Overview of the epidemiologic studies on the health effects of ELF magnetic and electric fields published in the second trimester of 2020

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1. Reviews

RECENT RESEARCH ON EMF AND HEALTH RISK – FOURTEENTH REPORT FROM SCIENTIFIC SWEDISH RADIATION SAFETY AUTHORITY (SSM), SCIENTIFIC COUNCIL ON ELECTROMAGNETIC FIELDS, 2019 SSM's Scientific Council on Electromagnetic Fields: Huss A, Poulsen AH, Dasenbrock C, van Rongen E, Danker-Hopfe H, Mjönes L, Moberg L, Röösli M. SSM Report number: 2020:04, ISSN: 2000-0456, March 2020. Available at www.stralsakerhetsmyndigheten.se.

The exposure of the general public to extremely low frequency (ELF) fields (>0 Hz-300 Hz) is primarily from 50 and 60 Hz electric power lines and from electric devices and wiring in buildings. Regarding the exposure to ELF magnetic fields and the development of childhood leukaemia, the latest studies did not consistently observe an association. However, these studies did not use new approaches and the same limitations apply as in previous research. Thus, the conclusion from previous Council reports still holds: epidemiologically, associations have been observed, but a causal relationship has not been established.

Epidemiology. No new study on residential exposure to ELF magnetic fields and childhood leukaemia was published since the last SSM report. Also research on other outcomes in relation to ELF magnetic fields is scarce and does not provide new insights for health risk assessment.

Human studies. The number of studies continues to be very low with just one study identified in the current reporting period. The sporadic publications over the years address different endpoints, for example postural shift this year with other than the hypothesised results, EEG last year. There is no substantial new information on effects of extremely low frequency (ELF) fields from human experimental studies.

PRINCIPLES FOR NON-IONIZING RADIATION PROTECTION. International Commission on Non-Ionizing Radiation Protection (ICNIRP). Health Phys. 2020 May;118(5):477-482.

In this statement, the International Commission on Non-Ionizing Radiation Protection (ICNIRP) presents its principles for protection against adverse health effects from exposure to non-ionizing radiation. These are based upon the principles for protection against ionizing radiation of the International Commission for Radiological Protection (ICRP) in order to come to a comprehensive and consistent system of protection throughout the entire electromagnetic spectrum.

Conclusions: The statement further contains information about ICNIRP and the processes it uses in setting exposure guidelines.

GAPS IN KNOWLEDGE RELEVANT TO THE "GUIDELINES FOR LIMITING EXPOSURE TO TIME-VARYING ELECTRIC AND MAGNETIC FIELDS (1 Hz- 100 kHz)". International Commission on Non-Ionizing Radiation Protection (ICNIRP). Health Phys. 2020 May;118(5):533-542.

Sources of low-frequency fields are widely found in modern society. All wires or devices carrying or using electricity generate extremely low frequency (ELF) electric fields (EFs) and magnetic fields (MFs), but they decline rapidly with distance to the source. High magnetic flux densities are usually found in the vicinity of power lines and close to equipment using strong electrical currents, but can also be found in buildings with unbalanced return currents, or indoor transformer stations. For decades, epidemiological as well as experimental studies have addressed possible health effects of exposure to ELF-MFs. The main goal of ICNIRP is to protect people and the environment from detrimental exposure to all forms of non-ionizing radiation (NIR). To this end, ICNIRP provides advice and guidance by developing and disseminating exposure guidelines based on the available scientific research. Research in the low-frequency range began more than 40 years ago, and there is now a large body of literature available on which ICNIRP set its protection guidelines. A review of the literature has been carried out to identify possible relevant knowledge gaps, and the aim of this statement is to describe data gaps in research that would, if addressed, assist ICNIRP in further developing guidelines and setting revised recommendations on limiting exposure to electric and magnetic fields. It is articulated in two parts: the main document, which reviews the science related to LF data gaps, and the annex, which explains the methodology used to identify the data gaps.

