International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435(Online) Volume 14, Issue 12, December 2025)

Occupational Health Risks Associated with Extremely Low Frequency-Electromagnetic Fields and Light-at-Night Exposure: A Focus on the Melatonin Hypothesis

Vemula Surender[1], Potti Ravindra Babu[2], R Tiwari[3]

[1]*Department of Life Sciences-UGC Research Unit, Bhavan's New Science College, Hyderabad, Telangana, India.*
[2]*Department of Biotechnology, Sreenidhi Institute of Science and Technology, Hyderabad, Telangana, India.*
[3]*Dean, Global Institute of Engineering & Technology, Moinabad, Hyderabad. Telangana, India.*

***Abstract*--Present day society is characterized by the widespread use of electric power, resulting in continuous exposure to electromagnetic fields (EMFs) and artificial light at night (LAN). The extensive use of electrical and electronic devices has led to increased emission of electromagnetic radiation, which some scientists suggest may produce biological effects. Extremely low-frequency electromagnetic fields (ELF-EMFs) and LAN has been hypothesized to alter hormonal regulation, particularly melatonin secretion, thereby potentially contributing to cancer development. Women, especially nurses, are considered a high-risk group due to occupational exposure to both ELF-EMFs and LAN. In this study, blood samples from occupationally exposed subjects and non-exposed controls were analyzed. Plasma melatonin levels were measured using radioimmunoassay (RIA). DNA damage was assessed using the alkaline comet assay and micronucleus test, along with gene expression analysis by RT-PCR. The results showed a statistically significant suppression of plasma melatonin levels in occupationally exposed subjects ($p < 0.05$). DNA damage ranged from 8 µm to 10 µm, with Group C exposed subjects exhibiting the highest levels of damage. Overall, occupationally exposed individuals were found to be more vulnerable to electromagnetic stress, as indicated by reduced melatonin concentrations and increased DNA damage.**

***Keywords*-- Melatonin, ELF-EMFs, Light at Night, DNA damage and MNT.**

I. INTRODUCTION

Melatonin is a neuroendocrine hormone and an indoleamine (N-acetyl-5-methoxytryptamine) secreted by pinealocytes of the pineal gland, which is located in the hypothalamic region of the brain. It plays a key role in regulating circadian rhythms and controlling the sleep–wake cycle, functioning as an internal 24-hour biological clock. Melatonin has also been reported to act synergistically with other agents and to significantly enhance anti-ulcer activity [1].

Melatonin exhibits hypothermic, antioxidant, and free-radical scavenging properties, which contribute to its role as an immune modulator and an oncostatic (anti-cancer) agent. According to the "melatonin hypothesis" of cancer, exposure to light at night (LAN) and anthropogenic electric and magnetic fields (EMFs) may increase the risk of breast cancer by disrupting normal melatonin secretion [2]. It is also important to note that night-shift workers are more likely to experience obesity and unhealthy lifestyle patterns, which may further contribute to breast cancer risk. In addition, controversial reports have increasingly suggested potential health effects of radiofrequency (RF) electromagnetic field exposure, including associations with neurodegenerative disorders and brain tumors [3].

At low frequencies, electromagnetic fields can affect the nervous system due to its high sensitivity to such exposures. Beyond neurological effects, EMFs may also influence psychological conditions. Furthermore, exposure to electromagnetic fields may lead to thermal effects, resulting in a rise in body temperature [4].

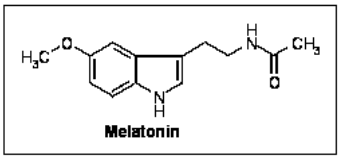

Fig 1: Melatonin

The aim of the present study was to examine the association between melatonin levels and the increased incidence of breast cancer in urbanized populations. It has been reported that night-shift work may lead to depletion of melatonin and disruption of circadian rhythms. Such sleep disturbances are thought to suppress immune function through reduced melatonin production. Breast cancer remains the leading cause of cancer-related mortality among women in industrialized countries [5].

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435(Online) Volume 14, Issue 12, December 2025)

Light and Melatonin:

The effects of light on pineal gland function in humans have been extensively investigated [6]. These effects are qualitatively similar to those observed in other mammals, where increased intensity of nocturnal illumination suppresses melatonin production to levels typically seen during daytime [7]. The normal melatonin rhythm in humans exhibits characteristics that may be relevant to breast cancer risk [8]. Experimental studies in animals have demonstrated that even very brief exposure to light at night-lasting only minutes or seconds-can significantly suppress melatonin secretion.

