
Exposure to Electromagnetic Environment in Vicinity to Power Transmission Lines and Possible Health Effects: A Review

Yogambal Jayalakshmi. N

Research scholar

Department of Electrical and Electronics Engineering

Anna University Regional Campus, Coimbatore.

S.N. Deepa

Associate Professor

Department of Electrical and Electronics Engineering

Anna University Regional Campus, Coimbatore.

ABSTRACT

The possible relationship between human exposure to electromagnetic environment in the vicinity to high and extra high voltage (EHV) power transmission lines and their adverse health effects has become a subject to considerable public interest and concern. The preparation of this review have been carried out for the purpose of quantitative assessment of biological interaction and to evaluate the possible risks from exposure to low frequency fields under high voltage power transmission lines. Further this review have been extended to the analysis of corona generated space charge effects on living forms.

Keywords: *Electromagnetic environment, low frequency fields, biological interaction, health effects, corona generated space charge effects.*

I. INTRODUCTION

Electrical energy plays important role in our day to day life, the power is generated at generating stations and transmitted to consumers through high voltage power carrying lines. As power is transmitted for long distance, there is always associated electromagnetic field which gets interact with ground objects through inductive, capacitive and resistive couplings, this leads to fatal electric shock when ungrounded or poorly grounded conducting objects in the vicinity to transmission lines handled improperly. The nature of field under AC transmission line is time varying, in which the voltage and current move in a wave like pattern. Unlike AC transmission line the nature of field under DC transmission line do not change their direction while the energy is transmitted. The strength of these fields depends on geometry of conductors, strength of voltage and current through the line, and position of conductors with respect to measuring point. The magnitude of these field finds very high value near to the conductors and diminishes as the distance increases. The electric field is shielded by trees, concrete walls, fence, large vehicles, buildings etc. Unlike electric field the magnetic field cannot be shielded, so the impact of these fields on biological systems need to be concerned, but still the biological response of interaction of these fields have not been linked to any specific health hazards. Numerous reports have appeared in past few decades, that climb to link the exposure to low frequency electromagnetic radiation under transmission line and associated potential health effects.

According to Abdel-Salam H.A. Hamza et al.[1], the maximum specified value of magnetic field for small animals is of $0.04 \sim T$ and this value will increase for larger body area like human and concludes that the vicinity of power transmission line have adverse health effect, if the field value is higher than that of safe value. The epidemiological study carried out by K. J. Bunch et al. [2] conclude that the elevated risks for childhood leukaemia can be observed at distance 600 m for the largest power line and to lesser distance of

smaller power lines. Sander Greenland et al. [3] and A. Ahlbom [4] have published pooled analyses of childhood leukaemia cases in relation to magnetic field exposures. Together, these analyses from a number of well-conducted studies and concludes that up to $0.4 \sim T$ there is no effective level of relative risks and shows significantly relative risk of exposure greater than $0.4 \sim T$.

The time varying magnetic field interact with finite particles in viscous medium such as blood and causes changes in orientation of the magnetic particles, which leads to circulating current in human body (Fig.1) and results in more specific hypothesis such as possibility of cancer. The magnetic field suppress the production of melatonin and increase the breast cancer risk through increasing the circulation of estrogen [5], [6]. The melatonin is produced from amino acid called tryptophan in pineal gland during night time. The laboratory studies reveals that the presence of melatonin prevents the growth of ER-positive cancer [7]. The changes in melatonin level due to the exposure to magnetic field have been investigated in animal studies [8], [9], but not yet confirmed.

The air ions are simply atmospheric molecules that have lost or gain electron, the interaction of these ions with human body have been under investigation, as these ions were susceptible to get deposited in respiratory track and skin by electrostatic force. The extent of ions to deep alveoli of lung depends on the intensity of electric field, Bailey et al. [10]. Further the corona ion emitted from power transmission lines gets attached to charged aerosols, because of increasing the electric charge on these aerosols due to the corona generated space charge electric field, the probability of increasing the deposition of these particles in lungs, Denis et al. [11]. The corona generated space charges, also reported to the hypothesis of disturbing the production of melatonin and/or the circadian rhythm, which in turn leads to illness like leukemia.