ELECTROMAGNETIC HYPERSENSITIVITY: A CRITICAL REVIEW OF EXPLANATORY EXPLANATORY HYPOTHESES Dieudonné M. Environ Health. 2020 May 6;19(1):48.

Electromagnetic hypersensitivity (EHS) is a condition defined by the attribution of non-specific symptoms to electromagnetic fields (EMF) of anthropogenic origin. Despite its repercussions on the lives of its sufferers, and its potential to become a significant public health issue, it remains of a contested nature. Different hypotheses have been proposed to explain the origin of symptoms experienced by self-declared EHS persons, which this article aims to review. As EHS is a multi-dimensional problem, and its explanatory hypotheses have far-reaching implications, a broad view was adopted, not restricted to EHS literature but encompassing all relevant bodies of research on related topics. This could only be achieved through a narrative approach. Two strategies were used to identify pertinent references. Concerning EHS, a complete bibliography was extracted from a 2018 report from the French Agency for Food, Environmental and Occupational Health & Safety and updated with more recent studies. Concerning related topics, the appropriate databases were searched. Systematic reviews and expert reports were favored when available. Three main explanatory hypotheses appear in the literature: (1) the electromagnetic hypothesis, attributing EHS to EMF exposure; (2) the cognitive hypothesis, assuming that EHS results from false beliefs in EMF harmfulness, promoting nocebo responses to perceived EMF exposure; (3) the attributive hypothesis, conceiving EHS as a coping strategy for pre-existing conditions. These hypotheses are successively assessed, considering both their strengths and limitations, by comparing their theoretical, experimental, and ecological value.

Conclusions: No hypothesis proves totally satisfying. Avenues of research are suggested to help decide between them and reach a better understanding of EHS.

2. Residential exposure

THE ROLE OF DWELLING TYPE WHEN ESTIMATING THE EFFECT OF MAGNETIC FIELDS ON CHILDHOOD LEUKEMIA IN THE CALIFORNIA POWER LINE STUDY (CAPS). Amoon AT, Crespi CM, Nguyen A, Zhao X, Vergara X, Arah OA, Kheifets L. Cancer Causes Control. 2020 Jun;31(6):559-567.

The type of dwelling where a child lives is an important factor when considering residential exposure to environmental agents. In this paper, The authors explore its role when estimating the potential effects of magnetic fields (MF) on leukemia using data from the California Power Line Study (CAPS). In this context, dwelling type could be a risk factor, a proxy for other risk factors, a cause of MF exposure, a confounder, an effect-measure modifier, or some combination. Information was obtained on type of dwelling at birth on over 2,000 subjects. Using multivariable-adjusted logistic regression, the authors assessed whether dwelling type was a risk factor for childhood leukemia, which covariates and MF exposures were associated with dwelling type, and whether dwelling type was a potential confounder or an effect-measure modifier in the MF-leukemia relationship under the assumption of no-uncontrolled confounding. A majority of children lived in single-family homes or duplexes (70%). Dwelling type was associated with race/ethnicity and socioeconomic status but not with childhood leukemia risk, after other adjustments, and did not alter the MF-leukemia relationship upon adjustment as a potential confounder. Stratification revealed potential effect-measure modification by dwelling type on the multiplicative scale.

Conclusions: Dwelling type does not appear to play a significant role in the MF-leukemia relationship in the CAPS dataset as a leukemia risk factor or confounder. Future research should explore the role of dwelling as an effect-measure modifier of the MF-leukemia association.

ENVIRONMENTAL AND OCCUPATIONAL RISK FACTORS OF AMYOTROPHIC LATERAL SCLEROSIS: A POPULATION-BASED CASE-CONTROL STUDY. Filippini T, Tesauro M, Fiore M, Malagoli C, Consonni M, Violi F, Iacuzio L, Arcolin E, Oliveri Conti G, Cristaldi A, Zuccarello P, Zucchi E, Mazzini L, Pisano F, Gagliardi I, Patti F, Mandrioli J, Ferrante M, Vinceti M. Int J Environ Res Public Health. 2020 Apr 22;17(8). pii: E2882.