Exposure to light at night (LAN) and anthropogenic electric and magnetic fields has been associated with an increased incidence of breast cancer, potentially due to disruption of melatonin production [9]. Although numerous studies have been conducted on this topic in recent years, the findings remain controversial and many questions are still unresolved [10]. Nevertheless, extremely low-frequency electromagnetic fields (ELF-EMFs) and LAN are hypothesized to induce alterations in hormonal regulation that may contribute to cancer development in women, particularly among night-shift workers [11]. The proposed mechanism by which ELF-EMF and LAN exposure may elevate cancer risk involves the possible oncostatic properties of melatonin and the reduction of its circulating levels [12].

Electric and Magnetic Fields and Melatonin:

The earliest reports suggesting that the pineal gland may respond to artificial electromagnetic fields (EMFs) emerged in the early 1980s [13]. Studies examining the electrical activity of pineal cells in anesthetized male guinea pigs provided initial evidence of such responsiveness. Subsequent experiments demonstrated that exposure of male Sprague–Dawley rats to a 60-Hz electric field suppressed the normal nocturnal increase in pineal melatonin production [14]. In humans, epidemiological studies have also indicated a possible association between the use of wireless phones and the incidence of brain tumors [15]. We propose that melatonin's antioxidant properties may explain the biological effects of electromagnetic fields (EMFs). The rationale for this study is that increased free radical production in response to magnetic field exposure may lead to a reduction in circulating melatonin levels. Suppression of melatonin, together with prolonged free radical lifetimes, may further exacerbate DNA damage [16].

II. Materials And Methods

Female workers (n = 342) engaged in night-shift duties for approximately five years were recruited from various hospitals and business process outsourcing (BPO) centers located across Hyderabad, India. Selection criteria for both the exposed group and the control group (n = 150), who were not involved in night-shift work, included age, dietary habits, and the presence of any recent infections.

A detailed questionnaire was administered to assess subjective symptoms potentially related to EMF exposure. This included self-reported evaluation of non-specific symptoms such as headache, dizziness, tinnitus, visual disturbances, and sleep-related problems.

Sampling:

After obtaining informed consent, 5 mL of peripheral blood was collected from each volunteer by venipuncture during late-night hours (between 12:00 a.m. and 4:00 a.m.). One milliliter of whole blood was allowed to clot for serum separation, while the remaining 4 mL was collected in heparinized tubes. All samples were immediately placed on ice to minimize exogenous damage. The collected samples were subsequently processed in the laboratory for the estimation of plasma melatonin levels using radioimmunoassay (RIA) and for the assessment of DNA damage using the comet assay.

1. Alkaline Comet Assay:

DNA damage was assessed using the alkaline comet assay, also known as single-cell gel electrophoresis (SCGE) [17]. Exposed blood aliquots were centrifuged at 1,000 rpm for 5 minutes to sediment the cells. Cells from each sample were suspended in 0.67% low–melting point agarose and layered onto microscopic slides between a base layer of 0.75% normal–melting point agarose and a top layer of low–melting point agarose.

The slides were immersed overnight in freshly prepared, chilled lysis buffer containing 2.5 M NaCl, 100 mM Na_2EDTA, 10 mM Tris, and 1% sodium lauryl sarcosinate, with 1% Triton X-100 and 10% DMSO added immediately before use. Following lysis, the slides were incubated in alkaline electrophoresis buffer (1 mM Na_2 EDTA and 300 mM NaOH, pH 13) for 20 minutes to allow DNA unwinding. Electrophoresis was then performed at 0.67 V/cm and 300 mA for 30 minutes in the same alkaline buffer.

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435(Online) Volume 14, Issue 12, December 2025)

After electrophoresis, the slides were neutralized with 0.4 M Tris buffer (pH 7.5) and rinsed with distilled water. All procedures were carried out under dim light conditions to prevent additional photochemical DNA damage. The slides were then air-dried and stained using a silver staining method.

The staining solution consisted of 32 ml of solution A (25 g sodium carbonate dissolved in 500 ml double-distilled water) and 68 mL of solution B (100 mg ammonium nitrate, 100 mg silver nitrate, 500 mg tungstosilicic acid, and 250 µL formaldehyde dissolved in 500 mL double-distilled water). Stained slides were examined under a bright-field transmission light microscope at 40× magnification. Comet tail length, an indicator of DNA damage, was measured for 100 cells per sample using an ocular micrometer fitted to the eyepiece.