The research on finding potential health effects are classified as experimental studies in laboratory settings, and epidemiological studies, among this the epidemiological studies can be classified into case-control studies and cohort studies. The case-control study is based on analyzing the exposure history of diseased and non – diseased populations under the area of interest and are reviewed in order to establish any significant changes identified in the exposure history. In case of cohort study, the analysis is based on the comparison of diseased and non-diseased groups among all the individuals under utility or concern, the individual group are classified as exposed and non-exposed group and are followed up for a period of time for the occurrence of diseases .

II. RISK RELATED TO CARCINOGENICITY IN ADULTS

A. CHILDHOOD LUKEMIA, BRAIN CANCER AND MELANOMA

A well designed epidemiological studies have been implemented for past few decades to investigate the health effects from exposure to low frequency electromagnetic environment. In the epidemiological study, within the area of exposure to interest and disease a population base is identified and during the course of study the disease status has been assessed periodically. Paul Elliott et al. [12] conducted a study to examine risks of adult cancer when exposed to extremely low frequency magnetic field in relation to distance from overhead power lines. In this study within 1000 m of a high voltage overhead power line about 7823 leukemia, 6781 brain/central nervous system cancer cases, 29202 female breast cancer cases, 9152 malignant melanoma cases were included such that considering one control per case of female breast cancer and three controls per case of all other diseases. The result of analysis includes, the mean magnetic field about $7.4 nT$ to $10.6 nT$ (nanotesla) ranged among controls and the odd ratios (ORs) ranged from 0.82 (0.61-1.11, for malignant melanoma, 95% CI) to 1.22(0.88-1.69, for brain/central nervous system (CNS) cancer) occurred at distance close to power transmission lines about (0-49 m). The ORs ranged from 0.68(0.39-1.17) for malignant melanoma to 1.08(0.77-1.51) for female breast cancer occurred at estimated field strength of $\geq 1000 nT$. This clearly indicates that there is no clear outlines of risk with distance from power lines.

The control study carried out by sahl et al. [13] at southern California Edison consist of 44 cases of leukemia and 32 cases of brain cancer were identified from death certificates. For each case under study 10 controls were selected based on age, gender and race of same frequency. The analysis was based on exposure to magnetic field of 776 days and the corresponding measurements were made with EMDEX II monitor among the employees in 35 occupational categories. The ORs based on the matrices scores of mean, median, 95th and 99th percentile, for duration of time exposed to $> 1.0 \sim T$ or $5.0 \sim T$ were close to less than 1.0. The ORs for leukemia and brain cancer in relation to various exposure scores does not reveal significant associations.

The childhood cancer investigation study carried out in the proximity to power transmission lines [14] implies that there is no evidence for any type of childhood leukemia or cancer possibility of occurrence from exposure to low frequency electromagnetic field. The investigation have been carried out among 3380 cases and 3390 control of children at a distance of 400 m from transmission lines or operating stations and about 20 m of underground cables. The vulnerability of risk for health hazard of the diseases have been reported with respect to distance from source of exposure and to the strength of exposed magnetic field. This study reveals that the ORs of 0.73(95% CI=0.42-1.26) for acute lymphoblastic leukemia, 1.08(95% CI=0.56-2.09) for CNS cancer, 0.75(95% CI=0.45-1.25) for all leukemia. The cases under exposure to the calculated magnetic field of $\geq 0.2 \sim T$ were compared with those exposed to the field strength of $< 0.1 \sim T$, the odd ratios have been estimated to be 0.51(95% CI=0.11-2.33) for acute lymphoblastic leukemia, about ROs of 0.48(95% CI=0.06-3.76) for CNS cancer, 0.41(95% CI=0.09-1.87) for total leukemia and 0.62(95% CI=0.24-1.61) for all malignancies were obtained.

