

# Overview of the epidemiologic studies on the health effects of ELF magnetic and electric fields published in the fourth trimester of 2011

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## 1. Reviews

### **EXPOSURE TO EXTREMELY LOW-FREQUENCY MAGNETIC FIELDS AND THE RISK OF CHILDHOOD CANCER: UPDATE OF THE EPIDEMIOLOGICAL EVIDENCE.**

Schüz J.

*Prog Biophys Mol Biol.* 2011; 107: 339-342..

There is an ongoing scientific controversy whether the observed association between exposure to residential extremely low-frequency magnetic fields (ELF-MF) and the risk of childhood leukaemia observed in epidemiological studies is causal or due to methodological shortcomings of those studies. Recent pooled analysis confirm results from previous studies, namely an approximately two-fold risk increase at ELF-MF exposures  $\geq 0.4 \mu\text{T}$ , and demonstrate consistency of studies across countries, with different design, different methods of exposure assessment, and different systems of power transmission and distribution. On the other hand, recent pooled analyses for childhood brain tumour show little evidence for an association with ELF-MF, also at exposures  $\geq 0.4 \mu\text{T}$ .

Conclusion: Overall, the assessment that ELF-MF are a possible carcinogen and may cause childhood leukaemia remains valid. Ongoing research activities, mainly experimental and few new epidemiological studies, hopefully provide additional insight to bring clarity to a research area that has remained inconclusive.

### **EXPLORING EXPOSURE--RESPONSE FOR MAGNETIC FIELDS AND CHILDHOOD LEUKEMIA.**

Kheifets L, Afifi A, Monroe J, Swanson J.

*J Expo Sci Environ Epidemiol.* 2011; 21: 625-633..

For 30 years, there have been suggestions that extremely low frequency magnetic fields such as those are produced by electric power systems may be associated with elevated risks of childhood leukemia. These suggestions are driven by epidemiological evidence, and it has been common to characterize that evidence as showing a threshold effect, with no increase in risk below a threshold, often 0.3 or 0.4  $\mu\text{T}$ , and a constant risk above it. Such a threshold would, however, be biologically unlikely. The authors tested alternative dose-response relationships quantitatively. They obtained five exposure data sets, applied several candidate dose-response relationships to each one, and performed a regression analysis to see how well they fit each of the three epidemiological data sets. Threshold dose-response relationships performed only moderately. Linear relationships were generally even poorer. The fit was improved by adding quadratic terms or performing non-linear regression. There are limitations in this analysis, stemming from the available data, but addressing this issue in a data-based, quantitative manner should improve understanding, allow better calculations to be made of attributable numbers, and hence ultimately inform public policy making.

## **2. Residential exposure**

### **EXPOSURE TO MAGNETIC FIELDS AND CHILDHOOD ACUTE LYMPHOCYTIC LEUKEMIA IN SÃO PAULO, BRAZIL.**

Wünsch-Filho V, Pelissari DM, Barbieri FE, Sant'Anna L, de Oliveira CT, de Mata JF, Tone LG, Lee ML, de Andréa ML, Bruniera P, Epelman S, Filho VO, Kheifets L.

*Cancer Epidemiol. 2011; 35: 534-539.*

Epidemiological studies have identified increased risks of leukemia in children living near power lines and exposed to relatively high levels of magnetic fields. Results have been remarkably consistent, but there is still no explanation for this increase. In this study we evaluated the effect of 60 Hz magnetic fields on acute lymphocytic leukemia (ALL) in the State of São Paulo, Brazil.

This case-control study included ALL cases (n=162) recruited from eight hospitals between January 2003 and February 2009. Controls (n=565) matched on gender, age, and city of birth were selected from the São Paulo Birth Registry. Exposure to extremely low frequency magnetic fields (ELF MF) was based on measurements inside home and distance to power lines.

For 24h measurements in children rooms, levels of ELF MF equal to or greater than 0.3microtesla ( $\mu$ T), compared to children exposed to levels below 0.1  $\mu$ T showed no increased risk of ALL (odds ratio [OR] 1.09; 95% confidence interval [95% CI] 0.33-3.61). When only nighttime measurements were considered, a risk (OR 1.52; 95% CI 0.46-5.01) was observed. Children living within 200 m of power lines presented an increased risk of ALL (OR 1.67; 95% CI 0.49-5.75), compared to children living at 600 m or more of power lines. For those living within 50 m of power lines the OR was 3.57 (95% CI 0.41-31.44).

