

# Overview of the epidemiologic studies on the health effects of ELF magnetic and electric fields published in the second trimester of 2014

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## 1. Reviews

### **CHILDHOOD LEUKEMIA NOT LINKED WITH ELF MAGNETIC FIELDS.**

Leitgeb N.

*Journal of Electromagnetic Analysis and Applications* 2014; 6(7):174-183.

The discussion whether extremely low frequency (ELF) magnetic fields (MF) are causally linked with childhood leukemia is ongoing for almost four decades. Results of epidemiologic studies have indicated such an association might exist and led to IARC's classification of ELF MF as possibly carcinogenic (class 2B). Although in the meanwhile many epidemiologic studies and meta-analyses of selected studies are available, this did not change the situation. By a new approach of pooling all epidemiologic data, this paper shows that it is possible to come to a convincing conclusion which explains controversial results and reports dose-response relationship, and provides answers to striking facts such as that epidemiologic results on childhood leukemia are independent from field source or exposure metric of whatever kind with no specific favorite.

Conclusions: The analysis revealed that the assumption of a causal link between ELF MF exposure and childhood leukemia is no longer plausible and hence that ELF MF's classification as possibly carcinogenic needs revision.

## 2. Residential exposure

### **MATERNAL RESIDENTIAL PROXIMITY TO SOURCES OF EXTREMELY LOW FREQUENCY ELECTROMAGNETIC FIELDS AND ADVERSE BIRTH OUTCOMES IN A UK COHORT.**

de Vocht F, Hannam K, Baker P, Agius R.

*Bioelectromagnetics*. 2014; 35(3):201-209.

Studies have suggested that exposure to extremely low frequency electromagnetic fields (ELF-EMF) may be associated with increased risk of adverse birth outcomes. This study tested the hypothesis that close proximity to residential ELF-EMF sources is associated with a reduction in birth weight and increased the risk of low birthweight (LBW), small for gestational age (SGA) and spontaneous preterm birth (SPTB). Closest residential proximity to high voltage cables, overhead power lines, substations or towers during pregnancy was calculated for 140356 singleton live births between 2004 and 2008 in Northwest England. Associations between proximity and risk for LBW, SGA and SPTB were calculated, as well as associations with birth weight directly. Associations were adjusted for maternal age, ethnicity, parity and for part of the population additionally for maternal smoking during pregnancy. Reduced average birth weight of 212 g (95% confidence interval (CI): -395 to -29 g) was found for close proximity to a source, and was largest for female births (-251 g (95% CI: -487 to -15 g)). No statistically significant increased risks for any clinical birth outcomes with residential proximity of 50 m or less were observed.

Conclusions: Living close (50 m or less) to a residential ELF-EMF source during pregnancy is associated with suboptimal growth in utero, with stronger effects in female than in males. However, only a few pregnant women live this close to high voltage cables, overhead power lines, substations or towers, likely limiting its public health impact.

**POTENTIAL ROLE OF SELECTION BIAS IN THE ASSOCIATION BETWEEN CHILDHOOD LEUKEMIA AND RESIDENTIAL MAGNETIC FIELDS EXPOSURE: A POPULATION-BASED ASSESSMENT.**

Slusky DA, Does M, Metayer C, Mezei G, Selvin S, Buffler PA.  
*Cancer Epidemiol.* 2014; 38(3):307-313.

Data from the Northern California Childhood Leukemia Study (NCCLS) were used to assess whether selection bias may explain the association between residential magnetic fields (assessed by wire codes) and childhood leukemia as previously observed in case-control studies. Wiring codes were calculated for participating cases (n=310) and non-participating cases (n=66) as well as for three control groups: first-choice participating, (n=174), first-choice non-participating (n=252) and replacement (non-first choice participating controls) (n=220).

Participating controls tended to be of higher socioeconomic status than non-participating controls, and lower socioeconomic status was related to higher wire-codes. The odds ratio (OR) for developing childhood leukemia associated with high wire-codes was 1.18 (95% CI: 0.85, 1.64) when all cases were compared to all first-choice controls (participating and non-participating). The OR for developing childhood leukemia in the high current category was 1.43 (95% CI: 0.91, 2.26) when participating cases were compared to first-choice participating controls, but no associations were observed when participating cases were compared to non-participating controls (OR=1.06, 95% CI: 0.71, 1.57) or to replacement controls (OR=1.06, 95% CI: 0.71, 1.60).

