

Overview of the epidemiologic studies on the health effects of ELF magnetic and electric fields published in the second trimester of 2007 .

*Dr. Maurits De Ridder
Occupational and Environmental Health Section
Ghent University*

1. Reviews

ENVIRONMENTAL HEALTH CRITERIA - MONOGRAPH N°238 : EXTREMELY LOW FREQUENCY FIELDS.

http://www.who.int/peh-emf/publications/elf_ehc/en/index.html

Fact Sheet No 322: ELECTROMAGNETIC FIELDS AND PUBLIC HEALTH. EXPOSURE TO EXTREMELY LOW FREQUENCY FIELDS.

<http://www.who.int/mediacentre/factsheets/fs322/en/index.html>

World Health Organisation, Geneva, Switzerland

Much of the scientific research examining long-term risks from ELF magnetic field exposure has focused on childhood leukaemia. In 2002, IARC published a monograph classifying ELF magnetic fields as "possibly carcinogenic to humans". This classification is used to denote an agent for which there is limited evidence of carcinogenicity in humans and less than sufficient evidence for carcinogenicity in experimental animals (other examples include coffee and welding fumes). This classification was based on pooled analyses of epidemiological studies demonstrating a consistent pattern of a two-fold increase in childhood leukaemia associated with average exposure to residential power-frequency magnetic field above 0.3 to 0.4 μT . The Task Group concluded that additional studies since then do not alter the status of this classification.

However, the epidemiological evidence is weakened by methodological problems, such as potential selection bias. In addition, there are no accepted biophysical mechanisms that would suggest that low-level exposures are involved in cancer development. Thus, if there were any effects from exposures to these low-level fields, it would have to be through a biological mechanism that is as yet unknown. Additionally, animal studies have been largely negative. Thus, on balance, the evidence related to childhood leukaemia is not strong enough to be considered causal.

Childhood leukaemia is a comparatively rare disease with a total annual number of new cases estimated to be 49,000 worldwide in 2000. Average magnetic field exposures above 0.3 μT in homes are rare: it is estimated that only between 1% and 4% of children live in such conditions. If the association between magnetic fields and childhood leukaemia is causal, the number of cases worldwide that might be attributable to magnetic field exposure is estimated to range from 100 to 2400 cases per year, based on values for the year 2000, representing 0.2 to 4.95% of the total incidence for that year. Thus, if ELF magnetic fields actually do increase the risk of the disease, when considered in a global context, the impact on public health of ELF EMF exposure would be limited.

A number of other adverse health effects have been studied for possible association with ELF magnetic field exposure. These include other childhood cancers, cancers in adults, depression, suicide, cardiovascular disorders, reproductive dysfunction,

developmental disorders, immunological modifications, neurobehavioral effects and neurodegenerative disease. The WHO Task Group concluded that scientific evidence supporting an association between ELF magnetic field exposure and all of these health effects is much weaker than for childhood leukaemia. In some instances (i.e. for cardiovascular disease or breast cancer) the evidence suggests that these fields do not cause them.

IMPLICATIONS FROM EPIDEMIOLOGIC STUDIES ON MAGNETIC FIELDS AND THE RISK OF CHILDHOOD LEUKEMIA ON PROTECTION GUIDELINES.

Schüz J.

Health Phys. 2007; 92 : 642-648.

The objective of this review is to discuss the impact of findings in epidemiological studies on magnetic fields and the risk of childhood leukemia on the definition of exposure limits. A large number of epidemiological studies have consistently shown an association between the risk of childhood leukemia and residential extremely low-frequency magnetic field exposures. There is virtually no supportive data from experimental research and, so far, no proposed explanation has reached a level beyond speculation. The contradictory results from epidemiological and experimental research may either be due to methodological limitations creating a spurious association in the epidemiological studies or to a failure of experimental research to examine mechanisms relevant in the complex origin of childhood leukemia. Taking this together, the overall evidence is not strong enough to demand a revision of the current guidelines for public protection. Application of precautionary measures may be an option; however, decision-makers should be advised that these measures are often not straightforward and a careful evaluation of a possible benefit needs to be performed for each individual situation. Undoubtedly there are gaps in research, and no substantial contribution for clarification of the apparent inconsistencies emerges from recent studies. However, there are important lessons to learn, either with respect to the etiology of childhood leukemia or with respect to the need for improving epidemiological methods for the identification of presumably weak associations.

