.75	65	0.58	0.45-0.74	625	0.71	0.66-0.77
Respiratory diseases	57	0.60	0.46-0.78	1	0.07	0.27-0.88	68	0.60	0.47-0.77
Digestive diseases	57	0.67	0.51-0.88	7	0.48	0.20-1.01	68	0.67	0.52-0.85
Genitourinary diseases	8	0.54	0.23-1.07	5	1.26	0.41-2.95	12	0.94	0.35-1.19
Deaths due to accidents and violence	126	0.51	0.43-0.62	54	1.01	0.77-1.33	191	0.63	0.55-0.73
Suicide	37	0.52	0.37-0.72	12	0.75	0.39-1.31	49	0.56	0.41-0.74
Motor vehicle accidents	42	0.54	0.40-0.74	13	0.74	0.40-1.28	60	0.63	0.48-0.81

[a] Value of the background blue or white collar whichever is greater

[b] Cause of death included in the table if the total number of observed deaths > 5

[c] Includes 120 observed deaths with no information on the last job held, therefore the total number of observed deaths in this column are sometimes greater than the total number of observed deaths from the columns of the background and above background groups

Table 5 : Standardized mortality ratios (SMRs) and 95 % confidence intervals for four exposure groups for electrical utility workers:1970-1988 (O=observed)

Magnetic fields (microtesla)	Background <=0.16 (mean=0.16)		Medium 0.17-0.49 (mean= 0.40)		High 0.50 -1.55 (mean= 1.03)		Very high >=1.56 (mean=2.07)			
	O	SMR 95% CI	O	SMR 95 % CI	O	SMR 95% CI	O	SMR 95% CI	X^2 (df=1)	p(two-sided)
Leukaemia	11	0.81(0.40-1.45)	3	1.15(0.25-3.35)	1	0.70(0.02-2.85)	2	2.37(0.29-8.55)	1.15	>0.20
Brain	12	0.95(0.49-1.67)	4	1.62(0.44-4.14)	3	2.18(0.45-6.39)	0	0 - -	0.20	<0.20
Deaths due accidents and and violence	95	0.45(0.37-0.56)	63	1.34(1.03-1.72)	13	0.59(0.22-0.92)	9	0.48(0.22-0.92)	5.20	0.02
Suicide	29	0.48(0.32-0.69)	15	1.07(0.60-1.77)	2	0.30(0.04-1.09)	3	0.52(0.11-1.53)	0.22	>0.20
Motor vehicle accidents	31	0.47(0.32-0.67)	14	0.91(0.50-1.52)	7	1.02(0.41-2.11)	3	0.48(0.10-1.40)	1.93	>0.20

Electric fields	Background <=5.76 (mean=5.42)		Medium 5.77 - 31.74 (mean=11.22)		High 31.75 - 83.18 (mean=44.00)		Very High >=83.18 (mean=83.18)			
	O	SMR 95% CI	O	SMR 95 % CI	O	SMR 95% CI	O	SMR 95% CI	X^2 (df=1)	p(two-sided)
Pancreatic cancer	12	0.54 (0.28-0.95)	5	1.24(0.40-2.90)	4	2.13(0.58-5.46)	2	1.53 (0.18-5.51)	6.62	0.01
Leukaemia	12	0.87(0.45-1.52)	3	1.16(0.24-3.40)	1	0.87(0.02-4.87)	1	1.00(0.03-5.59)	0.05	>0.20
Brain cancer	15	1.18(0.66-1.95)	3	1.24(0.26-3.62)	0	- - -	1	1.01(0.03-5.65)	0.41	>0.20
Deaths due to accidents and violence	105	0.50(0.41-0.60)	26	0.59(0.39-0.87)	11	0.59(0.30-1.07)	38	1.67(1.19-2.31)	34.19	>0.001
Suicide	31	0.50(0.35-0.72)	11	0.86(0.42-1.56)	2	0.35(0.04-1.28)	5	0.72(0.23-1.67)	0.50	>0.20
Motor vehicle accidents	32	0.48(0.33-0.68)	10	0.71(0.34-1.30)	4	0.69(0.19-1.76)	9	1.18(0.54-2.25)	5.98	>0.01

PEMF	Background <=23.70 (mean=3.66)		Medium 23.71-63.20 (mean= 34.46)		High 63.21-74.74 (mean=63.21)		Very high >=74.75 (mean=89.51)			
	O	SMR 95% CI	O	SMR 95 % CI	O	SMR 95% CI	O	SMR 95% CI	X^2 (df=1)	p(two-sided)
Leukaemia	15	0.95(0.53-1.57)	1	0.66(0.02-3.69)	0	- - -	1	0.89(0.02-4.95)	0.40	>0.20
Brain cancer	18	1.24(0.73-1.95)	0	- - -	0	- - -	1	0.67(0.02-4.99)	1.08	>0.20
Lung cancer	140	0.78(0.66-0.92)	18	1.07(0.63-1.68)	1	1.29(0.03-7.19)	16	1.47(0.84-2.38)	5.51	0.05
Deaths due accidents and violance	126	0.51(0.43-0.62)	14	0.54(0.29-0.90)	1	0.57(0.01-3.15)	39	1.54(1.11-2.12)	35.06	<0.001
Suicide	37	0.52(0.37-0.72)	6	0.78(0.28-1.69)	0	0.00(0.00-3.59)	6	0.78(0.28-1.69)	0.93	>0.20
Motor vehicle accidents	42	0.54(0.40-0.74)	4	0.48(0.13-1.22)	0	0.00(0.00-6.49)	9	1.06(0.49.2.03)	2.69	>0.20

6. A case-cohort study of suicide in relation to exposure to electric and magnetic fields among electrical utility workers

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Abbreviations

AM, arithmetic mean; GM, geometric mean; JEM, job exposure matrix; PEMF, pulsed electric and magnetic fields; RR; rate ratios, 95 % CI, 95 percent confidence interval; V/m, volts per meter; μT, microTesla; ppb, parts per billion.

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Running title : EMF and suicide

Abstract

This case-cohort study examines whether there is an association between exposure to electric and magnetic fields and suicide in a population of 21,744 male electrical utility workers from the Canadian Province of Québec. We identified 49 deaths from suicide between 1970 and 1988 and selected a sub-cohort comprising a one per cent random sample from this cohort as a basis for risk estimation. Cumulative and current exposures to electric fields, magnetic fields and pulsed electro magnetic fields (PEMF) were estimated for the sub-cohort and cases through a job-exposure matrix. Two versions of each of these six indices were calculated, one based on the arithmetic mean (AM), and one on the geometric mean (GM) of field strengths. For cumulative exposure, rate ratios (RR) for all three fields showed mostly small non-significant increases in the medium and high exposure groups. The most elevated risk was found in the medium exposure group for electric field-GM (RR=2.76, 95% CI 1.15-6.62). The results did not differ after adjusting for socioeconomic status (SES), alcohol use, marital status and mental disorders. There was a little evidence for an association of risk with exposure immediately prior to the suicide. Small sample size (deaths from suicide) and inability to control for all potential confounding factors were the main limitations of this study.

Key words: EMF, occupational exposure, suicide, case-cohort

Introduction

An association between suicide and overhead and underground high voltage power lines was first suggested by Reichmanis[1]. Estimates of residential exposures to electric and magnetic fields of 598 suicide victims were found significantly higher than that of controls. Perry[2] conducted a study using the same 598 cases of suicide. Measurements of magnetic fields were made at suicide and control addresses. More suicide than control measurements were above the median ($p<0.01$) and mean values of measured EMF for suicide residences were significantly higher than that of controls. Perry[3] also found that among residents of high rise apartments in England, significantly more people who were suffering from depressive illness than controls, had been living close to electric cables. McDowell[4] followed up 8000 persons in England who were living within 30 meters of electric transmission facilities. He found an SMR for suicide of 0.75, providing no support for an association with EMF. In another British survey Dowson and Lewith[5] demonstrated that people who were living close to 132-kV overhead power lines more likely suffered from headaches, migraines and depression than those in control group. Baris and Armstrong[6] found that men described as electrical workers on their death certificates did not have an elevated rate of suicide.

The results of these studies are subject to question because of their limited methodology and exposure measurements. Recently two more sophisticated studies have been published. Poole[7] reported an approximately two-fold increase in the prevalence of depressive symptoms among residents living in proximity to power lines. Magnetic field exposures were not measured, but the association was not explained by demographic variables associated with depression. Later, McMahan[8] investigated the depressive symptomatology in 152 female residents living close to overhead transmission lines in Orange County, California. No significant difference was found in depressive scores in residents adjacent to overhead transmission lines compared to subjects living one block away. Spot measurements taken at front doors were used to assess the magnetic field exposures.

An association between suicide and EMF exposure is made more plausible by observations that EMF may affect the nervous system and neuroendocrine function. Specifically, EMF has been observed to reduce the production of melatonin hormone by the pineal gland and disturb its circadian rhythm[9-12]. There is substantial evidence that disruption in the normal circadian rhythm of pineal melatonin secretion is associated with depression[13-18]. Finally there is firm evidence that depressive illness is strongly associated with suicide[19].

We conducted a case-cohort study to investigate the association between suicide and occupational exposure to electric fields, magnetic fields, and pulsed electric and magnetic fields (PEMF). The study base comprised a cohort of 21,744 electrical utility workers followed up from 1970 to 1988.

Methods

Design and study population

The study follows the case-cohort design[20]. This is similar to a "nested" case control design in including all cases and a sample of the cohort. However, the sample (sub-cohort) is a random one chosen from all cohort members, instead of controls matched to cases from survivors to the age of death of the case, and the methods of analysis are different. Case-cohort design is known as valid and more efficient than "nested" case-control design[20].

As described elsewhere[21], deaths in the entire cohort were identified from the company records if the worker died while an active employee, or through the retirement system if he had left the company but was entitled to claim benefits. Those who left the company without being qualified for pension were traced using provincial sources. We found 49 workers who had suicide as underlying cause of death (ICD-9 950.0-959.0) on their death certificates.

The sub-cohort of 217 subjects was selected as a 1% random sample of the entire cohort. Two were excluded because their job histories were not available, leaving 215 subjects eligible for the analysis.

Estimating exposure

We obtained the complete job histories of the sub-cohort members and cases from the company records. This information included job title, start and end date of each job, and job code. A job exposure matrix (JEM) comprising estimates of exposure to 60 Hz electric and magnetic fields and to PEMF for each job held in the company had been previously constructed for a case-control study of cancer[22]. In the JEM, for each job category, arithmetic means (AM) and geometric means (GM) of electric fields and magnetic fields were estimated from dosimeters worn for a week by a random sample of workers. The AM tends to reflect occasional excursions in very high fields. The GM is less affected by such "peaks", reflecting long periods in moderately elevated fields[23]. The distribution of PEMF exposure was extremely highly skewed. To deal with this, PEMF exposure was calculated in each job category of the JEM as the proportion of subjects measured with weekly mean AM of PEMF greater than 100 ppb (proportion > 100 ppb)[24]. This was used as a unit of exposure for PEMF in the analysis. The GM of PEMF was not used, as it was highly dependent on the value assumed for periods during which no PEMF were detected. Finally, the JEM was linked to each subject's work history to calculate their cumulative and current exposure for cases and the members of the sub-cohort.

We first considered long-term exposure as a risk factor for suicide. The hypothesis behind this was that chronic exposure might cause irreversible disruption in circadian rhythm, and this condition might lead first to depression and then to suicide. We used AM and then GM of the electric and magnetic fields to calculate two indices of cumulative exposure. The summary indices represent cumulative exposure to electric fields expressed in Volts per meter(V/m)-years and magnetic fields expressed in microtesla(μT)-years, equal to the mean (or geometric mean) over a subject's working life, times his duration of employment. For PEMF, the unit of cumulative exposure was proportion >100 ppb-years.

It is also possible that the effective exposure is that immediately prior to suicide, rather than chronic exposure. To examine this hypothesis, we considered current exposure, defined for suicide as the mean exposure for the year in which the suicide occurred. For the sub-cohort, current exposure was re-calculated for each suicide death, as the mean in the year of that death (see statistical analysis). We excluded eight cases of suicide from the analysis by current exposure because death occurred after the subjects left the company. This exclusion limited the analysis for current exposure to 38 cases who were still working prior to their suicide.

For cumulative exposure, three groups were defined:

1) low: < median;

2) medium: ≥ median but < 75th percentile

3) high: ≥ 75th percentile.

For current exposure indices, because of the effectively discrete nature of the estimated exposure, there were less than 10 subjects in the medium exposure group. Therefore, we combined low and medium exposure groups, and defined only two exposure groups as follows:

1) Low and medium: < 75th percentile

2) High: ≥ 75th percentile

Information on other risk factors for suicide

Socioeconomic status (SES) was assessed as a dichotomy: white collar or blue collar based on the first job held.

By reviewing the company medical files, we obtained for each study subject information on 1) history of mental disorders, 2) last available marital status, and 3) alcohol consumption. Medical files were available for all cases, but we were unable to find those of 4.2 % of the sub-cohort. As an indication of history of mental disorders, we abstracted all diagnoses from sickness absence records with the Ninth International Classification codes (ICD-9) 290-310. Information on alcohol consumption was recorded during the medical exam at the time of hire or at periodic examination. We classified individuals into three categories: non-users, users, and unknown. Marital status was usually recorded upon hiring. We also recorded any indication of change of marital status. If no further information was found, marital status at the time of hiring was used as the last available marital status.

Statistical analysis

Standard methods of relative risk (rate ratio or proportional hazard) (RR) regression analysis[25] adapted for the case-cohort[20] were used to obtain suicide RR for groups defined by exposure. We used the EPICURE computer program[26] for this purpose. The analysis implicitly controls for confounding by age. Confounding by other factors was controlled by entering additional variables into the regression models. It is possible that depression might be an intermediate variable on the causal pathway between exposure and suicide, as well as a confounder. We did not use any special analytical techniques to deal with this situation, but we reported results both with and without adjustment for variables associated with depression (see discussion). Cumulative and current exposure were treated as time-dependent in the analysis. Thus we computed each sub-cohort member's cumulative and current exposures at each age of death of a case. However, a fixed reference age was required for the tabulations by these variables to give a general impression of frequencies in exposure groups. The date of death for cases and the date corresponding one year before the date of ending follow up for the members of the sub-cohort were used to compute the fixed reference age for each subject.