Conclusions: Even though the results are consistent with the small risks reported in other studies on ELF MF and leukemia in children, overall these results do not provide support for an association between magnetic fields and childhood leukemia, but small numbers and likely biases weaken the strength of this conclusion.

### **MATERNAL EXPOSURE TO MAGNETIC FIELDS DURING PREGNANCY IN RELATION TO THE RISK OF ASTHMA IN OFFSPRING.**

Li DK, Chen H, Odouli R.

*Arch Pediatr Adolesc Med. 2011; 165: 945-950.*

The objective of this study is to determine whether maternal exposure to high levels of magnetic fields (MFs) during pregnancy is associated with the risk of asthma in offspring.

The participants were Pregnant Kaiser Permanente Northern California members in the San Francisco area.

Asthma was clinically diagnosed among 626 children who were followed up for as long as 13 years. All participants carried a meter to measure their MF levels during pregnancy.

After adjustment for potential confounders, a statistically significant linear dose-response relationship was observed between increasing maternal median daily MF exposure level in pregnancy and an increased risk of asthma in offspring: every 1-mG increase of maternal MF level during pregnancy was associated with a 15% increased rate of asthma in offspring (adjusted hazard ratio [aHR], 1.15; 95% confidence interval [CI], 1.04-1.27). Using the categorical MF level, the results showed a similar dose-response relationship: compared with the children whose

mothers had a low MF level (median 24-hour MF level,  $\leq 0.3$  mG) during pregnancy, children whose mothers had a high MF level ( $> 2.0$  mG) had more than a 3.5-fold increased rate of asthma (aHR, 3.52; 95% CI, 1.68-7.35), while children whose mothers had a medium MF level ( $> 0.3$ - $2.0$  mG) had a 74% increased rate of asthma (aHR, 1.74; 95% CI, 0.93-3.25). A statistically significant synergistic interaction was observed between the MF effect and a maternal history of asthma and birth order (firstborn).

Conclusion: These findings provide new epidemiological evidence that high maternal MF levels in pregnancy may increase the risk of asthma in offspring.

### **3. Occupational exposure**

#### **EVALUATION OF OCCUPATIONAL EXPOSURE TO MAGNETIC FIELDS AND MOTOR NEURON DISEASE MORTALITY IN A POPULATION-BASED COHORT.**

Parlett LE, Bowman JD, van Wijngaarden E.

*J Occup Environ Med.* 2011; 53 :1447-1451.

Epidemiologic evidence for the association between electromagnetic fields and amyotrophic lateral sclerosis, the most common form of motor neuron disease (MND), has been inconclusive. The authors evaluated the association between electromagnetic fields and MND among workers in occupations potentially exposed to magnetic fields

MND mortality (ICD-9 335.2) was examined in the National Longitudinal Mortality Study using multivariable proportional hazards models. Occupational exposure to magnetic fields was determined on the basis of a population-based job-exposure matrix. Age at entry, education, race, sex, and income were considered for inclusion as covariates

After adjusting for age, sex, and education, there were no increased risks of MND mortality in relation to potential magnetic field exposure, with hazard ratios around the null in all magnetic field exposure quartiles

Conclusions: This study does not provide evidence for an association between magnetic field exposure and MND mortality.

#### **GENOTOXIC HAZARD EVALUATION IN WELDERS OCCUPATIONALLY EXPOSED TO EXTREMELY LOW-FREQUENCY MAGNETIC FIELDS (ELF-MF).**

Dominici L, Villarini M, Fatigoni C, Monarca S, Moretti M.

*Int J Hyg Environ Health.* 2011; 215: 68-75.

Electric arc welding is known to involve considerable exposure to extremely low-frequency magnetic fields (ELF-MF). A cytogenetic monitoring study was carried out in a group of welders to investigate the genotoxic risk of occupational exposure to ELF-MF. This study assessed individual occupational exposure to ELF-MF using a personal magnetic-field dosimeter, and the cytogenetic effects were examined by comparing micronuclei (MN) and sister chromatid exchange (SCE) frequencies in the lymphocytes of the exposed workers with those of non-exposed control subjects (blood donors) matched for age and smoking habit. Cytogenetic analyses were carried out on 21 workers enrolled from two different welding companies in Central Italy and compared to 21 controls. Some differences between the groups were observed on analysis of SCE and MN, whereas replication indices in the exposed were found not to differ from the controls. In particular, the exposed group showed a significantly higher frequency of MN (group mean $\pm$ SEM:  $6.10\pm 0.39$ ) compared to

the control group ( $4.45 \pm 0.30$ ). Moreover, the increase in MN is associated with a proportional increase in ELF-MF exposure levels with a dose-response relationship.