The case study by the authors Lowenthal et al.[15] on the residential exposure to electric power transmission lines and risks, concludes that the possibility of risk for the development of myeloproliferative and lymphoproliferative disorders for prolonged residence close to high voltage power lines. This study have been carried out within the distance of 300 m from high voltage power lines on considering 854 cases who were diagnosed with LPD or MPD before the course of study had begun. The control were chosen based on age individually at the time of diagnosis. The odd ratios, OR of 2.06(95% CI=0.88-1.91) obtained for those living within 50 m from power transmission lines, for those who were living between 50 m and 300 m had OR of 1.30(CI=0.88-1.91), adult who had lived within 300m from power lines during their first 15 years were observed to prone to disease of risk ratio of 3.23 (CI=1.26-8.29), those who had lived for their first five years within the same distance had five times increased factor risk ratio of 4.74 (CI=0.98-22.9). Despite of limitations, the authors conclude that the risks of adult leukemia were strongly associated early childhood exposure to power transmission line magnetic field.

The epidemiological study of power lines and childhood cancer study in the UK [16], the cases were selected in subgroups of different age category and the risks have been analyzed based on distance from the nearest overhead transmission line to the case under study. The reference distance assumed to be (0-199) m, (200-599) m, (600-999) m, above 1000 m and subjects above 1500 m were omitted (table 1 of [16]). The overall study conclude that, there is some elevated risks for childhood leukemia associated with exposure to magnetic field under overhead transmission lines.

The pooled analysis of Kheifets et al.[17],[18],[19],[20] on childhood leukemia studies published between the year 2000 and 2010 did not shown any possibility of risk estimate at exposure level below $0.3 \sim T$, at exposure to magnetic field of levels $0.3 \sim T$ there is associated moderate risk but statistically non-significant. Swanson et al. studied the role of corona generated space charge from AC power transmission line in childhood cancer development. This study conclude that there is no empirical support for corona ion hypothesis on cancer development in the vicinity to power transmission lines.

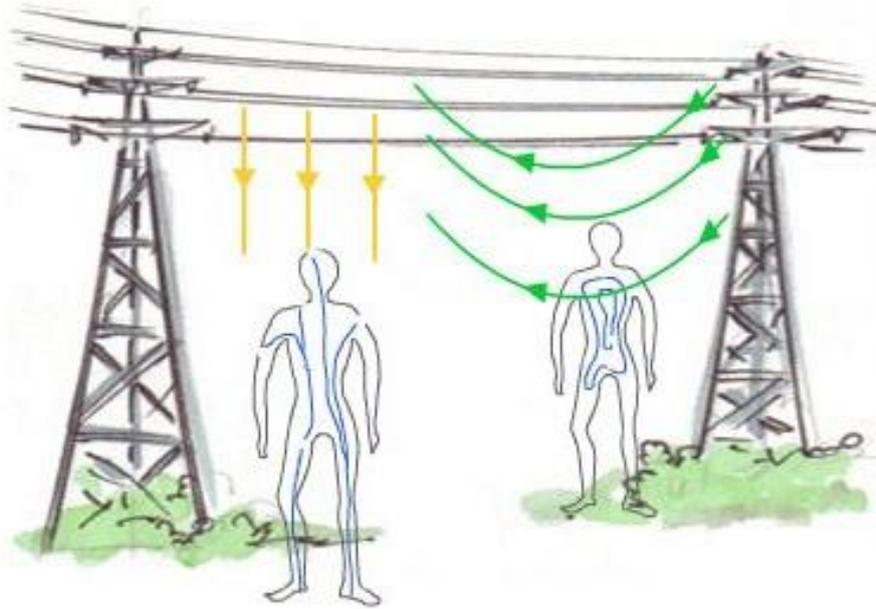


Fig 1: The induced current on human under transmission line due to electric and magnetic field of 50 Hz AC supply.

B. BREAST CANCER

The effect of magnetic field on breast cancer have been analyzed in several literatures for past few years, few epidemiological studies associated with this hypothesis have been analyzed and the observations were listed in this section.