Results

Table 1 shows the distribution of demographic and basic employment variables. Cases had somewhat earlier years of birth and years of hire than sub-cohort members. The job exposure matrix is presented in Table 2. The matrix consisted of rows of grouped job titles with similar expected exposure, and columns of corresponding mean exposures to electric, magnetic fields and PEMF. Table 3a shows the association of cumulative exposure to magnetic and electric fields with known risk factors for suicide(% of subjects in the sub-cohort with exposure level ≥ median), to assess potential for confounding. Broadly, exposure was higher among blue collar workers than among white collar workers. Exposure among alcohol users was very similar to that among non-users. The single workers showed greater exposure than married workers. Exposure was also higher among workers diagnosed with mental disorders than among workers with no diagnoses of mental disorders.

Table 3b shows the association of current exposure to the fields with known risk factors for suicide (% of subjects in the sub-cohort with exposure level ≥ 75th percentile). The pattern was similar to that for cumulative exposure, except the married workers showed greater exposure than single workers.

Rate ratios for suicide by these potential confounding factors (SES, alcohol use, marital status and mental disorders) are given in Table 4. Blue collar workers, single workers, and especially workers with diagnosis of mental disorders had higher risk of suicide.

Table 5 shows the correlations between the indices of the exposure calculated from the sub-cohort members at their final exposure levels. Seventy-five per cent of the correlations reported were equal or below 0.50. Two highest correlations were between i) the AM and GM of the electric fields of current exposure (r=0.80), and ii) between the GM of the electric fields of cumulative and current exposures(r=0.79).

Cumulative exposure

The rate ratios for suicide by cumulative exposure to fields are presented in Table 6. Unadjusted RRs for all three fields showed mostly small increases in the medium and high exposure groups. Adjustment for SES, alcohol use, marital status and mental disorders generally resulted in reduced RRs.

The most notable increase was found in the medium exposure group for electric field-GM (RR= 2.76,95 % CI 1.15-6.62), although the high group showed a less elevated rate (RR=1.96, 95% CI 0.65-5.91). This pattern remained after adjusting for the above-mentioned potential confounding factors. When the medium and high exposure groups were combined the adjusted RR was 2.56 (95% CI 0.87-7.58).

Given the possibility that mental disorders could be both a confounder and an intermediate variable, we reported the RRs adjusted for all confounders except mental disorders. The RRs were slightly different, lower or higher depending on the indices, than the RRs adjusted for all confounders. The highest RR was again found for electric fields-GM (RR=3.10, 95% CI 1.18-8.21).

Current exposure

Table 7 shows the association of suicide with current exposure to fields. Unadjusted RRs for all three fields showed mostly small increases in the high exposure groups. Adjustment for SES only or adjustment for alcohol use and marital status did not substantially change the RR estimates. The slightly elevated risk disappeared when additional adjustment was made for mental disorders, except for PEMF (RR=2.06, 95 % CI 0.50-8.35).

Discussion

For cumulative exposure, this study showed;

1) an increased risk of suicide for the medium exposure group by electric fields-GM, but no evidence for dose-response;

2) a slightly increased risk of suicide for electric fields-AM;

3) no association of suicide with magnetic fields or PEMF;

The increased risk of suicide for electric field-GM could not be explained by confounding by SES, alcohol use, marital status or mental disorders.

For current exposure, our results suggested;

1) a slightly increased risk of suicide with PEMF in the high exposure group;

2) no association with the other indices.

Overall, the strongest evidence was for cumulative exposure from electric fields using the geometric mean of exposure, but there was no evidence for dose-response. There was not much of an association

with cumulative exposure for electric fields-AM and with current exposure for electric fields-GM, although these two indices were highly correlated with cumulative exposure for electric fields-GM. One explanation for the difference between the RRs for cumulative and current exposure is the possibility of a stronger effect for a consistent exposure over a long period of time. These results may be subject to bias, either upwards or downwards- we consider these below.

A comparison of the suicide rate in the workers with that of the general population was possible from a cohort mortality study of HQ workers, covering the same follow-up period[22]. The standardized mortality ratio (SMR) for suicide for all HQ workers relative to the Québec population was 0.56 (49 observed deaths). The workers were classified crudely into two exposure groups, background and above background, for electric, and magnetic fields and PEMF using last job held at the utility. The SMRs for the above background groups for each field were higher (magnetic field-AM 0.75, electric field-AM 0.70, PEMF 0.75), but remained below one. Although there may be some healthy worker effect and some under-ascertainment of deaths, these low SMRs do not support the evidence for causal association.

Possible sources of bias

Incomplete case ascertainment

It is possible that we might have missed some suicide cases because of certification practice. The literature on the validity of the suicide diagnosis focuses mainly on the sensitivity of suicide certification[27-29] estimated at 56 % to 99 %. The specificity of the certification was always higher than 95 %. It seems unlikely that the certification practice will vary according to the exposure status. Thus, misclassification is likely to be non-differential, and would therefore bias the effect towards the null value[30]. This is a concern, since our study showed several small non-significant associations.

Misclassification of exposure

Despite the large number of exposure measurements made to create the JEM, some misclassification of exposure will have occurred. One source is the precision of the mean exposure estimates in the JEM. The confidence intervals of the mean exposure estimates which were given elsewhere[22] suggested that the broad patterns of exposure were established beyond reasonable doubt, but there remained considerable uncertainty. As well as from the error in estimating the means, misclassification of individuals would have occurred from the variation in exposure levels between workers in the same row of the JEM. The main effect of these misclassifications would be to bias the risk estimates toward the null.

There was an additional uncertainty in the assessment of PEMF exposure due to the inadequate current knowledge on what situations trigger the POSITRON PEMF channel limits. In fact, the meter apparently responds in this channel to walky talky and truck radio transmissions, as well as to classic PEMFs. This uncertainity was discussed in more detail elswhere[24].

Confounding factors

Lack of information on several important risk factors for suicide including stress, ethnicity and physical diseases, and imperfect measurement on the others, might have resulted in inadequate control of confounding in our study.

SES was measured according to the first job as a simple dichotomous variable. It is possible that misclassification of SES may have been differential as to exposure to EMF and may have led to a bias.

Although we obtained information on alcohol consumption, our data failed to identify alcohol abuse. Alcohol abuse is second only to depression as a risk factor for suicide[31]. It was reported that alcohol abuse has been found to be associated with 50 % of suicides[32]. The fact that we did not find any association between alcohol use and suicide suggests imperfect measurement of this variable, and consequently imperfect control of confounding by alcohol abuse. However, it is not obvious that alcohol abuse would be associated with exposure to electric and magnetic fields, at least after stratifying by SES.

Our data show slightly lower risk among married individuals. This result is compatible with the existing knowledge, as reported by Smith[33], that married individuals have lower suicide rates than persons who have never married or who have divorced. Marital status upon hiring was usually recorded as "single" in our study. If the worker had changed his status and if this change had not been recorded in the files, these workers could have been misclassified. Thus, this non-differential misclassification would have reduced the risk of suicide among those classified as single. Our data was too limited to identify divorced or widowed individuals. Again, there is a possible failure to completely control confounding by marital status.

History of mental disorders is a difficult risk factor to interpret in this study. Mental disorders are considered the major determinant of suicidal behaviour[34]. Schizophrenia, anxiety, depression, alcoholism, major affective and adjustment disorders are the most common conditions found in suicide deaths in general. Several studies have suggested that the history of mental disorders among people who committed suicide ranges between 50 to 90 per cent compared to only 15 per cent in individuals who died of other causes[35]. This association was confirmed in our study, in which only 9.3 % of the sub-cohort had at least one diagnosis of mental disorder recorded on their medical file, while 65.3 % of cases had been diagnosed with mental disorders prior to suicide. The most common diagnoses were anxiety and depression. This very high implied rate ratio of suicide (RR=15.17, 95 % CI 6.76-34.02) among subjects with mental disorder is comparable with other studies of suicide.

Thus, if men susceptible to mental disorders took disproportionatly high- or low-exposure jobs, mental disorders would be a confounding factor. However, it is also possible that depression might be a factor in the pathway of the events leading to suicide following exposure to electric or magnetic fields. If this were true, controlling for depression as a confounding factor would bias the risk estimates toward the null. We were unable to exclude either confounding by mental disorders, or mental disorders being an intermediate variable. There are special and relatively complex analytical techniques developed to deal with a situation when a variable is both confounder, which should be controlled in the analysis, and an intermediate variable, which should not be controlled in the analysis[36]. Pierce[37] noted the complexity of these types of analysis and the requirements of the strong modelling assumptions, and suggested that use of such models could cause confusion both in reader and investigator. Also, our data on history of mental disorders was partial, in particular lacking precision on time of onset. Therefore, we chose the simpler approach of presenting the risk estimates with and without adjustment for mental disorders. The unadjusted estimates are unbiased if there is no confounding, and the adjusted estimates are unbiased if mental disorders are not in the causal pathway (as intermediate variable). In fact, the analysis showed that controlling for mental disorders in general had limited impact on the risk estimates (Table 6&7), so that interpretation of results depends little on this issue. Similar comments apply to alcohol use and marital status.

Sample size

Another limitation of this study was the sample size. Small numbers of suicide deaths resulted in wide confidence intervals, especially after eliminating the 8 cases for the analysis of current exposure.

A high proportion of deaths from "injuries undetermined whether accidently or purposely inflicted"(ICD-9, E980-989) are in fact suicide deaths[37]. Thus including these would have maximized the sample size at the cost of some misclassification. However, there were only 3 subjects with such undetermined cause of death. Thus for clarity, we limited the analysis to deaths coded only as suicide.

Conclusion

We observed some evidence for an association between suicide and cumulative exposure to electric fields-GM. This specific index was not identified a priori as the most relevant index, but rather emerged a posteriori showing the most positive association with suicide among ten indices studied. Thus the evidence from this study for a causal association between exposure to electric fields and suicide is weak. However, the power of the study was limited by small sample size. Additional studies with larger sample size and more refined information on potential confounding factors would be of interest.

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Table 2: Arithmetic (AM) and geometric (GM) mean exposures to 60 Hz electric and magnetic fields and PEMF

	Number of worker-weeks	Magnetic fields (microTesla) AM	Magnetic fields (microTesla) GM	Electric fields (V/m) AM	Electric fields (V/m) GM	PEMF worker-weeks >100ppb[c] AM
Job group						
Jobs considered a priori to have background exposure						
Blue collar jobs[a]	15	0.15	0.03	5.02	1.28	23.00
White collar jobs[b]	24	0.16	0.06	5.76	1.33	0.00
Jobs considered a priori as likely to be exposed above background levels						
Hydroelectric generation						
Equipment electrician	20	0.99	0.23	18.21	1.59	33.30
Equipment mechanics	24	0.77	0.18	14.46	1.45	33.30
Foremen, operations&others.	9	0.50	0.07	12.42	0.98	37.50
Operator	11	1.56	0.67	6.34	1.36	25.00
Nuclear generation						
Equipment electricians	6	0.19	0.05	2.82	0.81	0.00
Operator, nuclear station	17	0.13	0.05	2.52	0.60	0.00
Diesel generation						
Operator, autononous network	11	0.32	0.12	4.82	1.05	40.00
Transmission						
Transmission splicer	12	1.79	0.24	15.79	1.28	83.30
Transmission linemen </= 735 kV	18	0.60	0.08	57.99	2.41	81.22
Substation						
Equipment electrician </=735 kV	29	2.36	0.24	52.13	1.84	42.10
Equipment electrician(735kV)	22	1.78	0.54	122.38	3.62	44.44
Maintenance worker, civil& mech. eng	23	1.05	0.09	31.75	1.92	4.80
Operator mobile	16	1.17	0.23	12.04	1.19	71.40
Operator, 735kV substation	12	1.78	0.76	36.89	2.06	16.60
Technician,automatic control	18	1.60	0.21	8.63	1.41	14.20
Distribution						
Emergency men	8	0.50	0.07	12.71	1.84	60.00
Foremen,OH lines	5	0.16	0.09	5.77	1.06	100.00
Foremen, UG lines	6	0.14	0.06	3.02	0.90	100.00
Linemen (contact & hotstic)	39	0.37	0.06	83.18	2.36	70.50
Linemen(contact)	24	0.83	0.13	123.39	2.45	70.50
Meter installer	10	0.42	0.08	5.48	1.52	37.54
Meter reader	14	0.17	0.05	10.03	2.48	0.00
Splicer, distribution	18	1.87	0.12	9.73	1.63	92.80
Tree trimmer	4	0.34	0.05	37.51	3.40	50.00
Others						
Estimator	10	0.13	0.06	4.31	1.25	0.00
Instructor	6	0.17	0.06	2.83	1.00	0.00
Licensed electricians	9	0.87	0.19	12.52	1.09	20.00
Operator, dispatcher	10	0.09	0.04	3.16	1.08	0.00
Technician, telecommunication	11	0.44	0.11	5.12	1.07	50.00

a blue collar jobs (vehicle and general mechanics, stockeeper, toolkeeper)
b white collar jobs (office workers)
c percent of subjects measured with weekly mean greater than 100 parts per billion

Table 1: Demographic description of the sub-cohort and cases

	Sub-cohort N*	%	Cases N	%
Total	215	100.00	49	100.00
Year of birth				
<1920	9	4.19	5	10.20
1920-1929	32	14.88	10	20.21
1930-1939	34	15.81	14	28.57
1940-1949	61	28.37	11	22.45
>1949	79	36.74	9	18.37
Year of hire				
<1950	22	10.23	7	14.29
1950-1959	31	14.42	16	32.65
1960-1969	45	20.93	13	26.53
1970-1979	80	37.21	11	22.45
>1979	37	17.21	2	4.08
Year of death				
<1975	0	0.00	3	6.12
1975-1979	1	0.46	11	22.45
1980-1984	3	1.39	16	32.65
1985-1988	5	2.32	19	38.78
alive in 1988	206	95.81	0	0.00
Total years of service at death or end of follow-up				
1-9	61	28.37	13	26.53
10-19	69	32.09	12	24.49
20-29	42	19.53	15	30.61
30-39	39	18.14	9	18.37
40+	4	1.86	0	0.00