Amyotrophic lateral sclerosis (ALS) is a progressive and fatal neurodegenerative disease with still unknown etiology. The authors aimed at investigating the association between environmental and occupational factors with ALS risk. They performed a population-based case-control study in four Italian provinces (Catania, Modena, Novara, and Reggio Emilia) by administration of tailored questionnaires to ALS cases (n = 95) and randomly selected population referents (n = 135). ALS risk was estimated by calculating the odds ratio (OR) with its 95% confidence interval (CI) using an unconditional logistic regression model. A positive association was found with disease risk for history of occupation in the agricultural sector (OR = 2.09, 95% CI 0.79-7.54), especially for longer than 10 years (OR = 2.72, 95% 1.02-7.20). Overall occupational exposure to solvents also suggested a positive association, especially for thinners (OR = 2.27, 95% CI 1.14-4.54) and paint removers (OR = 2.01, 95% CI 0.90-4.48). Both occupational and environmental exposure to electromagnetic fields show a slightly increased risk with OR = 1.69 (95% CI 0.70-4.09) and 2.41 (95% CI 1.13-5.12), respectively. Occupational but not environmental exposure to pesticides (OR

= 1.22, 95% CI 0.63-2.37), particularly fungicides, and exposure to metals (OR = 4.20, 95% CI 1.88-9.38), particularly lead, mercury, and selenium, showed an imprecise but positive association. Finally, there was an indication of increased risk for living in proximity to water bodies.

Conclusions: Despite the caution that needs to be used due to some study limitations, such as the low number of exposed subjects and the possibility of recall bias, these results suggest the potential role of some environmental and occupational factors in ALS etiology, among others electromagnetic fields.

ELECTRIC FIELD AND AIR ION EXPOSURES NEAR HIGH VOLTAGE OVERHEAD POWER LINES AND ADULT CANCERS: A CASE CONTROL STUDY ACROSS ENGLAND AND WALES. Toledano MB, Shaddick G, de Hoogh K, Fecht D, Sterrantino AF, Matthews J, Wright M, Gulliver J, Elliott P. Int J Epidemiol. 2020 Apr 1;49(Supplement 1):i57-i66.

Various mechanisms have been postulated to explain how electric fields emitted by high voltage overhead power lines, and the charged ions they produce, might be associated with possible adult cancer risk, but this has not previously been systematically explored in large scale epidemiological research. The authors investigated risks of adult cancers in relation to modelled air ion density (per cm3) within 600 m (focusing analysis on mouth, lung, respiratory), and calculated electric field within 25 m (focusing analysis on non-melanoma skin), of high voltage overhead power lines in England and Wales, 1974-2008. With adjustment for age, sex, deprivation and rurality, odds ratios (OR) in the highest fifth of net air ion density (0.504-1) compared with the lowest (0-0.1879) ranged from 0.94 [95% confidence interval (CI) 0.82-1.08] for mouth cancers to 1.03 (95% CI 0.97-1.09) for respiratory system cancers, with no trends in risk. The pattern of cancer risk was similar using corona ion estimates from an alternative model proposed by others. For keratinocyte carcinoma, adjusted OR in the highest (1.06-4.11 kV/m) compared with the lowest (<0.70 kV/m) thirds of electric field strength was 1.23 (95% CI 0.65-2.34), with no trend in risk.

Conclusions: These results do not provide evidence to support hypotheses that air ion density or electric fields in the vicinity of power lines are associated with cancer risk in adults.