2. Residential exposure

EXPOSURE TO MAGNETIC FIELDS AND SURVIVAL AFTER DIAGNOSIS OF CHILDHOOD LEUKEMIA: A GERMAN COHORT STUDY.

Svendson AL, Weihkopf T, Kaatsch P, Schüz J.

Cancer Epidemiol Biomarkers Prev. 2007; 16 : 1167-1171.

Inspired by a recent U.S. study showing poorer survival among children with acute lymphoblastic leukemia (ALL) exposed to magnetic fields above 0.3 microT, the authors examined the relationship in a German cohort of childhood leukemia cases derived from previous population-based case-control studies conducted between 1992 and 2001. A total of 595 ALL cases with 24-h magnetic field measurements are included in the analysis with a median follow-up of 9.5 years. They calculated the hazard ratios (HR) using the Cox proportional hazards model for overall survival, adjusted for age at diagnosis, calendar year of diagnosis, and gender. Elevated hazards are found for exposures between 0.1 and 0.2 microT [HR, 2.6; 95% confidence interval (95% CI), 1.3-5.2], based on 34 cases with 9 deaths as well as for exposures above 0.2 microT (HR, 1.6; 95% CI, 0.6-4.4), based on 18

cases with 4 deaths. After adjustment for prognostic risk group, the hazard for exposures above 0.2 microT increases to HR, 3.0 (95% CI, 0.9-9.8).

Conclusion: This study is generally consistent with the previous finding; however, the authors report the excess risk at field levels lower than those in the U.S. study. In all, the evidence is still based on small numbers, and a biological mechanism to explain the findings is not known.

EXTREMELY-LOW-FREQUENCY MAGNETIC FIELD EXPOSURE OF CHILDREN AT SCHOOLS NEAR HIGH VOLTAGE TRANSMISSION LINES.

Li CY, Sung FC, Chen FL, Lee PC, Silva M, Mezei G.

Science of the Total Environment 2007; 376) :151-159.

Many epidemiological studies have investigated residential exposure to extremely-low-frequency magnetic field (ELF-MF) for children, but exposure at schools where children may stay up to 8 h every weekday was rarely considered. Between March and June 2004, the authors carried out a field study in Taipei City and County of northern Taiwan to explore ELF-MF exposure pattern among children at schools with high voltage transmission lines (HVTL) running through the campuses. One hundred and one children attending 14 schools with nearby HVTL (exposed group) and 123 children of 18 schools at least 100 m away from HVTL (unexposed group) were monitored for 24-hour personal ELF-MF exposure. Selected classrooms and playgrounds within the buffer regions (i.e., within 30 m of HVTL) and those away from the buffer regions were also assessed, using spot measurements, to determine the extent to which HVTL may contribute to the environmental exposure on campuses. Results show that the two groups didn't differ significantly for both mean exposure and proportion of exposure greater than 0.4 micro-Tesla (microT) estimated for 24 h. However, the authors noted that 17.8% of the exposed children had a personal mean exposure greater than 0.4 microT during school hours, significantly ($p=0.011$) higher than that (6.5%) estimated for the unexposed children. An even higher percentage (27.3%) was observed for 11 students with their classrooms intersecting the buffer regions. Playgrounds near buffer regions showed a significantly higher ELF-MF than the other areas of the exposed schools (0.70 vs 0.18 microT, $p=0.043$). The study demonstrates a wide range of exposures to ELF-MF among school children at campuses adjacent to HVTL. Children attending the exposed schools may have a higher chance of experiencing a mean exposure greater than 0.4 microT during school hours.

USE OF ELECTRIC BLANKETS AND ASSOCIATION WITH PREVALENCE OF ENDOMETRIAL CANCER.

Abel EL, Hendrix SL, McNeeley GS, O'Leary ES, Mossavar-Rahmani Y, Johnson SR, Kruger M.

Eur J Cancer Prev. 2007; 16 : 243-250.