Conclusions: The observed risk estimates vary by type of control group, and no statistically significant association between wire codes and childhood leukemia is observed in the California population participating in the NCCLS.

### **3. Occupational exposure**

**MAGNETIC FIELDS AND LEUKAEMIA RISKS IN UK ELECTRICITY SUPPLY WORKERS.**

*Occup Med.* 2014; 64(3):150-156.  
Sorahan T.

The aims of this study were to investigate whether leukaemia risks are related to occupational exposure to low-frequency magnetic fields. Leukaemia risks experienced by 73 051 employees of the former Central Electricity Generating Board of England and Wales were investigated for the period 1973-2010. All employees were hired in the period 1952-82 and were employed for at least 6 months with some employment in the period 1973-82. Detailed calculations had been performed by others to enable an assessment to be made of exposures to magnetic fields. Poisson regression was used to calculate relative risks (rate ratios) of developing leukaemia or leukaemia subtypes for categories of lifetime, distant (lagged) and recent (lugged) exposure.

Findings for all leukaemias combined were unexceptional; risks were close to unity for all exposure categories and there was no suggestion of risks increasing with cumulative (or recent or distant) magnetic field exposures. There were no statistically significant dose-

response effects shown for acute myeloid leukaemia, chronic myeloid leukaemia or chronic lymphocytic leukaemia. There was a significant positive trend for acute lymphocytic leukaemia (ALL), but this was based, in the main, on unusually low risks in the lowest exposure category.

Conclusions: This study found no convincing evidence to support the hypothesis that exposure to magnetic fields is a risk factor for leukaemia, and the findings are consistent with the hypotheses that both distant and recent magnetic field exposures are not causally related to the generality of leukaemia. The limited positive findings for ALL may well be chance findings.

**NO EFFECTS OF POWER LINE FREQUENCY EXTREMELY LOW FREQUENCY ELECTROMAGNETIC FIELD EXPOSURE ON SELECTED NEUROBEHAVIOR TESTS OF WORKERS INSPECTING TRANSFORMERS AND DISTRIBUTION LINE STATIONS VERSUS CONTROLS.**

Li L, Xiong DF, Liu JW, Li ZX, Zeng GC, Li HL.  
*Australas Phys Eng Sci Med.* 2014; 37(1):37-44.

The authors aimed to evaluate the interference of 50 Hz extremely low frequency electromagnetic field (ELF-EMF) occupational exposure on the neurobehavior tests of workers performing tour-inspection close to transformers and distribution power lines. Occupational short-term "spot" measurements were carried out. 310 inspection workers and 300 logistics staff were selected as exposure and control. The neurobehavior tests were performed through computer-based neurobehavior evaluation system, including mental arithmetic, curve coincide, simple visual reaction time, visual retention, auditory digit span and pursuit aiming. In 500 kV areas electric field intensity at 71.98% of total measured 590 spots were above 5 kV/m (national occupational standard), while in 220 kV areas electric field intensity at 15.69% of total 701 spots were above 5 kV/m. Magnetic field flux density at all the spots was below 1,000  $\mu$ T (ICNIRP occupational standard). The neurobehavior score changes showed no statistical significance. Results of neurobehavior tests among different age, seniority groups showed no significant changes.

Conclusions: Neurobehavior changes caused by daily repeated ELF-EMF exposure were not observed in the current study.

**SEVERE COGNITIVE DYSFUNCTION AND OCCUPATIONAL EXTREMELY LOW FREQUENCY MAGNETIC FIELD EXPOSURE AMONG ELDERLY MEXICAN AMERICANS.**

Davanipour Z, Tseng CC, Lee PJ, Markides KS, Sobel E.  
*Br J Med Med Res.* 2014; 4(8):1641-1662.