Matanoski et al. [21] reported male breast cancer based on the study of 50582 technicians in a cohort of telephone employees. This included the both line and non-line workers, where the line workers like central office technicians were supposed to higher exposure of mean magnetic field than that of other line and non-line workers. The result shows that, among 65 men of central office technicians 2 were reported with positive breast cancer and 1 was in a cable splicer, and 1 was in non-line men workers. The study concludes that the complex field environment under which the central office technicians were supposed to work leads to higher risk factor for breast cancer than those among telephone line workers and cable splicers, whose major source of electromagnetic exposure from 60 Hz AC current. But later from the study by Malkin et al. [22] it was found that the exposure to ionizing radiations from radium gas tubes, which were carried by these technicians in their pocket prone to the risk of breast cancer.

The nested cohort study carried out by Li et al. [23] among more than 267,000 female workers in Shanghai. The authors identified the breast cancer cases between the years 1989 and 2000 and compared their estimated exposure to non-cases of 4,702. Based on the work history and their exposure the complete job exposure matrix have been developed for the cohort. The final conclusion implies that there is no elevated risks of breast cancer with exposure to low frequency electromagnetic field.

The combined effect of occupational and residential exposure to magnetic field and breast cancer in females have been studied by Feychting et al. [24] in Sweden based on the study base of 215820 women who had lived at least one year on the corridor within 300 meters from 220kV or 400 kV transmission line. The residential magnetic field assessment under the study was assumed to be the magnetic field generated from power transmission lines and the field was calculated theoretically. The occupational exposure to magnetic field assessment was based on the last census statistics before the diagnosis. The study have been carried out

for all three cases such as exposed only to residential magnet field, exposed only to occupational magnetic field, exposed to both occupational and residential magnetic field, in the interval at $0.10\sim T$ - $0.20\sim T$ and higher cutoff point $\geq 0.25\sim T$. This study reveals that the women of age group <50 years for whom the relative risk of breast cancer was estimated to be OR of 3.2(95% CI=0.5-9.8) under only occupational exposure case. In case of only residential exposure, the OR of 1.6(95% CI=0.5 to 4.8) and for the combined exposure of occupational and residential magnetic field, the risk was estimated to be ORs of 3.2(95% CI=0.5-18.9) for maximum cutoff point of magnetic field $\geq 0.25\sim T$. But this study has limitations like, no occupational information was found as for 10% of cases 11% were controls, in 26% of cases 25 % of controls were house wives. For employed women of 34% among cases, 32% of control were working in environment where no exposure to magnetic field. Lack of complete pair information for cases and control leads to negative associations.

The study [25], among more than 80,000 electricity generation and transmission workers between 1973 and 2008 for risk of breast cancer reveals that, there is no significant association were reported for either men or women breast cancer.

C. LUNG CANCER

The presence of power line generated corona charges in the environment can be associated with the modification of the earth's natural electric field, the charged ions are supposed to have ability to penetrate into the human body, the increase in deposition of charged aerosols in human body under power transmission lines increased by factor of two to three fold under strong field [26]. There is evidence in literatures indicating lung cancer is strongly associated with air pollution apart from smoking.

The study of authors David et al.[27] to investigate the possibility of lung cancer due to exposure of electromagnetic field strongly suggest that, the possibility of lung cancer is not associated with exposure magnetic field and also there is no risk found with respect to duration of exposure to the field. In this study, a cohort of 138 905 cases were followed up for mortality due to lung cancer to the end of two years from the date of study begun. The mortality from lung cancer have been surveyed based on strength of the field and duration of exposure to the 60 Hz magnetic field. The cumulative indices of RRs found to be 1.2 to 1.3 indicates that there is no positive association with respect to disease.