The objective of this study was to assess the relationship between electric blanket use and prevalence of endometrial cancer for women. Information relating to women enrolled in the Women's Health Initiative Observational Data Set ($n=93\ 676$) used to test the relationship factors associated with endometrial cancer included older age at screening, younger age at last menstrual period, region of domicile (highest prevalence in the South), less than a high school education, lower income, body mass index >25 kg/m, low parity, unopposed use of estrogen, never use of estrogen plus progesterone, past alcohol use, higher percentage of daily calories from fat and any electric blanket use. Following a univariate identification of factors significantly related to endometrial cancer, stepwise logistic regression analysis was

performed for those factors with P values of less than 0.001 in the univariate analysis. Using electric blankets was associated with a 15% higher prevalence of endometrial cancer than never having used electric blankets (odds ratio=1.15, 95% confidence interval: 1.03-1.27). After controlling for variables significantly associated with endometrial cancer, use of electric blankets for 20 years or more was associated with 36% higher prevalence of endometrial cancer (odds ratio=1.36, 95% confidence interval: 1.16-1.59). Although the authors were unable to determine the duration of electric blanket use before diagnosis of endometrial cancer, they found that women using electric blankets for 20 years or more had a significantly higher prevalence.

3. Occupational exposure

OCCUPATIONAL EXPOSURE TO LOW FREQUENCY MAGNETIC FIELDS AND THE RISK OF LOW GRADE AND HIGH GRADE GLIOMA.

Karipidis KK, Benke G, Sim MR, Yost M, Giles G.

Cancer Causes Control. 2007; 18 : 305-313.

The purpose of this population-based case control study was to investigate a possible association between occupational exposure to low frequency magnetic fields and the risk of low grade glioma (LGG) and high grade glioma (HGG).

The study population consisted of 414 histologically confirmed cases of glioma (LGG=110, HGG=304), first diagnosed between July 1987 and December 1991, and 421 controls from Melbourne, Australia, matched by age, sex and postcode of residence. A detailed occupational history was obtained for each subject. Exposure to low frequency magnetic fields was estimated using three different methods: self-report, expert hygienist review and a job exposure matrix (JEM).

Elevated but statistically non-significant risk estimates were found for all glioma and HGG when exposure was assessed by the expert hygienist. The odds ratios (OR) for the highest exposed group of workers when assessed by the expert hygienist were 1.4 (95% confidence interval, CI: 0.85-2.27) and 1.51 (95% CI: 0.90-2.53) for all glioma and HGG, respectively. There were inverse associations for the self-reported and JEM exposures for both LGG and HGG but these may reflect limitations in these exposure assessment methods.

Conclusion: These results do not support a role for occupational exposure to low frequency magnetic fields in the development of either LGG or HGG.

A CASE-CONTROL STUDY OF OCCUPATIONAL MAGNETIC FIELD EXPOSURE AND ALZHEIMER'S DISEASE: RESULTS FROM THE CALIFORNIA ALZHEIMER'S DISEASE DIAGNOSIS AND TREATMENT CENTERS.

Davanipour Z, Tseng CC, Lee PJ, Sobel E.

BMC Neurol. 2007; 7 : 13.

A few studies have investigated a possible relationship between Alzheimer's disease (AD) and occupations with extremely low frequency magnetic field (MF) exposure. The purpose of this study was to further evaluate this possible association in a large patient population with expert diagnoses.

Subjects came from the 8 of the 9 California Alzheimer's Disease Diagnostic and Treatment Centers not previously used in an earlier study. Cases had probable or definite AD; controls primarily had a dementia-related problem other than vascular dementia (VaD) and some were not demented upon expert examination. Occupations were classified as having low, medium or high MF exposure, based

upon previous research, replicating the exposure methodology used in our previous published studies.

Occupational information was available for 98.6% of the 1527 cases and 98.5% of the 404 controls with age-at-initial examination known to be at least 65. Among cases, 2.1% and 5.4% had high and medium occupational MF exposure, respectively, while among controls the percentages were 0.8% and 3.0%. In univariate analyses, the odds ratio (OR) for subjects with medium or high MF exposures combined was 2.1 ($p < 0.01$), while for high exposure alone the OR was 2.9 ($p < 0.08$). Two models were used in multivariate analyses, with gender, stroke, and either age-at-onset or age-at-initial examination as covariates. The ORs for MF exposure varied little between the two models: 2.2 ($p < 0.02$) and 1.9 ($p < 0.03$) for medium or high exposure; 2.7 ($p < 0.11$) and 3.2 ($p < 0.12$) for high exposure. OR estimates for females were higher than for males, but not significantly higher. There were no material differences between the ORs resulting from univariate and multivariate analyses.