* N=number of subjects

Table 3a: The association of electric and magnetic fields and PEMF with known risk factors or suicide

Risk factor exposure	% of subjects in the sub-cohort with exposure level >=median for cumulative exposure									
	Electric field				Magnetic field				PEMF[b]	
	AM		GM		AM		GM		AM	
	N[a]	% >=median	N	% >=median	N	% >=median	N	% >= median	N	% >=median
					Cumulative exposure					
SES (first job)										
White collar	20	27.9	30	41.7	16	22.1	24	28.3	1	1.4
Blue collar	88	61.5	79	55.9	92	64.3	84	58.8	109	76.2
Alcohol use										
No	26	50.0	26	50.0	22	43.3	22	43.3	25	47.5
Yes	69	50.7	72	50.9	74	54.4	75	55.1	76	55.9
Unknown	13	37.0	11	40.7	12	44.4	11	40.7	9	32.3
Last known marital status										
Single	68	53.5	66	51.9	69	54.3	69	54.3	63	49.6
Married	27	38.0	31	43.7	26	36.6	26	36.6	36	50.7
Unknown	13	77.1	12	70.6	13	76.5	13	76.5	11	64.7
Mental disorders										
No	88	47.3	88	47.1	88	47.1	87	46.7	92	49.5
Yes	12	60 0	14	70.0	12	60.0	13	75.0	11	55.0
Unknown	8	88.9	7	77.8	8	88.9	8	88.9	7	77.8

a N=number of subjects
b unit of exposure=% workers measured who had weekly mean exceeding 100 ppb

Table 3b: The association of electric and magnetic fields and PEMF with known risk factors for suicide

Risk factor exposure — % of subjects in the sub-cohort with exposure level >=75th percentile for current exposure

	Electric field				Magnetic field				PEMF[b]	
	AM		GM		AM		GM		AM	
	N[a]	% >=75th perc.	N	% >=75th perc.	N	% >=75th perc.	N	% >= 75 th perc.	N	% >=75th perc.
SES (first job)										
White collar	1	1.4	2	2.7	1	1.4	1	1.3	0	0.0
Blue collar	52	36.3	60	42.9	57	39.9	54	37.6	53	37.1
Alcohol use										
No	12	23.1	13	25.0	13	25.0	13	25.0	14	26.9
Yes	37	27.2	46	33.8	42	30.9	38	27.9	36	26.5
Unknown	4	14.8	3	11.1	3	11.1	4	14.8	3	11.1
Last known marital status										
Single	27	21.6	31	27.4	35	27.5	29	22.8	33	26.0
Married	20	28.2	25	35.2	19	26.8	20	28.1	16	22.5
Unknown	6	35.3	6	35.3	4	23.5	6	35.3	4	23.5
Mental disorders										
No	44	23.6	51	27.4	50	26.9	45	24.2	45	24.2
Yes	5	25.0	8	40.2	6	30.0	7	35.0	4	20.0
Unknown	4	44.4	3	33.3	2	22.2	3	33.3	4	44.4

a N=number of subjects
b unit of exposure=% workers measured who had weekly mean exceeding 100 ppb

Table 4: Rate ratios (RR) for suicide by SES, alcohol use, marital status and mental disorders

	Sub-cohort		Cases		RR (95 % CI)
	N	%	N	%	
Socioeconomic status (first job)					
White collar	72	33.5	11	22.5	1.00
Blue collar	143	66.5	38	77.5	1.88 (0.89-3.98)
Alcohol consumption					
No	52	24.2	15	30.6	1.00
Yes	136	63.3	21	42.9	0.55 (0.25-1.18)
Unknown	27	12.6	13	26.5	1.43 (0.57-3.58)
Last known marital status					
Single	127	59.1	29	59.2	1.00
Married	71	33.0	16	32.7	0.86 (0.41-0.78)
Unknown	17	8.0	4	7.1	0.63 (0.17-2.32)
Mental disorders (ICD-9, 290-310)					
No	186	86.5	16	32.7	1.00
Yes	20	9.3	32	65.3	15.17 (6.76-34.02)
Unknown	9	4.2	1	0.0	1.11 (0.12-10.02)

Table 6 : Relative Risk Estimates and 95 % Confidence Intervals for suicide in relation to cumulative exposure to electric, magnetic and PEMF

	Number of subjects		Rate Ratios and 95 % Confidence Intervals			
	Sub-cohort	Cases	Unadjusted	Adjusted for SES (using first job)	Adjusted for SES, alcohol use, marital status	Adjusted for SES, alcohol use, marital status and mental disorders
Electric fields (V/m) (AM)						
<136.10	107	21	1.00	1.00	1.00	1.00
>=136.10 & <308.60	54	15	1.37 (0.58-3.22)	1.18 (0.49-2.81)	1.08 (0.43-2.73)	1.58 (0.50-5.05)
>=308.60	54	13	1.49 (0.63-3.52)	1.10 (0.43-2.81)	1.25 (0.46-3.42)	1.68 (0.35-8.01)
Electric field (V/m)(GM)						
<23.10	106	16	1.00	1.00	1.00	1.00
>=23.10 & <40.30	55	20	2.76 (1.15-6.62)	2.59 (1.08-6.22)	3.10 (1.18-8.21)	2.75 (0.93-8.11)
>=40.30	54	13	1.96 (0.65-5.91)	1.61 (0.53-4.91)	2.23 (0.64-7.77)	1.77 (0.36-8.49)
Magnetic Fields (microTesla)(AM)						
<4.53	107	26	1.00	1.00	1.00	1.00
>=4.53 & <10.36	54	8	0.58 (0.23-1.46)	0.43 (0.16-1.13)	0.40 (0.13-1.13)	0.28 (0.06-1.20)
>=10.36	54	15	1.34 (0.60-3.02)	0.89 (0.36-2.19)	0.79 (0.28-2.17)	0.36 (0.09-1.99)
Magnetic Fields (microTesla) (GM)						
<1.25	107	24	1.00	1.00	1.00	1.00
>=1.25 & <2.08	53	14	1.21 (0.54-2.73)	1.16 (0.52-2.59)	1.26 (0.52-3.07)	0.81 (0.28-2.37)
>=2.08	55	11	1.21 (0.48-3.00)	0.97 (0.38-2.46)	1.85 (0.29-2.48)	0.48 (0.09-2.50)
PEMF-AM[a]						
<1.10	105	20	1.00	1.00	1.00	1.00
>=1.10 & <6.40	56	10	1.32 (0.58- 2.99)	0.94 (0.34-2.57)	0.96 (0.33-2.78)	1.14 (0.23-5.79)
>=6.40	54	19	1.91 (0.85- 4.32)	1.32 (0.47-3.75)	1.50 (0.50-4.53)	1.23 (0.27-5.70)

[a] unit of exposure= % workers measured who had weakly mean exceeding 100 ppb

Table 7: Relative Risk Estimates and 95 % Confidence Intervals for suicide in relation to current exposure to electric, magnetic fields and PEMF

	Number of subjects		Rate Ratios and 95 % Confidence Intervals			
	Sub-cohort	Cases	Unadjusted	Adjusted for SES	Adjusted for SES, alcohol use and marital status	Adjusted for SES, alcohol use marital status and mental disorders
Electric field-AM[a] (V/m)						
< 10.60	162	28	1.00	1.00	1.00	1.00
>=10.60	53	10	1.14 (0.52-2.54)	0.92 (0.40-2.15)	1.23 (0.50-3.01)	1.20 (0.32-4.51)
Electric field-GM [a] (V/m)						
< 1.50	153	24	1.00	1.00	1.00	1.00
>=1.50	62	14	1.45 (0.70-3.00)	1.21 (0.55-2.66)	1.63 (0.71-3.77)	0.84 (0.26-2.71)
Magnetic Fields-AM[a] (microTesla)						
< 0.37	157	24	1.00	1.00	1.00	1.00
>=0.37	58	14	1.58 (0.76-3.28)	1.33 (0.60-2.97)	1.62 (0.69-3.80)	0.94 (0.25-3.60)
Magnetic Fields-GM [a] (microTesla)						
< 0.07	160	27	1.00	1.00	1.00	1.00
>=0.07	55	11	1.10 (0.50-2.37)	0.86 (0.37-1.98)	0.91 (0.38-2.17)	0.69 (0.19-2.48)
PEMF-AM [a,b]						
< 40	162	25	1.00	1.00	1.00	1.00
>= 40	53	11	1.52 (0.73-3.16)	1.27 (0.57-2.82)	1.64 (0.70-3.87)	2.06 (0.50-8.35)

[a] because of the effectively discrete nature of estimated current exposure (one of the 32 job categories) the medium group (>median, <75th percentile) group was small, and combined with the low (<=median) group
[b] unit of exposure= % workers measured who had weakly mean exceeding 100 ppb

Table 5: Correlations between exposure indices

		CUMELAM	CUMMGAM	CUMPEMF-AM	CUMELGM	CUMMGGM	CURELAM	CURMGAM	CURPEMF-AM	CURELGM	CURMGGM
Cumulative exposure											
Electric fields-AM	(CUMELAM)	1.00									
Magnetic fields-AM	(CUMMGAM)	0.20	1.00								
PEMF-AM	(CUMPEMF-AM)	0.77	0.42	1.00							
Electric fields-GM	(CUMELGM)	0.72	0.02	0.50	1.00						
Magnetic fields-GM	(CUMMGGM)	-0.05	0.74	0.09	-0.07	1.00					
Current exposure											
Electric fields-AM	(CURELAM)	0.55	0.07	0.34	0.73	0.05	1.00				
Magnetic fields-AM	(CURMGAM)	0.06	0.41	0.11	0.15	0.52	0.32	1.00			
PEMF-AM	(CURPEMF-AM)	0.46	0.22	0.62	0.52	0.17	0.67	0.42	1.00		
Electric fields-GM	(CURELGM)	0.43	-0.04	0.25	0.80	-0.04	0.79	0.18	0.45	1.00	
Magnetic fields-GM	(CURMGGM)	-0.03	0.43	0.06	-0.01	0.71	0.12	0.71	0.25	0.04	1.00

7. Using last job held to estimate exposure to electric and magnetic fields: a validation study

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Abbreviations

JEM, job exposure matrix

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Running title: Exposure assessment and validity

Abstract

The credibility of occupational epidemiological studies depends in large part on the validity of the assessment of the exposure. In large cohort studies, the last job held is often used to assign exposure status to the study subjects. Exposure was assigned in this way for a mortality study of a cohort of an electrical utility workers in Quebec carried out by the authors. The objective of the present study was to investigate the validity of attributing magnetic field exposure by using "the last job held". This was done by comparing in a sample of the cohort, estimates obtained using last job with those obtained using full work histories. The correlations between indices based on the last job and on all jobs varied between 0.75 and 0.78. The mean was slightly lower when only last job was used. Last job was particularly good in identifying the highest exposed individuals (for the exposure cutpoint of 90th percentile for last job and for all jobs; sensitivity=0.69, specificity=0.97, kappa=0.66). The results suggest that although not all workers starting in highly exposed jobs stayed in them, it seemed that the workers who ended their working life in highly exposed jobs had stayed in these jobs throughout their working life. In conclusion, the results indicated some but not catastrophic loss of information when estimates of exposure were based on the last job only. These results are most likely to be generalizable to other industries in which highly exposed jobs are also skilled.

Key words: EMF, exposure assessment, validity

Introduction

It is desirable to obtain the most accurate estimate of exposure in occupational epidemiological studies. For occupational exposure to electric and magnetic fields, the best approach would be to obtain individual exposure data on each study subject by the use of personal dosimeters. However, this approach is not feasible for retrospective cohort studies or case-control studies. In these studies the usual approach is to use a job exposure matrix (JEM) to estimate individual exposures. A JEM consists of a list of job titles with a list of exposures corresponding to these job titles. The ideal situation is to have an accurate JEM that included the variations in exposure over time for each job title, and also have complete job histories for individuals. One can then calculate the cumulative exposures of individuals by applying the matrix to the individual job histories.

However, in large cohort studies, complete work histories may not be readily available. Quite frequently the "last job held" is the only information that investigators can obtain, as in our cohort mortality study of 21,744 electrical utility workers[1]. This cohort, henceforth referred to as the Québec cohort, was one of three cohorts on which cancer incidence was investigated in the "Canada-France" case-control study[2].

The objective of the present study was to investigate the validity of attributing magnetic field exposure by using "the last job held". This was achieved by comparing in a sample of the Québec cohort, estimates obtained using only last job with those obtained using the full work histories.

Methods

Study population

The Québec cohort consisted of all permanent male employees who had completed at least 1 full year of service in an electrical utility in the Province of Québec, Canada between 1970 and 1988. The validity study subjects were the cancer cases and the controls selected for the "Canada-France" case-control study. The details of the case identification and the selection of controls are described elsewhere[2].

Estimating exposure

The complete occupational histories of the cancer cases and the controls had been abstracted from the company records for the "Canada-France" case-control study. For the validity study, the cases' and controls' exposures to magnetic fields were estimated using four different approaches as described below.

1. Cumulative exposure using all jobs **(All jobs-cum)**.
   The cumulative exposure of each case and control was assessed by applying a JEM to the complete job histories. This approach was used by the "Canada-France" case-control study.

2. Cumulative exposure using the last job **(Last job-cum)**
   The "last job held" for a case means the job held at the time of the diagnosis (if the individual was active when diagnosed) or the last job held in the company (if the individual was retired or left). For a control, it means the job held at the time of the diagnosis of the corresponding case, or the last job held. The cumulative exposure was calculated as in 1., except that it was assumed that each individual held the same job (his last job) throughout his employment in the utility. Thus, the cumulative exposure of each individual was computed by applying the JEM to

the last job held and multiplying this value by the individual's total years of service in the utility.