The nature of corona generated space charges under AC and DC transmission lines are different. For large power transmission HVDC lines are used, in such case the field under positive polarity conductors mainly comprises of positive charges and the ionic environment under negative polarity consist of negative ions. The effect of positive and negative ion on human body have been under investigation, some studies strongly emphasis that, the positive ions create negative impact on body and negative ion provides positive impact to human health. The comprehensive review by Dominik D Alexander et al. [28] conveys that there is no basis of beneficial or deleterious effect of air ions or clusters of air ions on human respiratory function. The study was based on literatures published (1933 - 1993) that relevant met the hypothesis. Despite of numerous analytical and experimental difference across studies, the authors conclude that there is no appreciable role of positive and negative ions in respiratory function.

D. DEPRESSION AND ANXITY DISORDERS

The relation between exposure to ionic environment and human mood have been under investigation throughout the years, but still their evidences were inconsistent. The cardiac pressure of men and women of different ages were analyzed in the course of experiment under study, the subjects were submitted to the activity of positive and negative ions for several hours of the day. The peoples were subjected to the active negative ion concentrations of $10,000$ ions/cm³ resulted in 5% drop in systolic pressure and 2% drop in diastolic pressure yet it does not affect the pulse, exposure to the positive ion concentration of $25,000$ ions/cm³ was associated with destabilization of circulatory indicators.

The nested case control study of Van Wijngaarden et al. [29], studied about exposure to low frequency magnetic field and its relation to suicide. The methodology of the study was based on assumption of 536 cases of death from suicide and 5348 of control in a cohort of 138,905 male utility workers. The increased OR were found for the cases under exposure to higher magnetic field strength, the OR estimated to be 2.18(95%CI=1.25 to 3.80), OR of 1.59(95%CI=1.18 to 2.14), and OR of 0.67(95%CI=0.33 to 1.40) for electrician, lineman, and for power plant operators respectively. The study conclude that there is possibility of association between electromagnetic field and suicide that needs further evaluation.

The cohort study of 12,063 persons who have answered self-related depressive symptoms under exposure to overhead 110 kV to 400 V transmission lines about 20 years of exposure history were obtained from Finish Transmission Line Cohort study, Verkasalo PK et al. [30], the analysis provides some assurance that there is no elevated risk of depression found from exposure to magnetic field, but the severity increases for the distance within 100 m of transmission lines. The authors suggested that the better understanding of the relation between the course of depression and the characteristics of exposed magnetic field is to be further extended.

The meta- analysis of Anders Ahlbom [31] on neurodegenerative diseases, suicide and depression symptoms in relation to EMF, concluded that there is weak association between suicide and EMF but there is identified risk for amyotrophic lateral sclerosis and also the author suggests that there is not enough information for an assessment for disease such as Parkinson's disease.

In the systematic review of Chirstos Baliatsas et al. [32], the Meta–analyses were performed to strength the conclusion that there is no association between symptoms and higher EMF exposure. The odd ratios were found to be 1.65(95% CI=0.88-3.08) for head ache, 1.28(95% CI=0.56-2.94) for concentration problems, OR of 1.15(95% CI=0.59-2.27) for dizziness related problems for system severity, for system frequency the odd ratios found to be 1.01(95% CI=0.66-1.53) for head ache, 1.18(95% CI=0.80-1.74) for sleep related problems, OR of 1.12 (95% CI=0.60-2.07) for fatigue. The study did not find any evidence for direct association between frequency of exposure and severity of disease related symptoms.

III. OBSERVED RESULTS FROM REVIEWS MADE

All the identified literatures were studied and information relevant to the hypothesis was distinguished. The review has been carried out based on the following factors, first based on the environment under where the relative risk assessment was studied with respect to distance from the source of exposure and the strength of magnetic field. Second, to answer whether risk associated with specific job title. Third to make an attempt to relate the hypothesis and risk factor by considering most of pooled analysis in the literatures. On overall, from the comprehensive analysis of the review (Table.1), the diseases like childhood leukemia, brain/central nervous system cancer, melanoma, myeloproliferative and Lymphoproliferative disorders, breast cancer there is no risk found below magnetic field strength of $0.3 \sim T$, above $0.3 \sim T$ there is significant association found and it is yet to be proven. The studies which reveals strong association between the cause and effect also have limitations and lack of information.