Conclusion: Elevated occupational MF exposure was associated with an increased risk of AD. Based on previous published studies, the results likely pertain to the general population.

OCCUPATIONAL EXPOSURES AND BREAST CANCER AMONG WOMEN TEXTILE WORKERS IN SHANGHAI.

Ray RM, Gao DL, Li W, Wernli KJ, Astrakianakis G, Seixas NS, Camp JE, Fitzgibbons ED, Feng Z, Thomas DB, Checkoway H.

Epidemiology. 2007 ; 18 : 383-392.

The authors conducted a case-cohort study within a cohort of female textile workers who had participated in a randomized trial of breast self-examination in Shanghai, China. They compared 1709 incident breast cancer cases with an age-stratified reference subcohort ($n = 3155$ noncases). Cox proportional hazards modeling, adapted for the case-cohort design, was used to estimate hazard ratios for breast cancer in relation to duration of employment in various job processes and duration of exposure to several agents. They also evaluated the associations of cotton dust and endotoxin with breast cancer.

Conclusion: the authors did not observe consistent associations with exposures to electromagnetic fields, solvents, or other chemicals.

4. Childhood leukaemia studies

AETIOLOGICAL CLUES FROM THE DESCRIPTIVE EPIDEMIOLOGY OF CHILDHOOD ACUTE LYMPHATIC LEUKAEMIA AND OTHER MALIGNANCIES.

Terracini B, Maule MM.

J Epidemiol Community Health. 2007 ; 61 : 180-181.

There are suggestions that the incidence of childhood cancer is increasing, at least in European countries. However, our ability in distinguishing between real incidence increases and improved ascertainment criteria is inadequate, and confirmation that case registration has been exhaustive and constant in time is desirable.

Intrauterine exposure to diagnostic x rays at doses which are nowadays obsolete is a proved risk factor for ALL. Compared with adult cancers, geographical differences in the incidence of childhood cancer are limited, which suggests a role of genetic factors

although familial aggregation accounts for a minority of cases. Viral infections as explanation of some case of ALL has been recently reinforced by the observation of a relation between peaks in the incidence of ALL with years immediately after influenza epidemics. To date, for ALL as well as for other childhood cancers, there have been suggestions, but no definite confirmation, of a role of other putative aetiological factors such as very low frequency electromagnetic fields, parental occupational, and children's environmental exposures, socio-economic factors, parental age, perinatal characteristics, and others. Tobacco smoke does not seem to be associated with childhood cancer.

Even more than for adult cancer, for childhood cancer, the interaction between the above environmental and behavioural factors and between these and genetic characteristics is largely unknown.

EVIDENCE OF POPULATION MIXING BASED ON THE GEOGRAPHICAL DISTRIBUTION OF CHILDHOOD LEUKEMIA IN OHIO.

Clark BR, Ferketich AK, Fisher JL, Ruyman FB, Harris RE, Wilkins JR.
Pediatr Blood Cancer. 2007; 49: 797-802.

This ecologic study examined the geographic distribution of childhood leukemias in Ohio, 1996-2000, among children aged 0-19 for evidence that population mixing may be a factor. State incidence rates were compared to Surveillance, Epidemiology and End Results (SEER) rates for each year and for the 5-year period, 1996-2000; incidence rates for each of Ohio's 88 counties were compared to statewide rates; and county incidence rates were compared based on population density, population growth, and rural/urban locale. SEER*Stat version 5.0 was used to derive age-specific and 0-19 age-adjusted rates. Expected values, standardized incidence ratios (SIRs), and Poisson P-values were calculated with Excel using the indirect method of standardization.