Conclusion: A significant decrease in SCE frequency was observed in exposed subjects ( $3.73 \pm 0.21$ ) compared to controls ( $4.89 \pm 0.12$ ). The hypothesis of a correlation between genotoxic assays and ELF-MF exposure value was partially supported, especially as regards MN assay. Since these results are derived from a small-scale pilot study, a larger scale study should be undertaken.

**RISK OF CHILDHOOD ACUTE LYMPHOBLASTIC LEUKAEMIA FOLLOWING PARENTAL OCCUPATIONAL EXPOSURE TO EXTREMELY LOW FREQUENCY ELECTROMAGNETIC FIELDS.**

Reid A, Glass DC, Bailey HD, Milne E, de Klerk NH, Downie P, Fritschi L; Aus-ALL Consortium.

*Br J Cancer.* 201; 105: 1409-1413.

Earlier studies have reported moderate increases in the risk of acute lymphoblastic leukaemia (ALL) among children whose mothers have been occupationally exposed to extremely low frequency (ELF) electromagnetic fields. Other studies examining parental occupational exposure to ELF and ALL have reported mixed results.

In an Australian case-control study of ALL in children aged < 15 years, parents were asked about tasks they undertook in each job. Exposure variables were created for any occupational exposure before the birth of the child, in jobs 2 years before birth, in jobs 1 year before birth and up to 1 year after birth.

In all, 379 case and 854 control mothers and 328 case and 748 control fathers completed an occupational history. Exposure to ELF in all time periods was similar in case and control mothers. There was no difference in exposure between case and control fathers. There was no association between maternal (odds ratio (OR)=0.96; 95% CI=0.74-1.25) or paternal (OR=0.78; 95% CI=0.56-1.09) exposure to ELF any time before the birth and risk of childhood ALL.

Conclusion: The authors did not find an increased risk of ALL in offspring of parents with occupational exposure to ELF.

#### **4. Human experiment**

**HUMAN COGNITIVE PERFORMANCE IN A 3 MT POWER-LINE FREQUENCY MAGNETIC FIELD.**

Corbacio M, Brown S, Dubois S, Goulet D, Prato FS, Thomas AW, Legros A.

*Bioelectromagnetics.* 2011; 32: 620-633.

Extremely low frequency (ELF, <300 Hz) magnetic fields (MF) have been reported to modulate cognitive performance in humans. However, little research exists with MF exposures comparable to the highest levels experienced in occupations like power line workers and industrial welders. This research aims to evaluate the impact of a 60 Hz, 3 mT MF on human cognitive performance. Ninety-nine participants completed the double-blind protocol, performing a selection of psychometric tests under two consecutive MF exposure conditions dictated by

assignment to one of three groups (sham/sham, MF exposure/sham, or sham/MF exposure). Data were analyzed using a 3 × 2 mixed model analysis of variance. Performance between repetitions improved in 11 of 15 psychometric parameters (practice effect). A significant interaction effect on the digit span forward test ( $F=5.21$ ,  $P<0.05$ ) revealed an absence of practice effects for both exposure groups but not the control group. This memory test indicates MF-induced abolition of the improvement associated with practice.

Conclusion: Overall, this study does not establish any clear MF effect on human cognition. It is speculated that an ELF MF may interfere with the neuropsychological processes responsible for this short-term learning effect supported by brain synaptic plasticity.

#### **ACUTE EXPOSURE TO 50-HZ MAGNETIC FIELDS INCREASES INTERLEUKIN-6 IN YOUNG HEALTHY MEN.**

Selmaoui B, Lambrozo J, Sackett-Lundeen L, Haus E, Touitou Y.

*J Clin Immunol.* 2011; 31: 1105-1111.

Some epidemiologic studies have suggested that extremely low frequency magnetic fields might affect human health and, in particular, that the incidence of certain types of cancer might increase among individuals living or working in environments exposed to such fields. This study is part of a broad study we conducted in humans. The study presented here was designed to look for possible effects of acute exposure to 50-Hz magnetic fields (10  $\mu$ T) on the interleukin 1 beta (IL-1 $\beta$ ), interleukin 2 (IL-2), interleukin 6 (IL-6), interleukin-1 receptor antagonist (IL-1RA), and the interleukin-2 receptor (IL-2R) production. Thirty-two young men (20-30 years old) were divided into two groups (sham-exposed or control group and exposed group) of 16 subjects each. All subjects participated in two 24-h experiments to evaluate the effects of both continuous and intermittent (1 h "off" and 1 h "on" with the field switched "on" and "off" every 15 s) exposure to linearly polarized magnetic fields. The subjects were exposed to the magnetic field from 2300 to 0800 while recumbent. Blood samples were collected during each session at 11:00, 17:00, 22:00, 01:00, 04:00, 06:00, and 08:00.