The assessment report of WHO on static and magnetic and electric field effects in 2006 concludes that, there is association between exposure to magnetic field and acute affects for interval of field strength above 10,000 G, but according to IARC (2002) concludes that there is no sufficient evidence to draw any conclusion about carcinogenicity of magnetic fields based on experimental studies. According to NRPB (National Radiological Protection Board), for static electric fields the limiting exposure is between 20 kV and 25 kV/m, the direct perception cause micro shock due to static induction, and also there has been no risk found under exposure to magnetic field strength of 2 T (20,000 G), but there is possibility of biological effects about exposure to 5-8 T.

Table.1
Results noted from literatures

Reference	Disease	Observation
Greenland et al. [3]	Childhood Leukemia	No risk found
A Ahlbom et al.[4]	Childhood Leukemia	No risk found
Elliott et al.[12]	Leukemia, brain/central nervous system cancer, female breast cancer, malignant melanoma	No elevated risk found
sahl et al.[13]	Leukemia , Brain cancer	No elevated risk found
UK-Childhood cancer investigation[14]	Childhood leukemia and cancer	No risk found
Lowenthal et al.[15]	Myeloproliferative, Lymphoproliferative disorders.	Risk found with limitations
UK childhood cancer study [16]	Childhood leukemia	Risk found
Kheifets et al. [17],[18],[19],[20]	Childhood leukemia	No risk found
Matanoski et al.[21]	Male breast cancer	Risk found
Li W et al. [23]	Female breast cancer	No risk found
Feychting et al. [24]	Female breast cancer	No risk found on considering limitations
Sorahan T[25]	Male and female Breast cancer	No risk found
David et al.[27]	Lung cancer	No risk found
Dominik et al.[28]	Effect of air ions in respiratory system	No beneficial or deleterious role of positive or negative ions found
Van Wilingaarden et al. [29]	Suicide	Possibility of association between exposure to EMF and suicide
Verkasalo P K et al.[30]	Depression	No risk found
Anders Albom et al.[31]	1. Neurogenerative disease, suicide , depression 2. Amyotrophic lateral sclerosis	Weak association between suicide and Emf exposure Risk identified

IV CONCLUSION

The debate between the hypothesis and results sounds very familiar for past few decades, but still the major problem exists such that, none of the proposed studies validate how is the low frequency magnetic field interact with living system and supposed to cause diseases like cancer, leukemia, stress, depression, melanoma, etc. But also it is to be noted that a number of well-defined epidemiological studies have stated that there is no relation exist between exposure to low frequency electromagnetic field and human metabolic changes. There is insufficient evidence to prove the associated illness with exposure, overall the mechanism by which the interaction of power frequency electromagnetic in the vicinity to power transmission line with living system and related risk estimate to diseases remains unproven.