This report is the first study of the possible relationship between extremely low frequency (50-60 Hz, ELF) magnetic field (MF) exposure and severe cognitive dysfunction. Earlier studies investigated the relationships between MF occupational exposure and Alzheimer's disease (AD) or dementia. These studies had mixed results, depending upon whether the diagnosis of AD or dementia was performed by experts and upon the methodology used to classify MF exposure.

A population-based case-control study design was carried out by Neurology and Preventive Medicine, Keck School of Medicine, University of Southern California during 2 years. The study population consisted of 3050 Mexican Americans, aged 65+, enrolled in Phase 1 of the Hispanic Established Population for the Epidemiologic Study of the Elderly (H-EPESE) study. Mini-Mental State Exam (MMSE) results, primary occupational history, and other data were collected. Severe cognitive dysfunction was defined as an

MMSE score below 10. The MF exposure methodology developed and used in earlier studies was used.

Univariate odds ratios (OR) were 3.4 ( $P < .03$ ; 95% CI: 1.3-8.9) for high and 1.7 ( $P = .27$ ; 95% CI: 0.7-4.1) for medium or high (M/H) MF occupations. In multivariate main effects models, the results were similar. When interaction terms were allowed in the models, the interactions between M/H or high occupational MF exposure and smoking history or age group were statistically significant, depending upon whether two (65-74, 75+) or three (65-74, 75-84, 85+) age groups were considered, respectively. When the analyses were limited to subjects aged 75+, the interactions between M/H or high MF occupations and a positive smoking history were statistically significant.

Conclusions: The results of this study indicate that working in an occupation with high or M/H MF exposure may increase the risk of severe cognitive dysfunction. Smoking and older age may increase the deleterious effect of MF exposure.

**SLEEP QUALITY AND GENERAL HEALTH STATUS OF EMPLOYEES EXPOSED TO EXTREMELY LOW FREQUENCY MAGNETIC FIELDS IN A PETROCHEMICAL COMPLEX.**

Monazzam MR, Hosseini M, Matin LF, Aghaei HA, Khosroabadi H, Hesami A.

*J Environ Health Sci Eng. 201 ; 12:78.*

Advances in science and technology of electrical equipment, despite increasing human welfare in everyday life, have increased the number of people exposed to Electro-Magnetic Fields (EMFs). Because of possible adverse effects on the health of exposed individuals, the EMFs have been the center of attention. This study was performed to determine possible correlation between Extremely Low Frequency Electro-Magnetic Fields (ELF EMFs) and sleep quality and public health of those working in substation units of a petrochemical complex in southern Iran.

To begin with, magnetic flux density was measured at different parts of a Control Building and two substations in accordance with IEEE std 644-1994. Subsequently, the questionnaires "Pittsburgh Sleep Quality Index" (PSQI) and "General Health Quality (GHQ)" were used to investigate relationship between ELF exposure level and sleep quality and public health, respectively. Both questionnaires were placed at disposal of a total number of 40 workers at the complex. The filled out questionnaires were analyzed by T-test, Duncan and the Chi-square tests.

The obtained results revealed that 28% of those in case group suffered from poor health status and 61% were diagnosed with a sleep disorder. However, all members in control group were in good health condition and only 4.5% of them had undesirable sleep quality.

Conclusion: In spite of a significant difference between the case and control groups in terms of sleep quality and general health, no significant relationship was found between the exposure level and sleep quality and general health. It is worth noting that the measured EMF values were lower than the standard limits recommended by American Conference of Industrial Hygienists (ACGIH).

#### 4. Exposure assessment

##### **THE REVISED ELECTROMAGNETIC FIELDS DIRECTIVE AND WORKER EXPOSURE IN ENVIRONMENTS WITH HIGH MAGNETIC FLUX DENSITIES.**

Stam R.

*Ann Occup Hyg.* 2014; 58(5):529-541.