3. Mean exposure using all jobs **(All jobs-mean)**.
   The mean exposures were calculated by dividing the cumulative exposure from all jobs by the total years of service.

4. Mean exposure using last job **(Last job-mean)**.
   This approach was used in the Québec cohort mortality study involved simply assigning the value in the JEM for the last job.

Statistical analysis

The main goal of the analysis was to determine the extent of agreement between the different approaches in estimating individual exposure and identifying the "exposed" subjects for analysis in which subjects are grouped by exposure. First, the correlation coefficients between the four different approaches of exposure assessments were calculated. We then focused more detailed analysis specifically on the loss of information in relying only on last job, rather than in choosing cumulative versus mean exposure. Because the mean exposure from last job held was used for our cohort mortality study[1], we compared this with the mean exposure from all jobs, rather than comparing estimates of cumulative exposure.

We also calculated the sensitivity and specificity of methods based on last job in identifying "exposed" subjects on grouping by exposure. Exposure classification based on all jobs was taken as the working "gold standard". Sensitivity is defined as the proportion of those who are truly exposed and are correctly classified as exposed by the last job held. Specificity is defined as the proportion of those who truly are not exposed and are correctly classified as not exposed by the last job held. The Kappa statistic was examined as a further measure of agreement. A Kappa value of zero indicates a degree of agreement that would be expected by chance. The maximum value of Kappa is unity and values of Kappa greater than 0.50 are generally considered to represent good agreement[3-5].

Results

Table 1 shows descriptive information for the study subjects.

Table 2 shows the means for the estimates of exposure from the four different approaches and the correlations between them. The means were about 20% lower when the last job was used. The correlations between equivalent indices based on the last job and on all jobs varied between 0.75 and 0.78. The poorest correlation was 0.62, between the cumulative exposures from all jobs and the mean exposure from last job.

Table 3 shows the correlations between mean exposures based on last job and on all jobs, after dividing into groups by the case status, activity status, age at diagnosis, and duration of employment. The means of two indices are also given in each group. The pattern of slightly lower means when only last job was used was consistent across groups: cases and the controls; active, retired workers and leavers; or workers in each group of age at diagnosis (age <45,45-64, ≥65) for duration of employment (in years <10, 10-19, ≥20). However, the means were very close for the two methods in the following two groups: workers with duration of employment less than 10 years and leavers.

Correlations between two approaches were high in all groups. The highest correlation was among leavers (r=0.99) and for workers with less than 10 years of employment (r=0.95). This is not surprising as these workers very likely held the same job throughout their time at the utility.

Table 4 shows, separately for groups of workers according to the JEM job category of the last job that they had:

i) the average proportion of the subjects' total working lives at the utility spent in that job category;

ii) the proportion of the subjects who spent all of their working lives in that job category;

iii) the mean exposure calculated using all jobs;

iv) the mean exposures calculated using last job.

In general men ending in highly exposed jobs (e.g. equipment electricians, operators, maintenance workers, linemen) had spent a high proportion of their lives in those jobs. The highest mean proportion of working life spent in the last job was for those ending as equipment electricians (hydroelectric generation) (93%). Sixty-five percent of these workers spent all of their working life in that job.

The mean exposure from all jobs and the mean exposure from last job were generally very close for men in highly exposed last jobs. This is consistent with the observation that men ending in these jobs had spent most of their lives in them. For white collar and blue collar jobs classified a priori as unexposed, however, the mean exposure using all jobs was considerably higher than the exposure using last job. This indicated that some of the workers who held unexposed last jobs, had previously held exposed jobs.

Overall, the results in Table 4 suggest that although not all workers starting in high exposed jobs stayed in them, it seemed that the workers who ended their working life in highly exposed jobs had stayed in these jobs throughout their working life. Workers did not usually move to jobs with high exposure late in their working life.

Table 5 shows the sensitivity, specificity and Kappa statistics as quantitative indices of accuracy (validity) and agreement for assessing the exposure status, defined now as a dichotomy, using the last job held. The calculations were repeated for several different cutpoints defining "exposure". For the last job held, the cutpoints of 0.16 μT, 0.49 μT and 1.55 μT were chosen because they were used in the Québec cohort mortality study to define exposure groups[1]. Because of the lower mean exposure from using last job than that of using all jobs, using the same cutpoints (0.16 μT, 0.49 μT and 1.55 μT) to define groups according to mean based on all jobs leads to very different proportions of subjects "exposed". We therefore also compared classifications based on last job using the cutpoints 0.16 μT, 0.49 μT and 1.55 μT with those using all jobs according to cutpoints that gave the same proportion exposed as with last jobs. We also show agreement according to cutpoints at the median, 75th and 90th percentiles of exposure values.

Sensitivity ranged from 60 to 70 percent, specificity from 70 to 99 percent, and kappa from 36 to 66 percent. The highest accuracy was obtained when we used the cutpoint of 90th percentile for last job and for all jobs (sensitivity=0.69, specificity=0.97, kappa=0.66).

Discussion

Accuracy and agreement between the different approaches to estimating exposure to magnetic fields were assessed in a sample of a cohort of electrical utility workers in Quebec. The main purpose of this study was to compare a practical method of exposure assessment against a superior but less practical method. In particular, we wished to validate the use of the last job held in our historical cohort mortality study[1] because it was not feasible to abstract the complete occupational histories for all 21,744 members of the cohort. In this discussion, we first consider the implications of our results for the interpretation of our cohort study, then the possible generalizibility of these results to other studies using last job.

Our results showed high specificity of the methods based on last job in identifying "exposed" subjects: a high proportion of those workers truly not exposed were correctly classified as "unexposed", so that those classified as exposed were indeed exposed. Sensitivity of the method in identifying "exposed" subjects on grouping by exposure was lower: a significant proportion of those workers truly exposed were not classified as such, so that some of those classified as unexposed were actually exposed (Table 4). These results suggest that although using last job resulted in loss of information in our cohort study, this loss did not invalidate the study.

Alderson[6] discussed the possible biases from using the last occupation recorded at death registration as an indication of occupational exposures during a working life. He drew attention to the fact that the onset of occupational disease can result in changing job. His argument was that the worker's mobility might be related to his ill health from his occupational exposure. If this results in removal from the exposure by moving from heavy and exposed jobs to a lighter unexposed jobs, the effect of exposure would be lost in the analysis when the last job was used to assign exposure especially if the exposure of interest was related to the health effect causing change of job. The obvious consequence of this would be the underestimation of the risk. In the electrical industry, the exposed jobs are highly skilled and active ones. If exposure to EMF were associated with ill health, workers in the highly exposed jobs which usually demand high physical activity, might remove themselves from exposure by moving to less demanding unexposed jobs. This would result in some differential misclassification when the last job was used in assessing exposure in this industry if the ill health led to the death. It is unlikely that this problem occurred in our mortality study for cancer which is not usually preceded by disabling morbidity. It remains as a concern for the causes of death which may be preceded by disability.

Using all jobs is clearly superior to using last job. However, this does not make using all jobs a perfect measurement, a true "gold standard". Wacholder et al[7]. use the term of "alloyed gold standard" for a superior method of measurement but nevertheless had measurement error. They note that the correlation between an approximate and alloyed gold measurement will be different to that between an approximate and true gold standard. The difference depends on the extent of error in the alloyed gold standard, and magnitude of correlation of errors in the approximate measure studied and errors in the alloyed gold standard. We do not know how the error in the imperfect measurement (last job) and in the alloyed gold standard (all jobs) are correlated in our cohort study. However, it is likely that these errors were positively correlated since we used the same JEM for the two measurements.

One source of error in both our "gold" standard and approximate measure was that the changes over time in exposure in the same job were not allowed for in either. In fact, the JEM used for the Canada-France case-control study[1] allowed for the variation of exposure in the past. However, a preliminary analysis showed that the estimates corrected for differences in exposure in the past were very highly correlated with the estimates which were not so corrected (r>0.90). Therefore for simplicity, we only used the uncorrected estimates, thereby focusing on the loss of information in relying on only last job rather than on correcting for changes in levels of exposure in the past.

The last job held has been used in other occupational cohort studies of workers, in particular in one of telephone company workers, exposed to electric and magnetic fields[8]. As a part of her study, Matanoski evaluated the use of last job. Her results were broadly similar to ours. There was 85 % agreement between the last job and the longest job held in her study. The reason for the similar findings in the two studies could be that in both industries the exposed jobs require skills, so that if the workers end with the skilled jobs, they are likely to have stayed in them. Thus we conjecture that using last job is a good method of assessment of exposure in industries where the exposed jobs are also skilled "trade" jobs.

In conclusion, the results indicated some but not catastrophic loss of information when estimates of exposure were based on the last job only. Last job was particularly good for identifying the highest exposed individuals, at least in this particular industry. It is likely that the results can be generalized only to certain other industries. A decision on whether using last job to assess exposure is a sensible compromise between cost and precision requires the investigator's judgement based on the knowledge of job mobility, processes and exposures in the industry considered.

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Table 1: Descriptive information on the study population (N=1997)

	Mean	Minimum	Maximum
Year of birth	1924	1905	1960
Year of hire	1953	1920	1983
Year of end of employment	1983	1970	1988
Year of death	1981	1970	1988
Total years of employment	26	1	51
Age at diagnosis	57	22	82

Table 2: Correlation matrix between the estimates of exposure from the different approaches used (N=1997)

Approach used	Mean(μTesla)	Correlation coefficients (r): Cumulative exposure — All jobs	Cumulative exposure — Last job	Mean exposure — All job	Mean exposure — Last job
<u>Cumulative exposure</u>					
All jobs	12.14	1.00			
Last job	9.73	0.75	1.00		
<u>Mean exposure</u>					
All jobs	0.47	0.86	0.66	1.00	
Last job	0.39	0.62	0.87	0.78	1.00

Table 3: Correlation between the mean exposures (μTesla) to magnetic fields-AM by case and activity status and by age at diagnosis

		Mean			
	N[a]	All jobs	Last job	r	95% CI[b]
All subjects	1997	0.47	0.39	0.78	(0.76-0.80)
Case status					
Cases	774	0.48	0.38	0.76	(0.73-0.79)
Controls	1223	0.47	0.40	0.80	(0.78-0.82)
Activity status					
Active workers	1136	0.48	0.40	0.77	(0.75-0.79)
Retired workers	806	0.47	0.40	0.78	(0.75-0.81)
Leavers	55	0.38	0.38	0.99	(0.98-0.99)
Age at diagnosis					
<45	360	0.51	0.42	0.82	(0.78-0.85)
45-64	1034	0.46	0.37	0.76	(0.73-0.78)
>=65	603	0.47	0.41	0.79	(0.76-0.82)
Duration of employment					
<10 years	235	0.44	0.43	0.95	(0.94-0.96)
10-19 years	375	0.44	0.40	0.84	(0.81-0.87)
>=20 years	1387	0.49	0.38	0.74	(0.72-0.86)

[a] N=number
[b] 95% CI=95% Confidence intervals

Table 4: Proportion of working life spent in the last job category and the proportion of workers who spent 100% of their working life in their last job

Job category of last job	N[a]	Mean proportion of working life spent in the last job[b] (%)	Proportion of workers who spent all of their working life in their last job[c] (%)	Mean exposure (μTesla)	
				All jobs	Last job
Background exposure jobs					
White collar jobs	824	79	52	0.26	0.16
Blue collar jobs	284	60	43	0.30	0.15
Hydroelectric generation					
Equipment mechanics	40	86	62	0.80	0.77
Equipment electrician	17	93	65	0.98	0.92
Operator	32	76	31	1.54	1.56
Substation					
Equipment electrician	32	81	53	2.03	2.36
Maintenance worker	104	92	70	1.00	1.05
Distribution					
Linemen(contact&hot stick)	152	92	70	0.38	0.37
Meter installer	35	52	17	0.38	0.42
Meter reader	32	70	44	0.19	0.17
Transmission					
Linemen	22	89	59	0.59	0.60

a N=number of workers, included only if N ≥ 15
b proportion of working life spent in the job category in which the workers were classified based on their last job
c proportion of workers who spent 100 % of their working life in the job category in which they were classified based on their last job

Table 5: Sensitivity, specificity and Kappa statistics

Cut-point criteria: Last j.	Cut-point criteria: All j.	Number of subjects: Last j. E[a] / All j. E[b]	Last j. E / All j. NE	Last j. NE / All j. E	Last j. NE / All j. NE	Sensitivity	Specificity	Kappa	% Exposed: Last j.	% Exposed: All j.
>0.16 μT[c]	>0.16 μT	646	46	448	857	0.59	0.95	0.52	35	55
>0.16 μT	>65th perc.[d]	492	200	209	1096	0.70	0.84	0.55	35	35
>0.49 μT[c]	>0.49 μT	325	26	21	1435	0.60	0.98	0.65	17	27
>0.49 μT	>83rd perc.[d]	236	115	104	1542	0.70	0.93	0.58	17	17
>1.55 μT[c]	>1.55 μT	87	26	48	1836	0.64	0.99	0.67	6	7
>1.55 μT	>90th perc.[d]	82	31	39	1845	0.68	0.98	0.44	6	6
>Median	>Median	673	327	236	671	0.67	0.67	0.36	50	50
>75th perc.	>75th perc.	335	164	165	1333	0.67	0.89	0.56	25	25
>90th perc.	>90th perc.	138	62	61	1736	0.69	0.97	0.66	10	10

[a] E=Exposed
[b] NE=Non-exposed
[c] The cutpoints of 0.16μT, 0.49μT and 1.55μT were used in a cohort mortality study of electrical utility workers to define the background, above background-medium and above background-high categories of exposure
[d] For all jobs, the cutpoints were chosen to obtain the same proportion of workers in the exposed categories for both approaches

10. Conclusions

Analysis of mortality of 21,744 electrical utility workers provided no evidence of increased mortality overall. Death rates were substantially below the Québec male population, with an SMR of 75 % for all causes and 83% for all cancers. SMRs for major causes of death and for the site specific cancers were also less than one.