2. Melatonin Assay (Direct Radio Immuno Assay):

Plasma melatonin levels were quantitatively measured using a direct radioimmunoassay (RIA) as described by Fraser et al [18]. The assay is based on the principle that the amount of ^{125}I-labeled antigen bound to the antibody is inversely proportional to the analyte concentration in the sample. Standard melatonin from the Melatonin Direct RIA Kit (BA R 3300, LDN Labor Diagnostika Nord GmbH & Co. KG, Nordhorn, Germany) was used. During equilibrium, antibody-bound radioactivity is precipitated using a second antibody in the presence of polyethylene glycol. The resulting precipitate was counted using an Automatic Gamma Counter (Model No. 1480-11 Wizard 3, Perkin Elmer, USA). Quantification of unknown samples was performed by comparing their radioactivity to a standard calibration curve prepared with known melatonin concentrations.

Statistical Analysis

The mean ± standard error (SE) of each parameter was calculated for each exposure group. Comparisons between groups were performed using the Student's t-test and one-way analysis of variance (ANOVA).

III. Results

The general characteristics of the exposed group and controls are shown. The duration of occupationally exposed groups based on age shown.

The general characteristics of the exposed and control groups are presented in Table 1. The duration of occupational exposure, stratified by age, is also shown.

TABLE I
Occupationally Exposure characteristics based on duration

Duration Group	Age	Subjects (n)	Parameter	Mean ± SD
A (1-6 days)	19-45	121	Comet Tail length (CTL)	10.21 ± 1.28
		121	Melatonin (MEL)	38.1 ± 2.5
B (1 to 4 weeks)	19-45	114	Comet Tail length (CTL)	8.5 ± 1.1
		114	Melatonin (MEL)	37.5 ± 2.3
C (1 to 6 Months)	19-45	107	Comet Tail length (CTL)	8.8 ± 1.3
		107	Melatonin (MEL)	37.8 ± 2.5

Effect of ELF-EMFs on DNA by Comet Assay:

The comet tail was coinciding with 100 divisions of the Ocular ruler. Tail length observed was 4 divisions of Oculometer (OM). One Oculometer division (OD) for 40X objective lens was 2.5 µm. So the tail length of comet is 4 OD x 2.5 µm = 10 µm.

The results of basal DNA damage assessed by alkaline comet assay in terms of Mean ± SD comet tail length are summarized [Table I]. Independent t test showed significant difference in the mean comet tail length values [Figure 2 & 3] of exposed and control groups. [Table II].

TABLE II:
Results of Mean Concentrations of DNA damage, Melatonin, Micronucleus Test and RT-PCR levels between the Exposure and Control groups

Parameters	EXPOSED		CONTROLS		t-value	p-value
	N	Mean ± SD	N	Mean ± SD		
DNA damage	342	10.21 ± 1.28	150	4.21 ± 1.13	49.556	<0.001
Melatonin (pg/ml)	342	37.92 ± 2.72	150	98.00 ± 140.59	7.909	<0.001

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435(Online) Volume 14, Issue 12, December 2025)

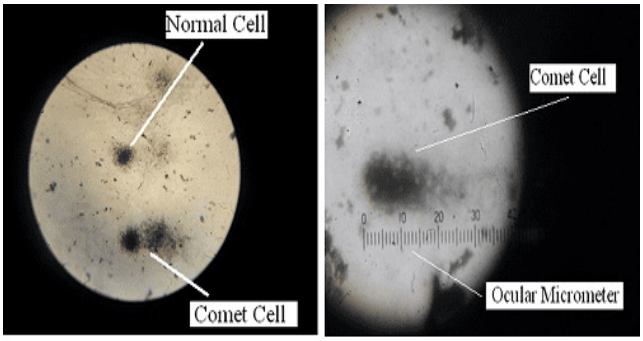

Fig 2: Single Cell Gel Electrophoresis Comet cell images

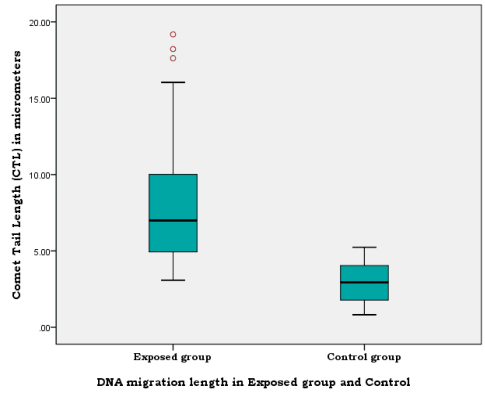

Fig 3: Box plot of DNA Damage in presence of comet tail length

Effect of ELF-EMFs on Melatonin Concentration:

The results of Melatonin concentration levels gradually decreased when the duration of exposure increased shown and also between Exposure and control groups [Table II]. [Figure 4].