RESIDENTIAL PROXIMITY TO POWER LINES AND RISK OF BRAIN TUMOR IN THE GENERAL POPULATION. Carles C, Esquirol Y, Turuban M, Piel C, Migault L, Pouchieu C, Bouvier G, Fabbro-Peray P, Lebailly P, Baldi I. Environ Res. 2020 Jun;185:109473.

The effect of ELF-MF on human health is still controversial, particularly as regards long-term health effects like cancer. The literature does suggest, however, that they could be involved in the occurrence of brain tumors, although results concerning residential exposure are scarce. The objective of this study was to investigate the association between residential proximity to power lines and brain tumors among adults in France by using a geographical information system. CERENAT is a population-based case-control study carried out in France in 2004-2006. Geographical data sources on power line location were used to create exposure scores based on distance between residence and power lines, and on the number of lines near residences.

Conditional logistic regression for matched sets was used to estimate Odds Ratios (ORs) and 95% confidence intervals (95%CI).

Conclusions: Significant associations were found between cumulated duration living at < 50 m to high voltage lines and: i) all brain tumors (OR 2.94; 95%CI 1.28-6.75); ii) glioma (OR 4.96; 95%CI 1.56-15.77). Further investigations are needed, particularly to improve the quality and availability of geographical and technical data on power lines.

3. Occupational exposure

CASE-CONTROL STUDY ON OCCUPATIONAL EXPOSURE TO EXTREMELY LOW FREQUENCY ELECTROMAGNETIC FIELDS AND THE ASSOCIATION WITH ACCOUSTIC NEUROMA. Carlberg M, Koppel T, Ahonen M, Hardell L. Environ Res. 2020 Aug;187:109621.

Exposure to extremely low-frequency electromagnetic fields (ELF-EMF) was in 2002 classified as a possible human carcinogen, Group 2B, by the International Agency for Research on Cancer at WHO based on an increased risk for childhood leukemia. In case-control studies on brain and head tumours during 1997-2003 and 2007-2009 the authors assessed life-time occupations in addition to exposure to different agents. The INTEROCC ELF-EMF Job-Exposure Matrix was used for associating occupations with ELF-EMF exposure (µT) with acoustic neuroma. Cumulative exposure (µT-years), average exposure (µT) and maximum exposed job (µT) were calculated. No increased risk for acoustic neuroma was found in any category. For cumulative exposure in the highest exposure category 8.52+ µT years odds ratio (OR) = 1.2, 95% confidence interval (CI) = 0.8-2.0, p linear trend = 0.37 was calculated. No statistically significant risks were found in the time windows 1-14 years, and 15+ years, respectively.

Conclusions: Occupational ELF-EMF was not associated with an increased risk for acoustic neuroma.

ELECTROMAGNETIC FIELD EXPOSURE IN POWER PLANTS: A QUALITATIVE ASSESSMENT OF WORK SAFETY PERCEPTIONS AMONG EMPLOYEES. Stege TAM, Bolte JFB, Claassen L, Timmermans DRM. J Risk Res, DOI:10.1080/13669877.2020.1750459.

Electromagnetic fields, or EMF, are ubiquitous in our daily life. Extremely low frequency magnetic fields (ELF MF) are generated by any device using electric current. Especially in workplace situations involving MRI scanners, welding equipment, induction heaters, and power plants, they are known for potentially high field strengths. These high field strengths may lead to adverse health effects if insufficient preventive measures are in place. This study investigates employees' perceptions on work safety regarding EMF exposure. The authors held 15 semi-structured interviews in three different (non-nuclear) power plants in the Netherlands. They found that power plants in this study made ample use of fences and warning signs where needed, creating a safe working environment. Nevertheless, some workers perceive that there are vague regulations, organizational issues and lack of clarity on the properties of EMF.

Participants also indicated that there is some room for improvement with respect to work safety meetings on EMF.

Conclusions: Employees want to be informed about EMF and its potential health effects and mitigation methods, but their information need is limited and straightforward. A simple warning system, along with safety information on paper, may be sufficient.