The results of the case-cohort study were also largely negative. For cumulative exposure to electric and magnetic fields, rate ratios (RR) for all three fields showed mostly small non-significant increases in the medium and high exposure groups. The most elevated risk was found in the medium exposure group for electric field-GM (RR=2.76, 95% CI 1.15-6.62). There was a little evidence for an association of risk with exposure immediately prior to the suicide. Small sample size (deaths from suicide) and inability to control for all potential confounding factors were the main limitations of this study.

The results of the validation study indicated some but not catastrophic loss of information when estimates of exposure were based on the last job only. Last job was particularly good for identifying the highest exposed individuals, at least in this particular industry. It is likely that the results can be generalized only to other industries in which the highest exposed jobs are skilled jobs.

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I would like to thank Dr. Ben Armstrong for his guidance and support throughout the course of this dissertation. He brought to this project tremendous insight and a wealth of experience. I cannot thank him enough for all he taught me and I absolve him of all responsibility for that which I could not learn.

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I am grateful to Hydro Québec for giving me the permission to carry out this study and for funding the collection of data for the Canada-France study on which these studies were based, also to L'Institut de recherche en santé et sécurité du travil du Québec for personal support and to Health and Welfare Canada for financial support for these studies.

Finally, I want to express my most profound appreciation to my family who put up with me over all these years. I want to thank especially my son Emre and my daughter Tara for being patient with their mother who did not have much time to play with them.

Appendix 1

le 18 janvier 1990

Docteur Gilles Thériault
École de santé au travail
Université McGill
1130, avenue des Pins
Montréal, Québec
H3A 1A3

Cher D^{r} Thériault,

J'ai pris connaissance de votre demande concernant le projet du D^{r} Dalsu Baris intitulé "Suicide and other non-malignant causes of death in electrical utility workers; their association to electric and magnetic field exposure" dans laquelle vous m'expliquez que le D^{r} Dalsu Baris est une étudiante au PhD à l'École de santé au travail et que vous désirez lui permettre de poursuivre cette recherche comme un second volet à l'étude que nous vous finançons sur les champs électromagnétiques et la santé.

Après avoir considéré le projet du D^{r} Dalsu Baris, nous sommes heureux d'y apporter notre appui.

Il est entendu que le D^{r} Baris entreprendra les démarches nécessaires pour obtenir l'autorisation de la Commission d'accès à l'information et qu'Hydro-Québec ne s'impliquera pas financièrement dans ce projet. Par ailleurs, nous comprenons que le D^{r} Baris devra avoir accès aux mêmes sources d'information que celles utilisées dans le projet original et nous accordons l'autorisation d'accès en autant que vous assumiez la direction de cette étudiante. Nous considérons qu'il s'agit là d'une activité différente du projet de recherche pour lequel nous avons signé une entente.

Il est aussi entendu qu'Hydro-Québec sera informée des résultats de cette recherche avant diffusion publique ou publication. Le D^{r} Baris s'engage aussi à se rendre disponible, si besoin était, pour fournir des explications supplémentaires sur les résultats de ses travaux. Enfin, nous souhaitons que le D^{r} Baris mentionne la collaboration d'Hydro-Québec à cette étude.

.../2

J'espère que vous pourrez donner suite à ces demandes. Je suis certain que les résultats des travaux du D^r^ Baris contribueront à l'avancement des connaissances et qu'ils seront un ajout valable aux travaux que vous conduisez.

Je vous prie d'agréer, cher D^r^ Thériault, mes salutations distinguées.

Le chef du service Santé,

Gilles Pineau

Gilles Pineau, m.d.

GP/lde

Appendix 2

SUICIDE AND OTHER NON-MALIGNANT CAUSES OF DEATH IN ELECTRICAL UTILITY WORKERS; THEIR ASSOCIATION WITH EXPOSURE TO ELECTRIC AND MAGNETIC FIELDS

1.LITERATURE REVIEW

1.1. Exposure to extremely low frequency electric and magnetic fields (ELFEMF)

The orderly arrangement of radiation according to wavelength or frequency is called the electromagnetic spectrum. This spectrum ranges from extremely low frequency (ELF)(10-300 Hz) through radiofrequencies (10^{4}-10^{10} Hz), microwaves (10^{8}-10^{11} Hz), infrared (10^{12}-10^{14} Hz), visible light (10^{15} Hz), ultraviolet (10^{15}- 10^{17} Hz), to x rays (10^{16}-10^{21} Hz) and gamma rays (10^{19}-10^{22} Hz). The various frequency ranges have different characteristics of emission, transmission and absorbtion in matter, and in particular interact with the biological systems differently (WEST Associates-Energy Task Force 1886). We are concerned here with only ELFEMF. ELFEMF have uncoupled components, **electric** (E) and **magnetic** (B) fields. The E **field** applies a force to any charged particle and is measured in volts per meter (V/m). B **field** applies a force any charged moving particle and is measured in Tesla (T).

Naturally occurring geomagnetic fields, home appliances, high tension transmission and distribution wires, industrial equipment, medical diagnostic and therapeutic equipment are the sources of ELFEMF exposure to humans. Examples of E and B fields measurements reported in the literature from these sources are given in Annex 1.

Although ELF electric and magnetic fields can occur separately they are generally correlated. A recent study which monitored 36 electric workers and a comparison group (background exposure group) using a pocket-size dosimeter for their occupational and domestic exposure to ELFEMF, found that E **and** B **fields** were correlated at r=0.63 (Deadman 1988). The same study showed that exposure to E and B fields in exposed utility workers was about 10 times than that in non exposed occupations (Annex 1)

1.2.Health effects of (ELFEMF)

1.2.1. General health effects (experimental and epidemiologic studies) Experimental research on biological effects of ELFEMF has been carried out primarily with small rodents, but a variety of other animal species have also been used. These experiments were undertaken to investigate the effect of 50-60 Hz EMF exposure on development, and reproduction, as well as endocrine, immune, mutagenic and other physiologic responses.

Gann (1976) found a decrease in heart rate and cardiac output in dogs exposed to 15 kV/m electric fields. Hilton and Phillips (1980) however reported no changes in ECGs of rats exposed to similar electric fields. Several studies showed alterations in blood chemistry such as increased lipid and protein levels with ELF magnetic field exposure (Anderson and Phillips 1983). Craig (1987) and Adey (1988) showed possible cancer-promoting effects of ELFEMF through stimulating ornithine decarboxylase, an essential enzyme for cell growth and DNA synthesis. Free (1981) reported suppressed testosterone levels in rats exposed to 60 Hz electric fields. Lymangrover (1983) reported elevation in steroid hormones of rat adrenal tissue exposed to 10 kV/m electric fields. Results from these experimental studies should not be extrapolated without great caution to humans. That there is an interaction between ELFEMF exposure and biological systems can however be considered established. Furthermore, there is a generally accepted mechanism for interaction with ELF fields and biological systems. The ELFEMF produce electrochemical alterations in the properties of the cell membranes, change their transport characteristics as well as their molecular structure and thus alter the physiological functions of the cell (Tenforde and Kaune 1987).

The first reports of symptoms in workers occupationally exposed to ELFEMF came from Soviet Union (Vyalov 1967, Asanova 1966, Sazanova 1967, Korobkova 1972). These studies report acute symptoms such as tiredness, headache, nausea, and increased irritability in power transmission line workers. One Spanish study supported these findings (Fole 1972). Although these early cross-sectional reports were limited due to some methodological weaknesses (i.e small number of subjects, lack of comparison groups, subjective reporting) they succeeded in starting considerable public and scientific debate over the adverse health effect of occupational exposure to electric fields. Subsequent studies of similar symptoms in switchyard workers and linesmen showed negative results (Malboysson 1976, Roberge 1976, Stopps 1979, Knave 1979).

More recently, a number of epidemiologic studies have suggested possible carcinogenic effects (in particular childhood leukemia) of residential exposure to these fields (Wertheimer and Leeper 1979, Savitz 1987). Also, several analyses of occupation data from death certificates considered occupational exposure to ELFEMF and cancer (Milham 1982, Wright 1982, McDowall 1983, Pearce 1985, Pearce 1989). Savitz and Colle (1987) calculated a summary estimate of the relative risk of all leukemia in exposed occupations across ten occupational studies of 1.2 with 95 % CI 1.1 - 1.3. The relative risk for acute myeloid leukemia for electrical workers in five studies ranged from 1.1 to 2.9 with an average estimate 1.5 (95 % CI , 1.2 - 1.8) (Shore 1988). Milham (1985), Lin et al (1985) and Spears et al.(1988) showed also significantly increased risk among electrical workers for deaths from brain tumours.

Authors of review papers which have discussed association between ELFEMF exposure and cancer (Sheikh 1986, Savitz and Colle 1987, Aldrich 1987, Alhbom 1988, Coleman 1988,) agree that no firm conclusion can be drawn from the current data and more studies are needed.

1.2.2. Depression and ELFEMF; experimental studies and biological plausibility

A number of reports indicate that ELFEMF may affect the nervous system and neuroendocrine function in animals and humans.

Observed effects include alterations in EEG patterns (Lott 1973), and alterations in neuromuscular transmission (Jaffe 1980). Wilson et al (1981, 1983, 1986, 1988a), demonstrated that exposure of rats to electric fields reduces melatonin production by the pineal gland. Work by Welker (1983), Samm (1983) and others has also demonstrated the pineal gland's sensitivity to low strength magnetic fields. A recent experiment in 42 volunteers showed that the urinary excretion of melatonin metabolites changed in some individuals with use of electric blankets (Wilson 1990). Melatonin is known as a neuroendocrine transducer. Its' levels in the pineal gland and circulation are low in day time and rise during the hours of darkness normally reaching a peak around 2 am. It thus provides the body with hormonal information on external light and helps maintains a number of circadian rhythms. One consequence of ELFEMF exposure may thus be a "functional pinealectomy" that causes a disruption in circadian rhythms and leads to other physiologic and behaviorl alterations. Rogers (1988a, 1988b) found that exposure to ELF fields produces behavioral alteration in nonhuman primates. Coelho (1987) and Orr (1987) also reported behavioral changes in baboons following exposure to 60 Hz ELFEMF.

There is substantial evidence that disruptions in the normal circadian rhythm of pineal melatonin secretion are associated with depression. Such disruptions may be in the phase or amplitude of melatonin signal, or both.

Breck-Friis et al (1985) showed low melatonin level in clinically depressed patients. Wetteberg (1978), Lewy et al. (1982), Claustrat et al.(1984), and Nair et al. (1985) found that low melatonin (or its metabolites) in blood and urine are correlated with depressive illness. In addition to that, trycylic antidepressant drugs increase the melatonin in human beings (Thompson et al. 1985). Wehr et al. (1979) and Lewy et al. (1982) showed that some depressive symptoms may be relived by inducing phase alterations in the circadian rhythm.

Mechanisms for the possible effect of melatonin in the etiology of depression are not well understood. Melatonin is inhibitory of most other endocrine glands. The night peak of melatonin maintains the circadian rhythm in gonads, pituitary and hypothalamus for example. Loss of synchronization in these glands may lead to inappropriate release of synthesis of mood altering steroidal hormones or neurotransmitters.

Finally there is firm evidence that depressive illness is strongly related with suicide (Monk 1987).

1.2.3. Suicide, depression an ELFEMF ; epidemiologic studies

Reichmanis (1979) examined the association between the act of suicide with ELFEMF arising from 50 Hz over- head high voltage transmission lines (OH-HV lines) at the domicile of 598 suicide victims and controls in the Midlands, England. The addresses of cases and controls were plotted on planimetric maps together with OH-HV transmission lines. The total electric and magnetic fields attributable to OH-HV lines were computed from this information for each case and control. On this basis cases had significantly higher exposure than controls ($p < 0.05$).

Later, Perry (1981) conducted a study using the same 598 cases of suicide. New controls were selected randomly from voter registration lists of the area. Measurements of magnetic fields were made at suicide and control addresses, 0.5 m away from the front door. More suicide than control measurements were above the median (278 suicides 232 controls, $p < 0.01$) and, the mean value of measured EMF for the suicide addresses (0.087 uT) was significantly higher than that of the controls (0.071 uT) ($p < 0.05$). The authors argued that confounding by socio-economic factors was unlikely, since the distribution of type of residence was not significantly different in cases and controls ($p > 0.20$).

These two studies were criticised by Bonnell (1981) for not using orthodox epidemiological approaches and inadequate controlling for confounding.

Perry (1988) found, in residents of high rise apartments in Wolverhampton, England, significantly ($p = 0.03$) more people suffering from depressive illness than controls had been living close to electric cables and hence exposed to ELFEMF.

McDowell (1986) followed up 8000 persons in England who were living within 30 meters of electric transmission facilities in 1971. The subjects were traced to 1983 and death certificates were obtained from national records. They found an SMR of 75 (8 observed) (95% CI 32,147) for suicide (5) and "undetermined" deaths (3) combined. For those cases resident less than 15 meters from the lines, the SMR was 143 (2 observed) (95 % CI 16 , 516). This study thus provided no support for an association between ELFEMF and suicide but was limited by small sample size.

1.2.4. Acute versus chronic effects of ELFEMF exposure on depression and suicide

The relevant animal studies have been of relatively acute effects (i.e from several weeks to several months) of ELFEMF exposure. The epidemiologic studies have considered exposure immediately prior to suicide, but this presumably correlates to some extent to longer term exposure. Thus plausibility is perhaps strongest for the hypothesis that current or recent exposure effects suicide risk, but it is also possible that a chronic exposure may cause a irreversible chronic disruption in circadian rhythms and this preexisting condition may lead to chronic depression and the act of suicide.

1.2.5 Summary

Experimental studies have shown some evidence of an association between ELFEMF exposure and decreased pineal function and between decreased pineal function and depression. Some epidemiologic studies have suggested an association between residential exposure to ELFEMF and suicide, but weaknesses in measures of exposure and control for confounding preclude confident conclusions being drawn from these studies.

A number of epidemiologic studies have suggested the carcinogenic effects (in particular leukemia and brain cancer) of residential and occupational exposure to ELFEMF but the data are not yet conclusive. Apart from suicide and cancer, some evidence from animal studies exists for effects of ELFEMF on endocrine and physiological functions of organ systems, so that there is some plausibility for an association with deaths due to endocrine diseases.