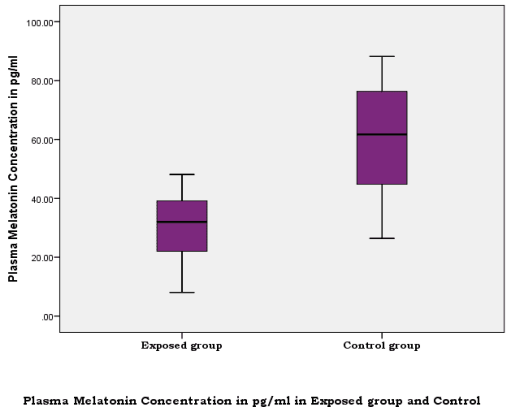

Fig 4: Box plot of Melatonin concentration levels

IV. Discussion

Research into the potential health effects of electromagnetic field (EMF) exposure has been ongoing for several decades. Numerous independent scientific committees and working groups have reviewed the literature and, with varying degrees of confidence, concluded that exposures to EMFs, as encountered in residential and most occupational settings, may pose adverse health effects in humans [19],[20]. Considering the overall "weight of evidence," particularly from human epidemiological studies, the International Agency for Research on Cancer (IARC) classified EMF exposure as a "possible human carcinogen" (IARC Class 2B)[21],[22],[23]. However, despite observed epidemiological associations between magnetic field exposure and certain health hazards, a definitive cause-and-effect relationship has not been established.

The present study indicates potential bioeffects of ELF-EMFs in subjects occupationally exposed to light at night. However, the general consensus in the scientific community is that, to date, evidence for harmful effects from environmental-level EMF exposure remains unsubstantiated, though the possibility cannot be entirely ruled out[24],[25].

V. Conclusion

Although the effects of EMFs on melatonin release have been extensively studied, the precise site and mechanism by which magnetic fields influence the pineal gland and alter melatonin synthesis remain unclear. It has been suggested that magnetic fields may affect melatonin production indirectly by altering neural inputs. Additionally, magnetic fields may be perceived by photoreceptors in the eye as a form of "light," leading to suppression of melatonin. This hypothesis has important implications for potential health effects associated with exposure to ELF magnetic fields in both public and occupational settings, particularly during nighttime.

Our results indicate a significant association between longer durations of intense night-shift work and altered melatonin levels, whereas shorter night-shift exposures showed relatively smaller effects. These findings underscore the need for further epidemiological studies that account for potential confounding factors.

Acknowledgements:

The authors gratefully acknowledge the University Grants Commission (UGC), New Delhi, for funding this major research project.

We also express our sincere gratitude to the late Prof. Y.R. Ahuja, Director of the Genetics Unit at Vasavi Medical and Research Centre, Hyderabad, and Co-Principal Investigator of this project, for his patient guidance and enthusiastic encouragement throughout the research. We are additionally thankful to the management of Bharatiya Vidya Bhavan's New Science College for their continuous support and cooperation.

Conflict of Interest:

The authors declare no conflicts of interest. They alone are responsible for the content and writing of this paper.

REFERENCES

[1] Nitin M. Girish M. Chetan M. Ather Javed. Krunal S. Krishna Kumar. Comparative Influence of Selected Antioxidants with Lansoprazole in Aspirin Induced Ulcer Model in Rats. Research Journal in Pharmacy and Technology. 2011;4(8):1273-1277

[2] Pepłońska B. Burdelak W. Krysicka J. Bukowska A. Marcinkiewicz A. Sobala W et al Night shift work and modifiable lifestyle factors. International journal of occupational medicine and environmental health. 2014; 27(5): 693-706. doi: 10.2478/s13382-014-0298-0.

[3] Choi KH. Ha M. Burm E. Ha EH. Park H. Kim Y et al Multiple assessment methods of prenatal exposure to radio frequency radiation from telecommunication in the Mothers and Children's Environmental Health (MOCEH) study. International journal of occupational medicine and environmental health. 2016; 29(6):959-972. doi: 10.13075/ijomeh.1896.00803

[4] Pedersen C. Poulsen AH. Rod NH. Frei P. Hansen J. Grell K et al Occupational exposure to extremely low-frequency magnetic fields and risk for central nervous system disease: an update of a Danish cohort study among utility workers. International archives of occupational and environmental health. 2017; 90(7): 619-628. doi: 10.1007/s00420-017-1224-0

[5] Ursin G. Bernstein L. Pike MC. Breast Cancer. Cancer Surv 1994;19/20:241-264. doi: 10.1186/bcr1525

[6] Wetterberg L. Light and Biological Rhythms in Man. Wenner-Gren International Series. Oxford: Pergamon Press 1993.