REFERENCES

- [1] Abdel-Salam H.A. Hamza, Shaher A. Mohmoud, Samy M. Ghania, Environmental pollution by magnetic field associated with power transmission lines, *Energy Conversion and Management* 43 (2002) 2443–2452.
- [2] K J Bunch, J Swanson, T J Vincent and M F G Murphy, Epidemiological study of power lines and childhood cancer in the UK: further analyses, *Journal of Radiological Protection, J. Radiol. Prot.* 36 (2016) 437–455.
- [3] Sander Greenland,1 Asher R. Sheppard,2 William T. Kaune,3 Charles Poole,4 and Michael A. Kelsh,5 for the Childhood Leukemia-EMF Study Group, A Pooled Analysis of Magnetic Fields, Wire Codes, and Childhood Leukemia, 2000.
- [4] A Ahlbom, N Day, M Feychting, E Roman, J Skinner, J Dockerty, M Linet, M McBride, J Michaelis, JH Olsen, T Tynes and PK Verkasalo, A pooled analysis of magnetic fields and childhood Leukaemia, *British Journal of Cancer* (2000) 83(5), 692–698.
- [5] Stevens R G, Electric power use and Breast Cancer: a Hypothesis, *Am J Epidemiol* 1987; 125:556 – 561.
- [6] Stevens R G, Biologically based epidemiological studies of electric power and cancer: *Environ Health Perspect* 1993; 101 (supply 4):93-100.
- [7] Hill S M, Blast D E, Effects of the pineal hormone melatonin on the proliferation and morphological characteristics of human breast cancer cells (MCF-7) in culture. *Rev.* 1986; 8:42-59.
- [8] Reiter R.J, Melatonin suppression by static and extremely low frequency electromagnetic field: Relationship to the reported increased incidence of cancer. *Rev Environ Health* 1994; 10:171-186.
- [9] Lambrozo J, Tocitou Y, William D, Exploring the Emf – Melatonin Connection: a review of the possible effects of 50/60Hz electric and magnetic fields on melatonin secretion. *Int J occup Environ Health* 1996; 2:37-47.
- [10] Biley W H, Bissell M; Brambi R M, Dron C R, Hoppel W A, Sheppard A R, Stebbings J H, A Health and Safety Evaluation of the +/- 400 kV DC power line. Minnesota Environmental Quality Board, December 1982.
- [11] Denis L. Henshaw, Jonathan P. Ward and James C. Matthews, Can disturbances in the atmospheric electric field created by power line corona ions disrupt melatonin production in the pineal gland?, *J. Pineal Res.* 2008; 45:341–350
- [12] Paul Elliott, Gavin Shaddick, Margaret Douglass, Kees de Hoogh, David J. Briggs, and Mireille B. Toledano, Adult Cancers Near High-voltage Overhead Power Lines, *Epidemiology* 2013.
- [13] Sahl, J.D., Kelsh, M.A. & Greenland, S. (1993). Cohort and nested case-control studies of hematopoietic cancers and brain cancer among electric utility workers. *Epidemiology*, 4, 104-114.
- [14] UK Childhood Cancer Study Investigators, Childhood cancer and residential proximity to power lines, 2000 Dec; 83(11): 1573–1580
- [15] Lowenthal M, Tuck D. M, and Bray I. C, Residential exposure to electric power transmission lines and risk of lymphoproliferative and myeloproliferative disorders: a case-control study, *Internal Medicine Journal* 37 (2007) 614–619
- [16] K J Bunch, J Swanson, T J Vincent and M F G Murphy, Epidemiological Study of Power Lines and Childhood Cancer in UK – Further Analysis. *J. Radiol. Prot.* 36 (2016) 437– 4555
- [17] Kheifets L, Monroe J, Vergara X, Mezei G, Afifi AA. Occupational electromagnetic fields and leukemia and brain cancer: an update to two meta-analyses. *J Occup Environ Med* 50: 677-688, 2008.
- [18] Kheifets L and Oksuzyan S. Exposure assessment and other challenges in non-ionizing radiation studies of childhood leukaemia. *Radiat Prot Dosimetry* 132: 139-147, 2008.