2. THE JOINT EPIDEMIOLOGIC STUDY OF CANCER AND ELFEMF (JES)

A "nested" case-control study, with ELFEMF as the exposure of interest, is currently being carried out of incident cases of cancer of all sites among utility workers in Quebec, Ontario, and France(the JES). For the JES, a complete cohort of male utility workers has been identified, and (for 22,000 Quebec workers) will be traced to death, and cause of death will be ascertained (as one means of identifying cancer cases, and to allow simple selection of controls). A job exposure matrix (JEM) linking job titles to exposure to ELFEMF will also be assembled using personal dosimeters.

We propose to make use of the data collected in Quebec for the JES to study causes of death other than cancer, and in particular suicide. (Comparable data from Ontario and France are not available).

3. OBJECTIVES

3.1. Primary objective:

To investigate the mortality due to suicide in electric utility workers, and specifically in workers exposed to ELFEMF.

Main hypothesis:

Electrical utility workers who are exposed to ELFEMF are at greater risk of committing suicide than the general population, and than non exposed workers.

3.2. Secondary objective:

To investigate the other causes of mortality among electrical utility workers, again with specific focus on workers exposed to ELFEMF.

3.3. Specific objectives

1. To compute standardized mortality ratios (SMRs) for suicide in a cohort of electric utility workers, categorized by exposure to ELFEMF.
2. To compute SMRs for other causes of death in this cohort.
3. To investigate, from a sample of the cohort, the relationship between risk of suicide, any of other causes of death with raised SMRs, and more refined exposure indexes, after accounting for potential confounders.

3.4. Justification for studying these objectives

1. Suicide currently takes over 6000 lives in Canada. Because of the relatively young age of suicide victims, the remitting years of life lost are enormous, second only to heart disease among other causes of death (National Task force on Suicide in Canada, Health and Welfare Canada 1987). Knowledge on the etiology of suicide is a precondition for successful preventive measures.
2. Suspicions have been raised that ELFEMF may cause suicides. Certain utility workers have high exposure to ELFEMF (Deadman 1988). This group is thus convenient for studying the effect of such an exposure and would benefit assuming preventive measures were possible if an association was found. However, the implications of prevention of suicide, if effects are found, go beyond utility workers to all persons exposed environmentally, and in particular, domestically.
3. Although nearly all cancer cases included in this study will be included in the JES also, our use of an alternative (cohort) design will allow a partially independent verification of the results of that study; in particular by making external comparisons of mortality with the Quebec reference population.
4. Although no a priori hypotheses of association between ELFEMF and other causes of death are strongly suggested, the margia cost of investigating these is small. Examining them (if the results are negative) will allay fears that hitherto unsuspected risks exist, or (if the results are positive) identify associations which should be studied further.
5. The existence of the JES makes this study a very economical way addressing these questions.

4. METHODS

4.1. Design

The design selected to meet the objectives of this proposal is a historical cohort mortality study using a crude exposure classification (Phase I) followed by a case-cohort study with adjustment for confounding and more refined exposure measures (Phase II).

4.2. Study population

The study cohort will consist of all male electrical utility workers who were employed by Hydro Quebec any time in between January 1st 1970 and December 31st in 1988 and who worked at least one continuous year (22,000 workers). The existing computer file supplied by Hydro Quebec for the JES includes the following information on each cohort member: name, social insurance number, date of birth, date of entry to the company, date of departure (if left).

4.3. Phase I

4.3.1. Tracing

For the historical cohort mortality study, vital status up to 31. December 1988, and cause of death for the complete cohort will be available from the JES. The causes of death will be identified (also for the JES) through the death certificates obtained from the Registre de reference a l'etat civil du Ministere de la Justice du Quebec. This work will be completed by February 1990.

4.3.2. Work history ascertainment

In phase I, because of the large size of the study population, we will seek only a crude readily available work history, last job held before leaving, retirement, or 31 December 1988, whichever comes first. The job codes for last job held are held by Hydro Quebec on one central magnetic tape for the members of the cohort who were active in December 31,1988. A manual search will be necessary in order to obtain the last job codes for the workers who retired (4500 subjects), those who left for reasons other than retirement (2000), and those who died in service (650). This information is available both in the pension and personnel files on a copy of standard form of departure, "Cessation d'emploi". Pension files, which are centralized and therefore easy to access, will be used for those who have such files. For the rest, the personnel files will be used. The personnel files may be kept for several years in the regions where the employee held the last job, before they are transferred to the central archive. For this reason, the information must be obtained from the regions in the Province for members of the cohort were left employment recently.

The following table summarizes the sources which will be used to obtain last job held for workers who retired, left or died in service.

	Alive (31.12.1988)	Pension files
Retired	Died (Beneficiary alive)	Pension files
	Died (No beneficiary)	Personnel files
Left without pension		Personnel files
Died in service	Beneficiary alive	Pension files
	Without beneficiary	Personnel files

4.3.3 Exposure assessment

Sub-cohorts will be defined on the basis of last job held, classified by level of exposure as identified in the Job-exposure matrix being constructed for the JES. The precise nature of summary measures (arithmetic, geometric, or other mean, peak, % time above threshold etc.) will be decided following the conclusion of a study aimed at identifying the differences between these measures, currently being carried out at the School of Occupational Health.

4.3.4 Analysis

We will calculate observed and expected numbers (i.e SMRs) of suicides and other causes of death for the complete cohort, and for sub-cohorts defined by exposure as above. The expected number of deaths will be calculated from Quebec death rates (person years at risk analysis).

For analyses directed at evaluating a hypothesis of an acute effect, only years at risk during employment will be considered. For years at risk after leaving, the exposure could only be classified as being unknown or zero occupational exposure so that its inclusion would add little information and possibly introduce bias because of the known negative association between active employment and suicide risk.

As generally with analysis of cohorts exposed to chronically acting contaminants, we will include all person-years in analyses directed at evaluating a hypothesis of chronic effect, including those after leaving employment as a electric utility worker. For these analyses person-years will be divided by duration as well as level of exposure.

4.4. Phase II

4.4.1 General description

Following the computation of SMRs in phase I, a case-cohort study will be carried out for suicide and any other causes of deaths for which an excess risk is suggested in Phase I ($P<0.05$ for SMR in high exposure group or for trend). This will allow us to obtain more detailed information on exposure assessment from a small fraction of the complete cohort, and thus maximise study efficiency. This method is known to be valid, and is more efficient than case control within a cohort ("nested") design (Prentice 1987). Also the random sample of the entire cohort (sub-cohort) can be used to make external comparisons and can constitute a "control" group for studying several diseases simultaneously (Wacholder and Boivin 1986).
Cancers will not be included in phase II of this study.

4.4.2. Selection of cases

Cases will be identified by ICD code on the death certificates. As suicide cases, in addition to deaths coded as suicide (E950-E959), those coded as "injury undetermined whether accidently or purposely self inflicted" (E980-E989) will be considered. (see section 4.2 Validity of suicide mortality data for further discussion).

4.4.3. Selection of sub-cohort

A stratified random sample of the complete cohort will be selected to obtain a case to sub cohort ratio of 1:4 for cases of suicide. (70 cases are expected, thus the sub-cohort will include about 1.5 % (280) of the complete cohort). The strata will be defined by year of birth and age at entry, and the sub-cohort will be selected from strata proportionally to the numbers of cases in that stratum. This stratification will maximize efficiency (Wacholder and Boivin 1986). If other causes of death are included in phase II, the sub cohort will be selected proportionally to the largest number of deaths in each stratum, so as to preserve the 1:4 case-control ratio (see Annex 3 for example). If a very common cause of death is studied, the 1:4 ratio may be reduced.

4.4.4. Work history ascertainment
Complete occupational histories will be sought for the members of the sub-cohort and cases (suicide and other cause of death to be studied in phase II). This data (job title, region, and dates of starting and finishing in each job held while employed by the utility) will be recorded blindly with respect to case status. Only personnel files contain the complete occupational history of the employee. They will be sought either at the centralized archive or at the regions. Data on the active (31.December 1988) subjects, subjects who retired or died in service only a few years before the start of our data collection will be most likely found in the regions. Those who retired or left will be assumed to have had no subsequent occupational exposure to EMF. (This may dilute the effect but is unlikely introduce a bias).

4.4.5 Exposure assessment
Two summaries of exposure, current and cumulative exposures (estimated from the complete work histories), will be used to evaluate the hypotheses of acute and chronic effects separetly.
1. Current exposure assessment: For each day under observation, exposure for cases and the sub-cohort, will be taken as the summary measures of exposure assigned in the JEM to the job held at that time .
2. Cumulative exposure (CE) will be calculated for each year of observation, for all cases and sub-cohort as the summed products of the summary measures of exposure (from the JEM) and time (months) spent in each of the jobs held up to that year. This measure is analogous to cumulative exposure to airborne contaminants (eg. fibre per cc X years of asbestos).

4.4.6. Confounding variables
Control for confounding factors will be impossible for phase I due to the prohibitive cost of obtaining the information on additional factors for the entire cohort. In phase II, potential confounding factors will be measured and adjusted for where possible.

Major etiologic risk factors for suicide include **social factors** [a) familial - divorce, childlessness; b)job-related - unemployment; c) social disorganization - criminality; d) ethnicity - immigrant status]; and **medico-psychiatric factors**
[a) physical illness - cancer patients; b) mental disorders- schizophrenia; depression; c) drug and alcohol abuse; e) stress; f) biological correlates - neurochemical, biochemical factors)
The following information, covering some but not all of the factors, will be obtained and used to control confounding.
1. Marital status at the time of hire will be obtained from the personnel files.
Latest available marital status will be obtained:
i) if deceased (status at the time of death) from the death certificates,
ii) if active, from personnel files,
iii) if retired, from pension files,(if left no further data will be available)
2. Highest education completed at hire will be obtained from the personnel files
3. Mental disorders (ICD-9 290-298, 300-312). Information will be extracted from "sickness absence" records. Depression will be treated carefully in the analysis as it may be in the causal pathway between ELFEMF and suicide.
4. Cancer (ICD 140-239) incidence cases during the study period will be identified for the JES.
5. Alcohol consumption: Self report of number of bottles, amount in ounces per week from medical files
Information on confounding factors for causes of death other than suicide studied in Phase II will be abstracted if it exists in company personnel or medical files (see Annex 2 for description of available information).

4.4.7. Analysis
Relative risk regression analysis for case cohort studies (Prentice 1986) will be used to obtain relative risk estimates for the different exposure groups after accounting for confounding variables. Exposure indexes will also be used to divide the subjects in to groups and will be considered as numerical variables. Because the sub-cohort is a stratified random sample of the complete cohort, external comparisons will also be possible (Wacholder and Boivin 1986). Using this method, estimated "SMRs" will be obtained for exposure groups using the Quebec population as a reference group.

5. VALIDITY OF MEASURES
5.1 Validity of suicide mortality data
The literature on the validity of the suicide diagnosis focuses mainly on the sensitivity of suicide certification (Litman 1963, Warshauer and Monk 1978, McCarthy and Welsh 1975, O'Carrol 1989) estimated at 56% to 99%. The specificity of the certification was always higher than 95 %. In these studies the clinical judgment of two psychiatrists or death investigating team was used as a "gold standard".

ICD-9 categories E980-E989 are used for "injuries undetermined whether accidently or purposely inflicted". There is a considerable evidence that a high proportion are in fact suicides (Holding and Barrachlough 1975). We will maximize effective sample size by including in our main analysis these deaths. This may however cause misclassification. A second analysis, will thus be carried out including only deaths coded as suicide (E950-958).

It seems unlikely that the certification practices will vary according to exposure status. Thus only non-differential misclassification is probable. Such a misclassification will bias the effect towards the null value (Copeland et al. 1977) and it will thus be of greater concern if the study shows no association between exposure and outcome (Checkoway 1989), in which case more emphasis will be put on the analysis restricted to suicides coded as such.

5.2. Validity of exposure assessments

In phase I, we will use only the last job held to estimate exposure of the complete cohort. The workers may have been employed in different jobs in previous years. Use of last job may thus result in misclassification (under or over estimate of exposure), probably non-differential because last job may not reflect the true relevant exposure.

The extent of this misclassification will be assessed in a validity study using the cases and members of the sub-cohort from phase II. Among these current and cumulative exposure indexes computed based on full occupational histories (a gold standard) will be compared to the crude exposure classification by last job held, used in phase I.

5.3. Validity and completeness of information on potential confounders

Although there are more data available on potential confounders in this than most occupational cohort studies, information is lacking on several important risk factors for suicide (including social disorganization, stress and ethnicity) and imperfectly measured on others. However given that most exposed and unexposed utility jobs have a similar social status, the potential for these risk factors to confound comparisons between these is limited. If a positive association is found, the indirect evidence (for example, from other surveys) on the distribution of risk factors in exposed and unexposed jobs will be sought, and if necessary, permission to collect further data will be requested.

6. ADEQUACY OF SAMPLE SIZE AND POWER OF THE STUDY

6.1. Phase I

Based on information on the currently available deaths (839) in the cohort we expect 70 deaths from suicide. For the purpose of this discussion, we consider a dichotomous classification into "non-exposed" and "exposed above background". Deadman (1989) estimates that about 15 % of workers in this study will be "exposed". Thus in the absence of an excess risk, we expect about 11 deaths among "exposed" workers, enough to detect a risk of about 2.0.

More generally if alpha=0.05, (one sided), the detectible relative risks for proportions exposed (Po) from 0.05 to 0.25 and power 80 % are given in the table below (Armstrong 1987).

Po	.05	0.10	0.15	0.20	0.25
RR	2.77	2.16	1.91	1.73	1.68

6.2. Phase II

A similar table of detectable relative risks in a case cohort study can be approximated using the formula for an unmatched case-control study (Wacholder and Boivin 1986).