Conclusion: Results showed that exposure to 50-Hz magnetic fields (10  $\mu$ T) significantly increases IL-6 when subjects were exposed to an intermittent magnetic field. However, no effect has been observed on interleukin IL-1 $\beta$ , IL-2, IL-1RA, and IL-2R.

## **5. Exposure assessment**

#### **OCCUPATIONAL AND ENVIRONMENTAL EXPOSURE TO EXTREMELY LOW FREQUENCY-MAGNETIC FIELDS: A PERSONAL MONITORING STUDY IN A LARGE GROUP OF WORKERS IN ITALY.**

Gobba F, Bravo G, Rossi P, Contessa GM, Scaringi M.

*J Expo Sci Environ Epidemiol.* 2011; 21: 634-645.

An inaccurate evaluation of exposure is considered a possible cause for the inadequate conclusiveness of epidemiological research on adverse effects of extremely low frequency-magnetic fields (ELF-MF). The objective of this study is to provide an evaluation of current ELF-MF exposure in workers, the specific contribution of occupational exposure to overall 24-h exposure, and the representativeness of a job exposure matrix (JEM). ELF-MF exposure was monitored in 543 workers for 2 days using personal meters. Time-weighted average

(TWA) levels at work, at home and outside the home were calculated. A JEM based on the 1988 International Standard Classification of Occupations (ISCO 88) was created. Median exposures at work, at home and outside the home were 0.14, 0.03 and 0.05  $\mu\text{T}$ , respectively. Occupational exposure accounted for about 60% of 24-h exposure. In the JEM, about 50% of the classified occupations included significantly different individual TWAs.

Conclusion: Occupational exposure to ELF-MF appeared low. Median exposure levels at home and outside were 20-28% of the occupational level, giving a minor contribution to overall day-to-day exposure. The frequent occurrence of workers with different TWA included under the same job title highlights the risk of misclassification in epidemiological studies on ELF-MF effects based on JEM.

**THE RELATIONSHIP BETWEEN RESIDENTIAL MAGNETIC FIELDS AND CONTACT VOLTAGE: A POOLED ANALYSIS.**

Kavet R, Hooper C, Buffler P, Does M.  
*Radiat Res.* 2011; 176: 807-815.

It has been suggested that residential exposure to contact currents may be more directly associated with the potential for an increased risk of leukemia in childhood than magnetic fields. Contact current exposure occurs when a child contacts a bathtub's water fixtures, which are usually contiguous with a residence's electrical ground, and when the drainpipe is conductive. The Northern California Childhood Leukemia Study (NCCLS) is the only epidemiological study known to address whether contact current may confound the reported association between residential magnetic fields and childhood leukemia. The study contributed contact voltage and magnetic-field data for over 500 residences of leukemia cases and control children. These data were combined these data with the results of previous measurement studies of contact voltage in other communities to conduct an analysis of the relationship of magnetic fields with contact voltage for a total sample of 702 residences. The Spearman correlation of magnetic field with contact voltage was 0.29 (Spearman,  $P < 0.0001$ ). Magnetic-field and contact voltage data were both divided into tertiles, with an upper magnetic-field cutpoint of 0.3  $\mu\text{T}$  suggested by values used in epidemiological results and an upper contact voltage cutpoint of 60 mV based on dosimetric considerations. Expressed as an exposure odds ratios (EOR), the authors report an association of contact voltage with magnetic fields of 15.1 (95% CI 3.6-61) as well as a statistically significant positive trend across magnetic-field strata (EOR of 4.2 per stratum with 95% CI 2.4-7.4).

Conclusion: The associations appear to be large enough to support the possibility that contact current could be responsible for the association of childhood leukemia with magnetic fields.

## **6. Leukaemia studies**

**EXPOSURE TO PROFESSIONAL PEST CONTROL TREATMENTS AND THE RISK OF CHILDHOOD ACUTE LYMPHOBLASTIC LEUKEMIA.**

Bailey HD, Armstrong BK, de Klerk NH, Fritschi L, Attia J, Scott RJ, Smibert E, Milne E; Aus-ALL Consortium.  
*Int J Cancer.* 2011; 129: 1678-1688.