Some of the strongest electromagnetic fields (EMF) are found in the workplace. A European Directive sets limits to workers' exposure to EMF. This review summarizes its origin and contents and compares magnetic field exposure levels in high-risk workplaces with the limits set in the revised Directive. Pubmed, Scopus, grey literature databases, and websites of organizations involved in occupational exposure measurements were searched. The focus was on EMF with frequencies up to 10 MHz, which can cause stimulation of the nervous system. Selected studies had to provide individual maximum exposure levels at the workplace, either in terms of the external magnetic field strength or flux density or as induced electric field strength or current density. Indicative action levels and the corresponding exposure limit values for magnetic fields in the revised European Directive will be higher than those in the previous version. Nevertheless, magnetic flux densities in excess of the action levels for peripheral nerve stimulation are reported for workers involved in welding, induction heating, transcranial magnetic stimulation, and magnetic resonance imaging (MRI). The corresponding health effects exposure limit values for the electric fields in the worker's body can be exceeded for welding and MRI, but calculations for induction heating and transcranial magnetic stimulation are lacking.

Conclusions: Since the revised European Directive conditionally exempts MRI-related activities from the exposure limits, measures to reduce exposure may be necessary for welding, induction heating, and transcranial nerve stimulation. Since such measures can be complicated, there is a clear need for exposure databases for different workplace scenarios with significant EMF exposure and guidance on good practices.

##### **INDUCED ELECTRIC FIELDS IN WORKERS NEAR LOW-FREQUENCY INDUCTION HEATING MACHINES.**

Kos B1, Valič B, Kotnik T, Gajšek P.

*Bioelectromagnetics.* 2014; 35(3):222-226.

Published data on occupational exposure to induction heating equipment are scarce, particularly in terms of induced quantities in the human body. This article provides some additional information by investigating exposure to two such machines—an induction furnace and an induction hardening machine. Additionally, a spatial averaging algorithm for measured fields we developed in a previous publication is tested on new data. The human model was positioned at distances where measured values of magnetic flux density were above the reference levels.

Conclusions: All human exposure was below the basic restriction. The lower bound of the 0.1 top percentile induced electric field in the body of a worker was 0.193 V/m at 30 cm from the induction furnace.

**OCCUPATIONAL EXPOSURE TO INTERMEDIATE FREQUENCY AND EXTREMELY LOW FREQUENCY MAGNETIC FIELDS AMONG PERSONNEL WORKING NEAR ELECTRONIC ARTICLE SURVEILLANCE SYSTEMS.**

Roivainen P1, Eskelinen T, Jokela K, Juutilainen J.

*Bioelectromagnetics. 2014; 35(4):245-250.*

Cashiers are potentially exposed to intermediate frequency (IF) magnetic fields at their workplaces because of the electronic article surveillance (EAS) systems used in stores to protect merchandise against theft. This study aimed at investigating occupational exposure of cashiers to IF magnetic fields in Finnish stores. Exposure to extremely low frequency (ELF) magnetic fields was also evaluated because cashiers work near various devices operating with 50 Hz electric power. The peak magnetic flux density was measured for IF magnetic fields, and was found to vary from 0.2 to 4  $\mu\text{T}$  at the cashier's seat. ELF magnetic fields from 0.03 to 4.5  $\mu\text{T}$  were found at the cashier's seat. These values are much lower than exposure limits. However, according to the International Commission on Non-Ionizing Radiation Protection (ICNIRP) occupational reference levels for IF magnetic fields (141  $\mu\text{T}$  for the peak field) were exceeded in some cases (maximum 189  $\mu\text{T}$ ) for short periods of time when cashiers walked through the EAS gates. As the ICNIRP reference levels do not define any minimum time for exposure, additional investigations are recommended to determine compliance with basic restrictions. Even if the basic restrictions are not exceeded, persons working near EAS devices represent an exceptional group of workers with respect to exposure to electromagnetic fields. This group could serve as a basis for epidemiological studies addressing possible health effects of IF magnetic fields. Compliance with the reference levels for IF fields was evaluated using both broadband measurement of peak fields and the ICNIRP summation rule for multiple frequencies. The latter was generally more conservative, and the difference between the two methods was large (>10-fold) for EAS systems using a 58 kHz signal with complex waveform. This indicates that the ICNIRP multiple frequency rule can be unnecessarily conservative when measuring complex waveforms.