Po	.05	0.10	0.15	0.20	0.25
RR	3.43	2.63	2.34	2.19	2.10

7. ETHICAL CONSIDERATIONS

The data sources to be used for this study are the same as those being used for the JES, which could be considered the "parent" of this study. The necessary permission for conducting the JES have of course been obtained, and confirmation that the inclusion of this additional component is acceptable is being sought. In the historical cohort mortality study and case -cohort study, there are no procedures that would imply a risk to (or indeed contact with) the study population. Confidentiality of data will be carefully preserved according to the usual procedures for epidemiologic studies. The written documents, computer files and identifying information will be stored in locked cabinets and only authorized persons will have the access to the information. The results will be sent to the relevant committees of the company and work force before publication.

TIME-TABLE AND JUSTIFICATION OF BUDGET

Phase I

Time	Stage		Expenses ($)
Months 1-5	Data collection	(16 weeks of clerical work)	= 5580
	* Travel to the regions for data collection		= 1500
	Data entry	(4 weeks of clerical work)	= 1470
Months 6-7	** Analysis	3 weeks programmer	= 3207
		Supplies	= 200

Phase II

Time	Stage		Expenses ($)
Months 8-11	Data collection	(10 weeks of clerical work)	= 3675
	* Travel to the regions for data collection		= 1500
	Data entry	(2 weeks of clerical work)	= 735
Months 12-14	** Analysis	1 week programmer	= 1069
		Supplies	= 200
Months 15-18	Report	Supplies	= 150
	Presentation of the results at an international conference		= 700
TOTAL 18 months			TOTAL = 19,986

*** ie. Regions Matapedia, La Grande, Manicouagan, (with the most economical transportation available)**

**** please see attached memorandum for computing expenses**

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LIST OF ANNEXES

Annex 1

*** Table 1: Reported levels of ELF E and B field measurements**

Natural EMF fields	**Frequency**	**E field (V/m)**	**B field (uT)**
Earth's natural fields	50-60 Hz	10^{-6}	10^{-6}

Home appliances	**E field (V/m)**	**B field (uT)**	
(60 Hz)	**(30 cm away)**	**(30cm away)**	Electric
blanket	250		
Broiler	130		
Stereo	90		
Refrigerator	60	0.01-0.25	
Electric iron	50	0.12-0.30	
Hand mixer	50	0.60-0.10	
Toaster	40		
Hair dryer	40	0.01-7.00	
Colour TV	30	0.04-2.00	
Coffee maker	16	0.08-0.15	
Can opener		0.08-9.00	
Drills		2.50-3.00	
Industrial equipment			
Arc welder			
Induction motors		$8x10^3$	
Heating devices		$70x10^3$	
Medical diagnostic equipment			
Nuclear magnetic resonance (NMR)		$2x10^3$	

High voltage power lines	**E field (V/m)**			**B field (uT)**		
(60 Hz)	**Max ****	**30m**	**60 m**	**Max****	**30m**	**60m**
115 kV	1500	70	10	3.50	0.20	0.05
230 kV	3300	200	30	9.7	0.90	0.20
500 kV	7500	1000	30	17.6	2.50	0.60

Source: WHO 1984, Lovsund 1982, Tenforde and Kaune 1987,

Table 2: Geometric means of average weekly exposures of electric utility workers

	E field V/m	B field uT
Domestic	7-15	0.2-0.5
White collar work	4-7	0.1-0.2
Utility work	20-100	1.1-2.5

Source: Deadman 1988

* These fields levels are approximate. Actual field levels will depend on design and operating conditions

** Maximum on the ground level

Examen médical d'embauchage

Les buts poursuivis par cet examen sont :

1. Identifier les caractéristiques de santé nécessaires à l'exécution du travail postulé.
2. Évaluer les caractéristiques de santé du/de la candidat(e) en relation avec les tâches de l'emploi postulé afin de prévenir toute atteinte à sa santé, sa sécurité ou son intégrité physique.
3. Identifier toute atteinte à la santé pouvant être aggravée par le travail.
4. Constituer un dossier dans lequel seront consignées toutes les données subséquentes recueillies pendant la vie active de l'employé(e) dans l'entreprise.

nº d'assurance-maladie	lieu de travail		
nº d'assurance sociale	nom, prénom(s)	☐ homme ☐ femme	date de naissance a m j
adresse		code postal	nº de téléphone

titre de l'emploi postulé		☐ permanent ☐ temporaire	unité administrative
devra conduire véhicule d'H.-Q ☐ non ☐ oui	a déjà été au service d'Hydro-Québec ☐ non ☐ oui	du a m j / au a m j	endroit
préposé(e) à l'embauchage	titre	téléphone	a m j

963-1477 87-09

Antécédents familiaux

parents	vivant (âge)	décédé		autres maladies
		âge	causes *	
père				
mère				
frère(s)				
soeur(s)				

* 1 - cancer
2 - diabète
3 - maladies cardio-vasculaires
4 - hypertension artérielle
5 - surdité
6 - épilepsie
7 - glaucome
8 - tuberculose
9 - maladie psychiatrique
10 - accident
11 - autres

remarques

____

____

Antécédents personnels

1. antécédents professionnels

A - expositions antérieures

nº	période allant de a m	à a m	employeur	poste occupé	exposition à *
1					
2					
3					
4					
5					

* 1 - bruit
2 - poussière
3 - gaz
4 - chaleur
5 - froid
6 - produits chimiques
7 - radiations ionisantes
8 - effort physique - a) ☐ important b) ☐ faible c) ☐ aucun
9 - vibrations
10 - écrans cathodiques
11 - radiations non ionisantes (I.R., U.V., M.O.)

B - accidents du travail et maladies professionnelles

nº	dates a m j	employeur	limitations
1			
2			
3			

Antécédents personnels (suite)

2. antécédents médicaux personnels

maladies antérieures	remarques
☐ T.B.	
☐ rhumatisme articulaire aigu	
☐ angine, infarctus myocarde	
☐ hypertension artérielle	
☐ épilepsie	
☐ troubles mentaux (dépression, psychose, etc.)	
☐ allergie	
☐ asthme	
☐ maladie du sang	
☐ alcoolisme, dépendance médicamenteuse	
☐ bronchite	
☐ syphilis, gonorrhée, chlamydia, sida	
☐ maux de dos	
☐ ulcères d'estomac ou duodénum	
☐ glaucome	
☐ maladie de peau	
☐ autres	

3. accidents hors travail ou personnels

nº	dates a m j	employeur	limitations
1			
2			
3			
4			

4. chirurgies et hospitalisations

nº	dates a m j	nom de l'hôpital
1		
2		
3		
4		

5. radiographies antérieures

nº	dates a m j	examen
1		
2		
3		
4		

6. avez-vous consulté depuis cinq (5) ans ?

☐ un médecin
☐ un psychologue
☐ un psychiatre
☐ un chiropraticien

Habitudes de vie

1 - boisson alcoolisée consommation ☐ régulière ☐ occasionnelle bière ______ /jour ______ /sem. ______ /mois vin ______ /jour ______ /sem. ______ /mois spiritueux ______ /jour ______ /sem. ______ /mois	remarques
2 - tabac ☐ fumeur ☐ non fumeur ______ nbre d'années ______ nbre de cig./jour (moyenne)	
3 - boisson non alcoolisée café, thé, cola ______________ /jour	
4 - drogues actuellement, consommez-vous des drogues ? ☐ non ☐ oui lesquelles ☐ hashich ☐ marijuana ☐ cocaïne ☐ héroïne ☐ autres	
5 - médicaments nom du médicament / posologie 1 ______ / ______ 2 ______ / ______ 3 ______ / ______ 4 ______ / ______	
6 - activités sportives ☐ non ☐ oui ______ heures/sem. activités ______________	

À signer après avoir complété le questionnaire

Je, soussigné(e), certifie avoir bien compris les questions et avoir donné les réponses au meilleur de ma connaissance. Je consens à subir un examen médical et les analyses nécessaires. J'autorise le médecin examinateur à transmettre les résultats de l'examen au Centre de santé d'Hydro-Québec.

Ces renseignements sont strictement confidentiels.

signature du candidat	a	m	j	signature du témoin

Examen physique

(à l'usage du médecin)

kg	taille m	t.a.	pouls

	N	A		N	A		N	A
O.D.	☐	☐	oreille D.	☐	☐	nez	☐	☐
O.S.	☐	☐	oreille G.	☐	☐	gorge	☐	☐
FUNDI	☐	☐				dents	☐	☐

thyroïde
☐ masse ☐ souffle

carotides
☐ pouls ☐ souffle

jugulaires
☐ normales ☐ distendues

thorax et poumons
☐ normaux ☐ matité
☐ M.V. ☐ bruits anormaux

seins
☐ normaux ☐ nodules
☐ écoulement

adénopathies
☐ cervicales ☐ sus-claviculaires
☐ axillaires ☐ inguinales

coeur
rythme : ☐ régulier ☐ irrégulier - *décrire*
souffle : ☐ non ☐ oui - *localisation*
bruits : ☐ normaux ☐ anormaux
galop :

abdomen
☐ normal ☐ masses
☐ viscéromégalie ☐ hernie
☐ sensibilité ☐ cicatrices

hernies
☐ inguinale ☐ fémorale

vaisseaux	droit	gauche	souffle
pouls huméral			
pouls radial			
pouls fémoral			
pouls tibial poster.			
pouls pédieux			

examen neurologique	N	A
II - XII	☐	☐
Romberg	☐	☐
épreuves cérébelleuses	☐	☐
sensibilité profonde et superficielle	☐	☐
force musculaire	☐	☐

R.O.T.	N	A		N	A
bicipitaux - droit	☐	☐	- gauche	☐	☐
tricipitaux - droit	☐	☐	- gauche	☐	☐
rotuléens - droit	☐	☐	- gauche	☐	☐
achilléens - droit	☐	☐	- gauche	☐	☐

appareil locomoteur		N	A
membres supérieurs	- mouvements	☐	☐
	- difformités	☐	☐
membres inférieurs	- mouvements	☐	☐
	- difformités	☐	☐
colonne vertébrale	- mouvements	☐	☐
	- difformités	☐	☐

attitude
☐ normale ☐ anormale

(à l'usage du médecin)

numero d assurance sociale	nom de l'employé(e)

diagnostic principal

diagnostic associé

restrictions médicales suggérées

date de la permanence	a m j	remarques

nom du médecin	signature	n° de permis	a m j

adresse

(rev. 87-07)

Revue des systèmes

(à l'usage du médecin)

	remarques
1 - état général ☐ 1. asthénie ☐ 2. pâleur ☐ 3. irritabilité ☐ 4. somnolence	
2 - ophtalmologie ☐ 1. infection ☐ 2. acuité ☐ 3. diplopie ☐ 4. couleurs	
3 - O.R.L. ☐ 1. infection ☐ 2. surdité ☐ 3. bourdonnements ☐ 4. vertiges	
4 - seins	
5 - système endocrinien (thyroïde) ☐ 1. frilosité ☐ 2. perte poids ☐ 3. obésité	
6 - système respiratoire ☐ 1. toux ☐ 2. expectorations ☐ 3. dyspnée ☐ 4. douleurs thoraciques ☐ 5. hémoptysies	
7 - système cardio-vasculaire ☐ 1. D.R.S. ☐ 2. dyspnée paroxystique nocturne ☐ 3. orthopnée ☐ 4. claudication ☐ 5. oedème ☐ 6. varices ☐ 7. palpitations ☐ 8. dyspnée d'effort	
8 - système gastro-intestinal ☐ 1. appétit ☐ 2. poids ☐ 3. nausées ☐ 4. vomissements ☐ 5. ictère ☐ 6. selles ☐ 7. méléna ☐ 8. flatulence ☐ 9. rectorragie ☐ 10. hématémèse ☐ 11. hémorroïdes ☐ 12. diarrhée ☐ 13. constipation	

Revue des systèmes (suite)

	remarques
9 - système génito-urinaire	
☐ 1. G / P / A cycle	
☐ 2. dernier ex. gynécologique	
☐ 3. hématurie	
☐ 4. pollakiurie	
☐ 5. brûlements mictionnels	
☐ 6. incontinence	
☐ 7. impotence	
☐ 8. date des dernières menstruations	
☐ 9. dysménorrhée	
☐ 10. leucorrhée	
☐ 11. saignement dysfonctionnel	
10 - système locomoteur	
☐ 1. arthralgie	
☐ 2. gonflements	
☐ 3. raideur	
☐ 4. dorsalgie	
☐ 5. lombalgie	
☐ 6. cervicalgie	
11 - système neurologique	
☐ 1. céphalées	
☐ 2. perte de conscience	
☐ 3. engourdissements	
☐ 4. étourdissements	
☐ 5. paralysie, parésie	
☐ 6. troubles de la parole	
☐ 7. troubles à la démarche	
☐ 8. tremblements	
12 - troubles mentaux	
☐ 1. stress	
☐ 2. modification de l'humeur et du comportement	
☐ 3. difficulté de concentration et de jugement	
☐ 4. difficulté de relation interpersonnelle	
☐ 5. anxiété	
☐ 6. angoisse	
☐ 7. phobie	
☐ 8. obsession	
☐ 9. dépression	
☐ 10. inappétence, insomnie	
☐ 11. euphorie, exubérance	
☐ 12. hyperactivité	
☐ 13. hallucinations	
☐ 14. dépersonnalisation	
☐ 15. agressivité	

ANTECEDENTS pointez les réponses affirmatives

familiaux	cancer	tuberculose	diabète	maladies cardiaques	hypertension
	maladie mentale	épilepsie			
[illegible]nnels / maladies ou affections	polyomyélite	allergies	tuberculose	maladie de la peau	dépress. nerveuse
	maladie digestive	arthrite	épilepsie	diabète	mal. des poumons
	maladie des vaisseaux	maladie cardiaque	maladie des reins	maladie des yeux	mal. des oreilles
	maux de gorge	maladie du nez	fièvre typhoide	hépatite-(jaunisse)	scarlatine
	fièvre rhumatismale	maladies vénériennes	mononucléose		autres
consultations	médecin	psychiatre	psychologue	chiropraticien	autres
examens	électro-encéphalogramme		électrocardiogramme		radiographie
	analyses de laboratoire		épreuve de la thyroide		autres

autres renseignements

avez-vous déjà: été hospitalisé(e) — subi une intervention — été victime d'accident
été victime d'acc. du travail — souffert d'une incapacité — reçu des rentes ou indemnités
été exposé(e) aux rayons ionisants
avez-vous déjà fait usage de:
thé — café — alcool — tabac — drogue (mari, etc.)