[7] Lynch HJ. Deng MH. Wurtman RJ. Light intensities required to suppress nocturnal melatonin secretion in albino and pigmented rats. Life Sciences 1985; 35(8): 841-847. doi: 10.1016/0024-3205(84)90409-0

[8] Morris M. Lack L. Barrett J. The effect of sleep/wake state on nocturnal melatonin excretion. Journal of pineal research. 1990; 9(2):133-138. doi: 10.1111/j.1600-079x.1990.tb00701.x.

[9] Reiter R. Action spectra, dose-response relationships, and temporal aspects of light's effects on the pineal gland. Annals of the New York Academy of Sciences.1985; 453: 215-230. doi: 10.1111/j.1749-6632.1985.tb11812.x.

[10] Halgamuge MN. Pineal melatonin level disruption in humans due to electromagnetic fields and ICNIRP limits. Radiation protection dosimetry 2013; 154(4):405-416. doi: 10.1093/rpd/ncs255

[11] Singh H. Kumar C. Bagai U. Effect of Electromagnetic Field on Red Blood Cells of Adult Male swiss albino Mice. International Journal of Theoretical & Applied Sciences 2013; 5(1): 175-182.

[12] Ohayon MM. Stolc V. Freund FT. Milesi C. Sullivan S. The potential for impact of man made super low and extremely low frequency electromagnetic fields on sleep. Sleep medicine reviews 2019. doi: 10.1016/j.smrv.2019.06.001

[13] Semm P. Schneider T. Vollrath L. Effects of an earth-strength magnetic field on electrical activity of pineal cells. Nature. 1980; 288 (5791): 607-608. doi: 10.1038/288607a0

[14] Wilson BW. Anderson LE. Hilton DI. Phillips RD. Chronic exposure to 60-Hz electric fields: effects on pineal function in the rat. Bioelectromagnetics 1981; 2(4): 371-380. doi: 10.1002/bem.2250020408

[15] Falcioni L. Bua L. Tibaldi E. Lauriola M. De Angelis L. Gnudi F et al Report of final results regarding brain and heart tumors in Sprague-Dawley rats exposed from prenatal life until natural death to mobile phone radiofrequency field representative of a 1.8 GHz GSM base station environmental emission. Environ Res 2018; 165:496-503. doi: 10.1016/j.envres.2018.01.037

[16] Ravindra T. Lakshmi NK. AhujaYR. Melatonin in pathogenesis and therapy of Cancer. Indian journal of Medical Sciences 2006; 60 (12): 523-535.

[17] Singh NP. McCoy MT, Tice RR, Schneider EL. A simple technique for quantitation of low levels of DNA damage in individual cells. Experimental Cell Research 1988; 17:184–191.

[18] Fraser S, Cowen P, Franklin M, Franey C, Arendt J. Direct radioimmunoasssay for melatonin in plasma. Clin Chem 1983; 29: 396–397.

[19] El-Setouhy M, Loffredo CA, Radwan G, Abdel Rahman R, Mahfouz E, Israel E, et al. Genotoxic effects of waterpipe smoking on the buccal mucosa cells. Mutat Res. 2008;655(1-2):36–40.

[20] AGNIR-Advisory Group on Non-Ionising Radiation, Power Frequency Electromagnetic Fields, Melatonin and the Risk of Breast Cancer. Chilton, Health Protection Agency 2006; (Documents of the Health Protection Agency, Series B: Radiation, Chemical and Environmental Hazards, RCE-1)

[21] The International Agency for Research on Cancer (IARC). Non-ionizing Radiation, Part 2: Radiofrequency Electromagnetic Fields 2013; 102: 462 pages.

[22] Radiofrequency (RF) Evaluation Report. 2013; URS, Omaha Nebraska.

[23] Position Statement on EMF Radiation Concerns. 2018; https://ehs.unc.edu/radiation/emf/.

[24] Jackson JD. Are the stray 60-Hz electromagnetic fields associated with the distribution and use of electric power a significant cause of cancer? Proc Natl Acad Sci 1992; 89(8): 3508-3510.

[25] Ravindra T, Lakshmi NK, Ahuja YR. Melatonin in pathogenesis and therapy of Cancer. Indian journal of Medical Sciences 2006; 60 (12): 523-535.