Previous studies suggest that exposure to pesticides increases the risk of childhood acute lymphoblastic leukemia (ALL). The aim of this analysis was to investigate whether professional pest treatments in or around the home before birth or during childhood increased the risk of childhood ALL. Data from 388 cases and 870

frequency-matched controls were analyzed using unconditional logistic regression, adjusting for study matching variables and potential confounders, to calculate odds ratios (ORs). A meta-analysis of these findings with the published findings of previous studies was also conducted. The ORs for any professional pest control treatments were 1.19 (95% CI 0.83, 1.69) in the year before pregnancy, 1.30 (95% CI 0.86, 1.97) during pregnancy and 1.24 (95% CI 0.93, 1.65) for those done after the child's birth. The ORs for exposure after birth were highest when it occurred between the ages of two and three years. ORs were elevated for termite treatments before birth. ORs were higher for pre-B than T cell ALL and for t(12;21) (ETV6-Runx-1) than other cytogenetic sub-types. The pooled OR from a meta-analysis of our study with three previous studies of professional pest control treatments during pregnancy was 1.37 (95% CI 1.00, 1.88).

Conclusion: The results of this study, and those of the meta-analysis, provide some evidence of a modestly increased risk of ALL for professional pest control treatments done during the index pregnancy and possibly in the child's early years. The analysis of pooled data from international collaborations may provide more certainty regarding these potentially important associations.

**PARENTAL OCCUPATIONAL EXPOSURE TO EXHAUSTS, SOLVENTS, GLUES AND PAINTS, AND RISK OF CHILDHOOD LEUKEMIA.**

Reid A, Glass DC, Bailey HD, Milne E, Armstrong BK, Alvaro F, Fritschi L.  
*Cancer Causes Control. 2011; 22) :1575-1585.*

It is unknown whether parental occupational exposure to chemicals before during and after pregnancy increases the risk of acute lymphoblastic leukemia (ALL) in the offspring. Few studies on this topic have assessed maternal exposures.

In an Australian case-control study of ALL in children aged <15 years, parents were asked about tasks they undertook in each job using a set of job-specific modules (JSMs). An expert reviewed the likelihood of exposure to exhausts, solvents, glues, and paints. Exposure was examined in each job 2 years, 1 year and anytime before birth of the child, and up to 1 year after birth of child.

Solvent exposure was similar for case and control mothers in all time periods. More case mothers had moderate/high exposure to exhausts than control mothers anytime before the birth of the child ( $p = 0.010$ ). Exposure to moderate or substantial levels of exhausts by mothers (OR = 1.97 95% CI 0.99-3.90) or fathers (OR = 1.37 95% CI 1.01-1.86) before the birth increased the risk of ALL in their offspring. Exposure to paints, pigments, glues, and resins was similar in case and control parents.

Conclusion: Little evidence was found that parental occupational exposure to solvents, glues, and paints was associated with childhood ALL. There was some evidence ALL was associated with exhaust exposure.

**REFUELLING OF VEHICLES, THE USE OF WOOD BURNERS AND THE RISK OF ACUTE LYMPHOBLASTIC LEUKAEMIA IN CHILDHOOD.**

Bailey HD, de Klerk NH, Fritschi L, Attia J, Daubenton JD, Armstrong BK, Milne E; Aus-ALL Consortium.  
*Paediatr Perinat Epidemiol. 2011; 25: 528-539.*

It is plausible that exposure of the parents before birth or of the child to sources of benzene increases the risk of childhood acute lymphoblastic leukaemia (ALL). The aim of this analysis was to investigate whether refuelling a vehicle with petrol before

birth or burning wood to heat the home before or after the child's birth increased the risk of childhood ALL. Data from 389 cases and 876 frequency-matched controls were analysed using unconditional logistic regression, adjusting for study matching factors and potential confounders. The odds ratio (OR) for the mother ever refuelling a vehicle with petrol for non-occupational purposes before or during the pregnancy was 0.97 [95% confidence interval (CI) 0.69, 1.38]. The OR for the father for this exposure in the year before conception was 0.88 [95% CI 0.52, 1.48]. The OR for use of a closed wood burner to heat the home in the year before or during pregnancy was 1.41 [95% CI 1.02, 1.94] and 1.25 [95% CI 0.92, 1.70] after birth. Conclusion: The authors found no evidence that non-occupational refuelling a vehicle with petrol in the year before or during pregnancy increased the risk of ALL in the offspring. There was weak evidence that burning wood in a closed burner to heat the home increased the risk, but there was no dose-response relationship and chance could explain the finding.