ETAT DE SANTE ACTUEL

maladies ou affections

A) instabilité émotive — anxiété — dépression — agressivité — phobies (peurs)
tremblements — insomnie — fatigue — maux de tête — perte de conscience
convulsions

B) dyspnée (essoufflement): au repos — à l'effort — couché

accompagnée de: palpitations — oedème (enflure) — douleurs à la poitrine
crampes — frissons — engourdissement

C) toux — expectoration de sang — expectoration — transpiration

D) augmentation ou diminution: de l'appétit — de la soif — du poids

dyspepsie (mauvaise digestion) — gonflement(estomac) — brûlure d'estomac
douleurs abdominales — nausées — vomissements — vomissements de sang
diarrhée — constipation — sang dans les selles — selles noires

E) difficulté à uriner — douleur à la miction — sang dans les urines
urine: combien de fois le jour? — la nuit?

F) douleurs menstruelles — dernière menstruation (j m a) ______ — nombre de grossesse ______
irrégularités menstruelles — pertes — avortement — anovulant

G) éruptions — démangeaisons — douleurs articulaires

autres renseignements

Vous considérez-vous en bonne santé ? — oui — non
Etes-vous présentement: sous traitement — en repos — à la diète
Prenez-vous des médicaments ? — oui — non
Faites-vous usage de: thé — café — alcool — tabac — drogue (mari, etc.)

observations

____

____

____

[illegible] avoir lu et compris les questions et avoir donné des réponses exactes. Je consens à subir un examen médical et me soumettre aux analyses nécessaires. J'autorise le médecin examinateur à transmettre les résultats de l'examen à la DIRECTION de l'Hydro-Québec, 75 ouest, boul. Dorchester. (Ces renseignements sont strictement confidentiels.)

signature du candidat	j m a	signature du médecin

√

Hydro-Québec

Fiche d'examen médical périodiqu 141

nom	adresse à domicile	âge
genre d'occupation	lieu de travail	région
nom du médecin traitant	adresse	

apparence	taille	poids	température

analyses et exemens dont les résultats ont été portés au dossier

urine	Hb	MULTI-12	VDRL	Rx pulm.	ECG	O.R.	AUDIO	SPIRO

TETE	yeux	réflexes oculaires	
	nez	oreilles	
	bouche	dents	gorge
COU	thyroïde	ganglions	
THORAX	aspect	poumons	
	coeur (bruits):	rythme	T.A.:
ABDOMEN	aspect	masses anormales	
	foie	rate	
	anus	prostate	
	canaux inguinaux	organes génitaux	
MEMBRES	supérieurs	inférieurs	
REFLEXES	ostéo-tendineux	cutanés plantaires	
COLONNE VERTEBRALE	aspect	mouvements	
PEAU			

diagnostic provisoire

recommandations

limitations

signature du médecin ou de l'infirmière — j m a

963-3738 (6'73) M

oui non

1. Avez-vous à vous plaindre de votre état de santé actuel?

2. Avez-vous consulté un médecin pour un accident ou une maladie depuis deux (2) ans?

3. Fumez-vous? Combien de cigares: de cigarettes: de pipes: par jour?

4. Avez-vous remarqué un changement dans votre appétit (faim ou soif)? (dans l'affirmative, soulignez)

5. Votre poids a-t-il augmenté ou diminué de plus de 10 livres depuis un an?

6. Négligez-vous de manger des fruits ou des légumes tous les jours?

7. Mangez-vous beaucoup d'aliments gras?

8. Mangez-vous beaucoup de sucreries?

9. Buvez-vous des boissons alcooliques ? Combien d'onces d'alcool: de vin: de bouteilles de bière: par semaine ?

10. Faites-vous usage de médicaments, de drogues ?

11. Négligez-vous le sport ou les exercices physiques réguliers?

Souffrez-vous des maux suivants (soulignez s'il y a lieu):

12. Insomnie, fatigue anormale, dépression, anxiété?

13. Maux de tête, vertiges, étourdissements?

14. Evanouissements, faiblesse, tremblements?

15. Allergie?

16. Essoufflement, gonflement des chevilles, douleurs dans la poitrine?

17. Engourdissements ou crampes dans les mollets?

18. Toux, expectorations? (y a-t-il du sang?)

19. Brûlures d'estomac, vomissements? (y a-t-il du sang?)

20. Constipation, diarrhée, sang dans les selles, selles noires?

21. Douleurs dans les membres ou dans la colonne vertébrale?

22. Avez-vous remarqué un changement dans l'état de votre peau?

23. Avez-vous remarqué une diminution de votre acuité visuelle ou auditive dernièrement?

24. Avez-vous négligé de suivre les conseils reçus lors de votre dernier examen?

remarques:

signature de l'employé

j m a

Annex 3

Hypothetical tables for the selection of sub-cohort in Phase II

		# of cases		# of subjects
Stratum	Cause A	Cause B	Cause C	in sub-cohort
1	10	13	12	13 x 4 = 62
2	13	17	20	20 x 4 = 80
3	22	15	19	22 x 4 = 88
4	7	15	19	19 x 4 = 96
5	10	11	12	12 x 4 = 48
Total	62	71	82	344

Appendix 3

CORRESPONDENCE

Suicide among electric utility workers in England and Wales

Sir,—There is concern that exposure to electric and magnetic fields of the type associated with electrical power lines and equipment could give rise to health effects. Most of the epidemiological studies have focused on cancer,[1] but some have suggested an association with depression[2] and suicide.[3,4] Recent experimental studies support a plausible biological mechanism for these exposures causing depression through an effect on the pineal gland and hence melatonin concentrations.[5]

We examined mortality from suicide in men with occupations likely to have resulted in exposure to electric and magnetic fields, using the British occupational mortality data from two independent decennial supplements (1970–2 and 1979–83).[6,7] Occupational titles selected as potentially exposed were those used by McDowall[7,8] in his similar examination of risk of leukemia. In the same way as McDowall[8] we used proportional mortality ratios (PMRs) to summarise suicide risk to avoid the numerator/denominator bias in standardised mortality ratios (SMRs) for these occupational groups.

The 1970–2 data (table 1) showed no excess proportion of deaths due to suicide in all potentially exposed occupations combined, although PMRs were significantly raised in radio and radar mechanics, and in telegraph and radio operators. The 1979–83 data (table 2) showed suicide mortality in each exposed occupation similar to that expected. In 1979–83, telegraph and radio operators (occupation code 051·3) had a PMR of 74 (O = 5, 95% confidence interval (CI) 24–173), giving a PMR for the two supplements combined of 141 (O = 15, 95% CI 79–233).

In 1979–83 the group radio and radar mechanics was called radio and TV mechanics (occupation code 123·1) but with the same definition. It had a PMR of 144 (O = 23, 95% CI 91–216) giving a combined PMR of 148 (O = 42, 95% CI 107–196).

With the exception of excess suicide in radio and TV mechanics, who were not identified a priori as having particularly high exposure, the results are broadly negative. Imperfect information on outcome (suicide) or on exposure, however, may have diluted an excess risk if one existed. In particular, many workers in occupational groups selected as potentially exposed may not have had significant exposure. As more becomes known about exposure in these occupations, the extent of dilution will become clear. The linesmen and cable jointers group, including power and telephone linesmen, currently has the best documented exposure. Relative to background levels, occupational exposures were raised on average in power linesmen by a factor of about 10,[9] and in telephone linesmen by a factor of about three.[10] The 1970–72 PMR for this group was 68 (O = 5, 95% CI 22–159), and that for 1979–83 (occupation code 122·2) was 132 (O = 10, 95% CI 63–243) giving a low combined PMR of 101 (O = 15, 95% CI 57–167).

The PMRs are also subject to confounding bias in that exposed occupations may be more or less subject to other risk factors for suicide than employed persons generally, who serve as a comparison group. Age has been accounted for in analysis. We have also information on social class, most exposed occupations being in the skilled manual category (IIIM).[7] The PMR for category IIIM was 89 for the 1970–2 data and 86 for the 1979–83

Table 1 Suicide† mortality for men aged 15–64 in electrical occupations: England and Wales 1970–2

Occupations††	*Observed*	*Expected*	*PMR (95% CI)*
024: Radio and radar mechanics	19	12·4	153* (92–239)
025: Installers and repairmen (telephones)	16	28·1	57 (33–93)
026: Linesmen, cable jointers	5	7·3	68 (22–159)
027: Electricians	58	72·5	80 (61–102)
028: Electrical and electronic fitters	6	10·3	58 (21–126)
029: Assemblers (electrical equipment)	2	3·2	63 (8–226)
030: Electrical engineers (so described)	16	19·3	83 (47–135)
128: Telegraph radio operators	10	3·9	256** (123–471)
197: Electrical engineers (professional)	6	6·1	98 (36–213)
198: Electronic engineers (professional)	16	10·2	156 (89–253)
Total	154	173·0	89 (75–104)

*p < 0·05 one sided; **p < 0·01 one sided.
†Based on International Classification of Diseases (ICD) 8th revision E950–959.
††Office of population census and surveys, classification of occupations 1970, HMSO 1970.
Note: produced from microfiche tables 1 and 2.

Table 2 Suicide† mortality for men aged 20–64 in electrical occupations: England and Wales 1979–80 and 1982–3

Occupations††	*Observed*	*Expected*	*PMR (95% CI)*
027.1, 027.2, 121.3: Electrical and electronic engineers	70	76·9	92 (72–115)
120.2, 120.2, 121.1, 121.2: Electricians, fitters, plant operators	148	132·1	112 (95–131)
048.4, 048·4, 051·2, 051.3: Telephone and radio, telegraph operators	17	17·7	96 (56–154)
120.4, 120.5, 120.6, 120.7, 122.1, 122.2, 123.1, 123.2: Telephone fitters, linesmen, radio and TV mechanics	83	83·8	99 (79–121)
129.5, 129.6, 131.6, 131.7, 134.1, 135.6: Electronic wiremen, coil winders, assemblers	12	13·6	88 (45–154)
108.6, 110.3: Electroplaters	3	3·8	78 (16–228)
022.2: Sound, vision equipment operator	7	6·7	104 (42–214)
Total	341	334·3	102 (91–113)

*p < 0·05 one sided.
†Based on ICD 9th revision E950–959.
††Office of population census and surveys, classification of occupations 1980, HMSO 1980.
Note: produced from microfiche tables 45–52.

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} (21–126)
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ıs 1970, HMSO

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96 (56–154)
99 (79–121)
88 (45–154)
78 (16–228)
104 (42–214)
102 (91–113)

ns 1980, HMSO

data suggesting that adjusting for social class would increase risk estimates slightly.

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Mortality among workers potentially exposed to epichlorohydrin

Sir,—In a recent study, Enterline *et al* (1990;47:269–76) reported the mortality experience of workers at two Shell Oil Company chemical plants. These men had had potential exposure to epichlorohydrin (ECH). That work was supported by Shell, and the Company recognises that the investigation was thorough and well done. We do not share, however, the interpretation that ECH alone or in combination with allyl chloride is associated with deaths due to heart disease.

Our table reproduces the essential findings. The study group as a whole had a mortality from heart disease that is 32% below that of the general population. Furthermore, there is no consistent pattern of excess deaths. Among men with nil or light exposure, the SMR is significantly ($p = 0.03$) low even after 20 years or more of follow up. Among the men with moderate or heavy exposure, there is but a slight (less than one observed death in excess) and non-significant ($p = 0.89$) excess only 20 years or more after exposure was initiated. In other words, even for this group, there is no true excess of heart disease. Curiously, for all deaths, the average age at death for the moderate to heavy exposure group is 10 years older than that for the nil to low exposure group, and about five years older for deaths due to heart disease—the reverse of that expected for an exposure induced outcome. Important confounders such as smoking and dietary habits were not examined. It should also be pointed out that "follow up" in this study is not necessarily a good surrogate for extent of exposure. That is, the duration of exposure is not the same as the period of follow up.

In the Abstract, the authors state that "The relation of heart disease and exposure does not appear to be an artifact, although the fact that many other causes of death were also related to exposure argues against a casual relation." Finally, we point out that the suggestion that a possible interaction between ECH and allyl chloride is responsible for the "excess" of disease upon heart deaths is a speculation. Enterline *et al* point out that men who had worked in ECH production were more likely to have been exposed to allyl chloride than were other ECH workers. In fact, this study has made no effort to distinguish the effects (if any) of ECH alone from those of ECH in combination with allyl chloride. The authors state on page 276 of the article that "There is little in human or animal experience to suggest a relation between allyl chloride and cardiovascular disease." This statement, we believe, places their interpretation in a more correct perspective.

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Author's reply:
I would agree that the findings we reported with regard to heart disease among men with potential exposure to epichlorohydrin are curious. Ross points to the fact that the group of workers we studied had a mortality from heart disease 32% below that of the general population. Whereas this is true, the SMR for these workers was higher than the SMR for heart disease for the chemical plant as a whole.[1] Moreover, as we pointed out in our article, the SMR of 54·4 in the nil to light exposure group 20 years from first exposure was not much different than an SMR of 51·1 for the entire chemical plant. Thus it appeared to us that the SMR of 101·6 for the higher exposure group was the one that was unusual. This points to a problem in using rates for the general population to calculate expected deaths in an industrial cohort.

Ross also points out the age at death in the higher exposure group was roughly five years older than the age at death in the lower exposure group. We did not make this calculation; the difference, however, is probably because the workers in the higher exposure group were older than those

Standardised mortality ratio and observed number of deaths (in parentheses) for heart disease according to potential ECH exposure and time since start of exposure (data from Enterline et al)

ECH exposure	*Follow up period* < 20 years	≥ 20 years	*All*
Nil, light	56 (6)	39 (5)	47 (11)
Moderate, heavy	73 (7)	105 (17)	9[illegible] (24)
All	64 (13)	76 (22)	71 [illegible]