Of the 585 cases, 73.3% were acute lymphocytic leukemia (ALL), 16.6% acute myelogenous leukemia (AML), 3.2% acute monocytic leukemia (AMoL), and 2.6% chronic myelogenous leukemia (CML). Rates for total leukemia burden were significantly below national levels for all races ($P = 0.00001$), likely due to poor ascertainment of cases. Yearly incidence rates for 1996-2000 were stable for ALL and AML; CML rates declined over the period. Based on 2000 Census and intercensal population estimates for 1996-2000, statistically higher rates for ALL were noted for counties experiencing >10% population change 1990-2000 ($P < 0.05$), especially for ages 1-4 ($P < 0.03$) in counties with 10-20% growth. Counties 67.9-99.2% urban experienced fewer than expected cases of AML + AMoL ($P < 0.06$).

Conclusion: These data support Kinlen's theory of population mixing and warrant further studies in Ohio, the US and other countries.

EFFECTS OF MATERNAL AGE AND COHORT OF BIRTH ON INCIDENCE TIME TRENDS OF CHILDHOOD ACUTE LYMPHOBLASTIC LEUKEMIA.

Maule MM, Merletti F, Pastore G, Magnani C, Richiardi L.
Cancer Epidemiol Biomarkers Prev. 2007; 16 : 347-351.

Several studies report increasing trends in the incidence of childhood acute lymphoblastic leukemia (ALL). Because ALL may generate in utero, this study investigated if maternal age and birth cohort influence ALL temporal trends. Data on 252 ALL cases in children ages 1 to 5 years were extracted from the population-based Childhood Cancer Registry of Piedmont, Italy. Information on cases' maternal age and year of birth was obtained from the registry, whereas population data were

obtained for children born in 1980 to 1997. Incidence rates were analyzed using an age-period-cohort approach, in which the period effect was represented by the child year of birth, the age effect by the maternal age at the time of delivery, and the cohort effect by the maternal birth cohort. ALL incidence increased over the study period [annual percentage change 2.49%; 95% confidence interval (95% CI), 0.09-4.93]. A linear effect of the maternal time variables ($P = 0.012$) was found, which was equally described by maternal age (direct association) and maternal birth cohort (inverse association). The annual percentage change was 1.83% (95% CI, -0.59-4.31), when maternal age was included in the model, and 5.72% (95% CI, 2.29-9.27), when maternal year of birth was included.

Conclusion: maternal characteristics substantially affect temporal trends in childhood ALL incidence.

EXAMINATION OF GENDER EFFECT IN BIRTH WEIGHT AND MISCARRIAGE ASSOCIATIONS WITH CHILDHOOD CANCER (UNITED KINGDOM).

Dorak MT, Pearce MS, Hammal DM, McNally RJ, Parker L.

Cancer Causes Control. 2007; 18 : 219-228.

Higher birth weight and maternal history of miscarriage has been associated with an increased risk of childhood leukemia. The possibility that this association may be sex-specific has not been explored in detail in previous studies. In a retrospective case-control study, 732 childhood (< or =14 years) cancer cases from a population-based Registry in Northern England whose hospital birth records could be accessed and 3,723 controls matched for date and hospital of birth to the cases were compared. Birth weight for sex-specific associations with childhood cancer was examined. Conditional logistic regression analysis was used for statistical evaluation of associations. In acute lymphoblastic leukemia (ALL) (225 cases and 1,163 matched controls), birth weight and sex showed a strong interaction ($P = 0.003$). In boys with ALL, but not in girls, there was a nonlinear association with birth weight (P for trend = 0.008; OR = 3.05 for the highest quintile compared to the second lowest quintile, 95% CI = 1.40-6.64; $P = 0.005$). When birth weights were adjusted using UK standards for gestational age and sex, the risk associations were similar in statistical significance and magnitude. Maternal history of miscarriage showed an association with all cancers and individually with ALL. The miscarriage association with ALL was statistically significant in boys only (OR = 1.91, 95% CI = 1.07-3.42; $P = 0.03$). A multivariable model for ALL containing other examined maternal and reproductive variables confirmed the independence of the birth weight and miscarriage associations. There was no birth weight or miscarriage associations in other cancers. Conclusion: This study confirmed the risk associations with birth weight and miscarriages in childhood ALL. Statistically significant association of size at birth suggested marked differences in etiology between girls and boys.