4. Human experimental studies

CO-DESIGNED EXPOSURE PROTOCOL IN THE STUDY OF IDIOPATHIC ENVIRONMENTAL INTOLERANCE ATTRIBUTED TO ELECTROMAGNETIC FIELDS. Ledent M, Vatovez B, Pirard W, Bordarie J, Prignot N, Oftedal G, Geuzaine C, Beauvois V, Bouland C, Verschaeve L, Dieudonné M. Bioelectromagnetics. 2020 Jun 29.

The hypothesis of an electromagnetic origin of idiopathic environmental intolerance (IEI) attributed to electromagnetic fields (EMF) has been widely investigated by provocation studies, which consist of deliberately exposing people with IEI-EMF in laboratory settings to particular EMF to observe volunteers' reactions. In the majority of these studies, reactions have been found to be independent of exposure. However, most of these studies suffer from design and methodological limitations that might bias their findings or reduce their precision. As provocation studies are best suited for isolating the effects of EMF, innovative protocols should be applied. In the ExpoComm project (PNREST Anses, EST/2017/2 RF/19), several innovations have been introduced: the involvement of people with IEI-EMF in the development of the protocol, the attenuation of the anxiogenic nature of the tests, the individualization of the protocol, the validation of the neutral or normal reactivity state before the test, and the use of a cocktail of real, rather than artificially generated, sources. The objective of involving people with IEI-EMF was to increase the relevance and acceptability of the protocol, while respecting technical constraints and scientific quality requirements.

Conclusions: This paper describes the protocol resulting from the collaborative process.

HUMAN POSTURAL CONTROL UNDER HIGH LEVELS OF EXTREMELY LOW FREQUENCY MAGNETIC FIELDS. Bouisset N, Villard S, Legros A. IEEE Access Volume 8. 2020 May 26;101377 – 101385

International agencies such as the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and the International Committee on Electromagnetic Safety (ICES) of the Institute of Electrical and Electronics Engineers (IEEE) need further data to set international guidelines to protect workers and the public from potential adverse effects to Extremely Low-Frequency Magnetic Fields (ELF-MF). Interestingly, electromagnetic induction has been hypothesized to impact human vestibular function (i.e. through induced electric fields). To date, a theoretical 4 T/s vestibular threshold was proposed to modulate postural control, but data is lacking above this limit. This research aimed to investigate the impact of full head homogeneous ELF-MF stimulations above the 4 T/s threshold on human postural control. Postural control of twenty healthy participants was analyzed while full head homogeneous ELF-MF stimulations (20 Hz, 60 Hz, and 90 Hz) up to 40 T/s were applied. Velocity, main direction and spatial dispersion of

sway were used to investigate postural modulations. Despite a conclusive positive control effect, no significant effects of ELF-MF exposures on velocity, spatial dispersion, and direction of the postural sway were found for our 3 frequency conditions.

Conclusions: The homogeneous full head MF stimulations oriented vertically and delivered at high frequencies induced E-fields having a weaker impact than anticipated, possibly because they impacted only a small portion of the vestibular system. This resulted in an absence of effect on postural control outcomes.

5. Exposure assessment

EXPOSURE OF LIVE-LINE WORKERS TO MAGNETIC FIELDS: A DOSIMETRIC ANALYSIS. Bottauscio O, Arduino A, Bavastro D, Capra D, Guarneri A, Parizia AA, Zilberti L. Int J Environ Res Public Health. 2020 Apr 2;17(7). pii: E2429.

In this paper the authors present the results of a dosimetric analysis related to the exposure of live-line workers to the magnetic fields generated by high voltage overhead lines and substations. The study extends the work published by Dawson et al. in 2002, considering more evolved anatomical models nowadays available, the new reference limits given by the 2013/35/EU Directive, and a new methodology, based on the intercomparison of two alternative solvers and the use of data filtering. Moreover, additional exposure scenarios are here considered with respect to the studies already available in literature.