- [19] Kheifets L, Bowman JD, Checkoway H, Feychting M, Harrington JM, Kavet R, Marsh G, Mezei G, Renew DC, van Wijngaarden E. Future needs of occupational epidemiology of extremely low frequency electric and magnetic fields: review and recommendations. *Occup Environ Med* 66: 72-80, 2009.
- [20] Kheifets L, Ahlbom A, Crespi CM, Draper G, Hagihara J, Lowenthal RM, Mezei G, Oksuzyan S, Schüz J, Swanson J, Tittarelli A, Vinceti M, Wunsch Filho V. Pooled analysis of recent studies on magnetic fields and childhood leukaemia. *Br J Cancer* 103: 1128-1135, 2010.
- [21] Genevieve M. Matanoski, Electromagnetic field exposure and male breast cancer, *The Lancet*.
- [22] Malkin, R., Moss, C.E., Loomis, D.P., Savitz, D.A. & Ananth, C.V. (1994). Re: breast cancer mortality among female electrical workers in the United States (letter and reply). *Journal of the National Cancer Institute*, 86, 1801-1802.
- [23] Li W, Ray RM, Thomas DB, Yost M, Davis S, Breslow N, Gao DL, Fitzgibbons ED, Camp JE, Wong E, Wernli KJ, Checkoway H. Occupational exposure to magnetic fields and breast cancer among women textile workers in Shanghai, China. *Am J Epidemiol* 178: 1038-1045, 2013.
- [24] Forssen UM, Feychting M, Rutqvist LE, Floderus B, Ahlbom A, Occupational and residential magnetic field exposure and breast cancer in females. *Epidemiology* 2000 Jan;11(1):24-9.
- [25] Sorahan T. Cancer incidence in UK electricity generation and transmission workers, 1973-2008. *Occup Med (Lond)* 62: 496-505, 2012.
- [23] Li W, Ray RM, Thomas DB, Yost M, Davis S, Breslow N, Gao DL, Fitzgibbons ED, Camp JE, Wong E, Wernli KJ, Checkoway H. Occupational exposure to magnetic fields and breast cancer among women textile workers in Shanghai, China. *Am J Epidemiol* 178: 1038-1045, 2013.
- [24] Forssen UM, Feychting M, Rutqvist LE, Floderus B, Ahlbom A, Occupational and residential magnetic field exposure and breast cancer in females. *Epidemiology* 2000 Jan; 11(1):24-9.
- [25] Sorahan T. Cancer incidence in UK electricity generation and transmission workers, 1973-2008. *Occup Med (Lond)* 62: 496-505, 2012.
- [26] Fews A.P, Henshaw D. L, Keitch P.A, Close J.J, Wilding R.J, Increased Exposure to pollutant aerosols under High Voltage Power Lines, *International Journal of Radiation Biology*, 1999.
- [27] David A Savitz, Vincent Dufort, Ben Armstrong, Gilles Theriault, Lung cancer in relation to employment in the electrical utility industry and exposure to magnetic fields. *Occupational and Environmental Medicine* 1997; 54:396-402.
- [28] Dominik D Alexander, William H Bailey, Vanessa Perez, Meghan E Mitcheil, and Steave Su, Air ions and respiratory function outcomes: a comprehensive review, *International Journal of negative results in Biomedicine* 2013.
- [29] Van Wijngaarden E, Savitz DA, Kleckner RC, Cai J, Loomis D, Exposure to electromagnetic fields and suicide among utility workers: a nested case- control study, *Occup Environ Med* 2000;57:258-263.
- [30] Verkasalo P K, Kaprio J, Varjonen J, Romanov K, Heikkila K, Koskenvuo M, Magnetic fields of transmission lines and depression. *Am J Epidemiol*.1997.
- [31] Anders Ahlbom, Neurodegenerative Diseases, Suicide and Depressive Symptoms in Relation to EMF, *Bioelectromagnetics Supplement* 5:S132-S143 (2001).
- [32] Christos Baliatsas, Irene Van Bolte, Maarten Schipper, Joris Yzermans, Erik lebre, *Environment International*, 2012.
- [33] N. Yogambal Jayalakshmi, S.N.Deepa, Modelling Of Electric and Magnetic Fields under High Voltage Ac Transmission Line, *IOSR Journal Of Electrical and Electronics Engineering*, 2016.
- [34] Adel Z. El Dein, Calculation of the Electric field around the tower of the overhead transmission Lines, *IEEE Transactions on Power Delivery*, Vol. 29, No. 2, April 2014.
- [35] Zhilong Zou, Dayong Li, Jiayu Xu, Xiang Cui, Tiebing Lu, Xingming Bian, Impact of fine particles on the direct current electric field of the conductor due to corona discharge, *Journal of Electrostatics*, 2017.
- [36] E.M. Bazelyan, Yu.P. Raizer, N.L. Aleksandrov The effect of space charge produced by corona at ground level on lightning attachment to high objects, *Atmospheric Research-153* (2015).