## **5. Leukaemia studie**

**RESIDENTIAL TRAFFIC EXPOSURE AND CHILDHOOD LEUKEMIA: A SYSTEMATIC REVIEW AND META-ANALYSIS.**

Boothe VL, Boehmer TK, Wendel AM, Yip FY.

*Am J Prev Med. 2014; 46(4):413-22.*

Exposure to elevated concentrations of traffic-related air pollutants in the near-road environment is associated with numerous adverse human health effects, including childhood cancer, which has been increasing since 1975. Results of individual epidemiologic studies have been inconsistent. Therefore, a meta-analysis was performed to examine the association between residential traffic exposure and childhood cancer.

Studies published between January 1980 and July 2011 were retrieved from a systematic search of 18 bibliographic databases. Nine studies meeting the inclusion criteria were identified. Weighted summary ORs were calculated using a random effects model for outcomes with four or more studies. Subgroup and sensitivity analyses were performed.

Childhood leukemia was positively associated (summary OR=1.53, 95% CI=1.12, 2.10) with residential traffic exposure among seven studies using a postnatal exposure window

(e.g., childhood period or diagnosis address) and there was no association (summary OR=0.92, 95% CI=0.78, 1.09) among four studies using a prenatal exposure window (e.g., pregnancy period or birth address). There were too few studies to analyze other childhood cancer outcomes.

Conclusions: Current evidence suggests that childhood leukemia is associated with residential traffic exposure during the postnatal period, but not during the prenatal period. Additional well-designed epidemiologic studies that use complete residential history to estimate traffic exposure, examine leukemia subtypes, and control for potential confounding factors are needed to confirm these findings.

#### **MODE OF DELIVERY AND RISK OF CHILDHOOD LEUKEMIA.**

Francis SS, Selvin S, Metayer C, Wallace AD, Crouse V, Moore TB, Wiemels JL, Buffler PA.

*Cancer Epidemiol Biomarkers Prev.* 2014; 23(5):876-881.

Childhood infection and immune response have long been suspected in the etiology of childhood leukemia, specifically acute lymphoblastic leukemia (ALL). Normal primary inoculation of the core human microbiome is circumvented by cesarean section (CS) delivery, which is a proposed modulator of both immune response and early-life infection.

In this study the authors examined CS delivery and the risk of childhood leukemia using data from the California Childhood Leukemia Study (CCLS) case-control study and additive logistic regression models. They observed no association between CS and acute myelogenous leukemia [OR, 0.96; 95% confidence interval (CI), 0.52-1.55]. They observed a suggestive association for ALL and CS (OR, 1.22; 95% CI, 0.97-1.54). When examining common ALL (cALL), defined as ALL with expression of CD10 and CD19 surface antigens and diagnosis occurring between 2 and 5.9 years of age, they found a significant association with CS (OR, 1.44; 95% CI, 1.0-2.06). ALL subjects that are not cALL showed a similar risk as ALL overall (OR, 1.15; 95% CI, 0.91-1.44). Because of previous findings suggesting effect modification, the authors stratified cALL subjects by Hispanic status. Although they observed no relationship for CS in non-Hispanics (OR, 1.14; 95% CI, 0.72-1.79), they did observe a strong association between cALL and CS in Hispanics (OR, 2.34; 95% CI, 1.23-4.46).

Conclusion: Within the CCLS, CS delivery seems to be associated with cALL and Hispanic subjects may be driving the association.

#### **EXPOSURE TO INFECTIONS AND RISK OF LEUKEMIA IN YOUNG CHILDREN.**

Marcotte EL, Ritz B, Cockburn M, Yu F, Heck JE.

*Cancer Epidemiol Biomarkers Prev.* 2014; 23(7):1195-1203.

Epidemiologic studies indicate that infections in early childhood may protect against pediatric acute lymphoblastic leukemia (ALL). The authors identified 3,402 ALL cases among children 0 to 5 years of age using the California Cancer Registry. From California birth records they randomly selected controls in a 20:1 ratio and frequency matched them to cases by birth year. They investigated markers of exposure to infections, including month of birth, timing of birth in relation to influenza and respiratory syncytial virus (RSV) seasons, and birth order based on data from California birth certificates and national infection surveillance systems.