Conclusions: The results of this dosimetric analysis show that for the exposure scenario of high voltage live line works with bare hand method, in any analyzed position, the exposure limits for the tissues of the central nervous system, as well as for all other tissues, are never exceeded, despite in some cases the action levels are exceeded. For the exposure of workers in substations near 220 kV and 380 kV line trap coils exposure is compliant with the regulatory limits if the current flowing through the line trap does not exceed the value of 1000 A. Finally, for the exposure of workers in substations near cable connections, electric field values induced in the body are always lower than regulatory limits with a phase current value equal to 1600 A rms.

6. Leukaemia studies

ASSOCIATION OF POPULATION MIXING AND ACUTE LYMPHOCYTIC LEUKEMIA IN CHILDREN AND ADULTS. Lubega J, Hallman MD, Lupo PJ, Fu Y, Peterson L, Scheurer ME. Cancer Epidemiol. 2020 Apr 27;66:101722.

The association of population mixing (PM) with childhood acute lymphocytic leukemia (ALL) has been reproduced in multiple studies. However, the mechanism underlying this association is unknown. The authors performed a ecological study of incidence of pediatric ALL among 253 counties in the State of Texas (USA) using surrogates of genetic and environmental PM. ALL incidence data were obtained from Texas Cancer Registry and county population statistics from the US Census Bureau. Poisson regression was used to compare ALL incidence and PM. A

substantial and variable genetic and environmental PM was observed among counties in Texas. Indicators of genetic PM including proportion of multiracial households, ratio of Hispanics to non-Hispanics, and ratio of foreign to native-born residents were all significantly associated with a higher incidence of ALL (IRR3 1.81 (95CI 1.05-3.13), 1.67 (95CI 1.16-2.37), and 1.59 (95CI 1.03-2.48), respectively). Surrogates of environmental PM namely population density and persons per household were not associated with incidence of ALL; IRRs 1.29 (95CI 0.4-4.15) and 1.47 (95CI 0.89-2.43).

Conclusions: These findings are consistent with prior patterns and magnitudes of PM association with ALL. The study suggest that the implicated mechanism of leukemogenesis in PM may be genetically transmitted rather than environmental.

HISTORY OF EARLY CHILDHOOD INFECTIONS AND ACUTE LYMPHOBLASTIC LEUKEMIA RISK AMONG CHILDREN IN A U.S. INTEGRATED HEALTH CARE SYSTEM.
Morimoto LM, Kwan ML, Deosaransingh K, Munneke JR, Kang AY, Quesenberry C Jr, Kogan S, de Smith AJ, Metayer C, Wiemels JL. Am J Epidemiol. 2020 Apr 23.

Surrogate measures of infectious exposures have been consistently associated with lower childhood acute lymphoblastic leukemia (ALL) risk. However, recent reports have suggested that physician-diagnosed early life infections increase ALL risk, thereby raising the possibility that stronger responses to infections may promote risk. The authors examined whether medically diagnosed infections were related to childhood ALL risk in an integrated health care system in the United States. Cases of ALL (n=435) diagnosed between 1994-2014 at age 0-14 years along with matched controls (n=2170) were identified at Kaiser Permanente Northern California. Conditional logistic regression was used to estimate risk of ALL associated with history of infections during first year of life and across the lifetime (up to diagnosis).

Conclusions: History of infection during first year of life was not associated with ALL risk (odds ratio [OR]: 0.85, 95% confidence interval [CI]: 0.60, 1.21). However, infections with at least one medication prescribed (i.e., more "severe" infections) were inversely associated with risk (OR: 0.42, 95% CI: 0.20, 0.88). Similar associations were observed when the exposure window was expanded to include medication-prescribed infections throughout the subjects' lifetime (OR=0.52, 95% CI: 0.32, 0.85).