An increased risk of ALL for spring and summer births was observed, and for those first exposed to an influenza or RSV season at nine to twelve months of age compared with

those exposed during the first three months of life, and this association was stronger among first born children [odds ratios (OR), 1.44 and 95% confidence intervals (CI), 1.13-1.82, for influenza exposure at nine to twelve months of age]. Decreased risk was observed with increasing birth order among non-Hispanic whites but not Hispanics (OR, 0.76 and 95% CI, 0.59-0.96, for fourth or higher birth order among whites).

Conclusion: These results support the hypothesis that infections in early childhood decrease risk of ALL.

**TOBACCO SMOKE AND RISK OF CHILDHOOD ACUTE LYMPHOBLASTIC LEUKEMIA: FINDINGS FROM THE SETIL CASE-CONTROL STUDY.**

Farioli A, Legittimo P, Mattioli S, Miligi L, Benvenuti A, Ranucci A, Salvan A, Rondelli R, Conter V, Magnani C.

*Cancer Causes Control. 2014; 25(6):683-692.*

Tobacco smoke could cause childhood acute lymphoblastic leukemia (ALL) through at least three pathways: (1) prenatal parental smoking; (2) fetal exposure through maternal smoking during pregnancy; and (3) childhood exposure to secondhand smoke (SHS). The authors tested these hypotheses in a large population-based case-control study (SETIL) primarily designed to evaluate the role of electromagnetic fields in childhood hematopoietic malignancies. From 1998 to 2003, 602 incident cases of ALL from 14 Italian Regions were enrolled, and 918 controls were individually matched by birthdate, sex, and area of residence. Cases (n = 557) and controls (n = 855) with complete information were analyzed; odds ratios (OR) and 95 % confidence intervals (95 % CI) were estimated with logistic regression models conditioned on matching variables and adjusted by birth order, birthweight, duration of breastfeeding, parental age at delivery, education, and occupational exposure to benzene.

No evidence associating paternal smoking in the conception period or maternal smoking during the pregnancy with ALL was found. An association of ALL with maternal exposure to SHS during pregnancy (adjusted OR for mothers exposed more than 4 h/day = 2.18, 95 % CI 1.39-3.42) was observed, but recall bias cannot be excluded. Exposure of the children to SHS was associated with ALL only in unadjusted analysis (unadjusted OR for highly exposed children = 1.64; 95 % CI 1.10-2.45).

Conclusions: This study does not support the hypothesis that parental active smoking is associated with ALL. There was very weak evidence of increased risk of ALL for children exposed to SHS. Maternal exposure to SHS was associated with ALL, but recall bias is likely to inflate our estimates.

**QUANTITATIVE ASSESSMENTS OF INDOOR AIR POLLUTION AND THE RISK OF CHILDHOOD ACUTE LEUKEMIA IN SHANGHAI.**

Gao Y, Zhang Y, Kamijima M, Sakai K, Khalequzzaman M, Nakajima T, Shi R, Wang X, Chen D, Ji X, Han K, Tian Y.

*Environ Pollut. 2014; 187:81-89.*

The authors investigated the association between indoor air pollutants and childhood acute leukemia (AL). A total of 105 newly diagnosed cases and 105 1:1 gender-, age-, and hospital-matched controls were included. Measurements of indoor pollutants (including nitrogen dioxide (NO<sub>2</sub>) and 17 types of volatile organic compounds (VOCs)) were taken with diffusive samplers for 64 pairs of cases and controls. Higher concentrations of NO<sub>2</sub> and almost half of VOCs were observed in the cases than in the

controls and were associated with the increased risk of childhood AL. The use of synthetic materials for wall decoration and furniture in bedroom was related to the risk of childhood AL. Renovating the house in the last 5 years, changing furniture in the last 5 years, closing the doors and windows overnight in the winter and/or summer, paternal smoking history and outdoor pollutants affected VOC concentrations.

Conclusions: These results support the association between childhood AL and indoor air pollution.