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Occupational EMF exposure and risk of breast cancer

Abstract. In this work the author introduced the procedure using the current knowledge relating to biological effects of the occupational exposure on electromagnetic fields. The relationship between exposure to EMFs and human breast cancer was discussed. The biological effects of EMFs are still controversial, in general, the negative effects should not be ignored.

Streszczenie. Przedstawione zostały aspekty związane z ekspozycją środowiskową na sztucznie generowane pole elektromagnetyczne oraz raportowane przez badaczy powiązania wzrostu ryzyka zachorowania na raka piersi u osób ekspozowanych na oddziaływanie PEM. Wyniki badań, gdzie wskazuje się negatywny wpływ ekspozycji powinny być rozwijane. (**Ekspozycja zawodowa PEM a ryzyko zachorowania na raka piersi**).

Keywords: breast cancer, electromagnetic field, occupational exposure.

Słowa kluczowe: rak piersi, pole elektromagnetyczne, ekspozycja zawodowa.

Introduction

People in the modern world frequently are exposed to electromagnetic fields (EMFs). Human exposure to EMFs comes from many sources. There are several references that classify EMFs. In general, the review of research on protecting workers from proven and possible EMF health risks, consist of four types: (1) RF (radio frequencies), (2) ELF (extremely low frequencies), (4) IF (intermediate frequencies), (4) static magnetic fields. Since the 80s of the last century scientists are investigated the interaction of EMF with biological systems. The opinions of researchers about the influence of EMF on living organisms are divided. This is due to the fact that studies ambiguously indicate negative, positive or neutral influence of electromagnetic fields or electromagnetic radiation. The scale of this problem illustrated fact that in the US National Library of Medicine of National Institutes of Health [1], from 2000 year over 200 epidemiological studies (results was filtered for phrase "emf exposure mobile phone") were published about the effects of electromagnetic fields generated by mobile phones on human health and being.

The indicated effects of these fields are very diversified. The public controversy arose especially over the issue of safety of use of microwave oven, cell phones, base stations or power lines. Several studies published in the 1980s and early 1990s reported that people who worked in some electrical occupations that exposed them to ELF radiation had higher-than-expected rates of some types of cancer, particularly brain tumors, leukemia and male breast cancer. The evaluation conducted by the World Health Organization [2] indicated that extremely low-frequency magnetic fields are possibly carcinogenic to humans, while static electric and magnetic fields and extremely low-frequency electric fields are not classifiable as to their carcinogenicity to humans. Extremely low frequency electromagnetic fields are 0-300 Hz electromagnetic fields mainly generated by "power transmission lines, power equipment or appliances" [2, 3]. On the other hand the rapid development of industry and technology caused that exposure to ELF-EMFs is increasing. People are exposed to various types of electric devices generated electromagnetic field. The questions of cancer in relation to EMF's bio-effects and power-frequency magnetic and electric fields need to be investigated.

Occupational electromagnetic field (EMF) exposure has been suggested as a risk factor for human breast cancer [4, 5, 6, 7, 8, 9, 10, 11]. Breast cancer is a multifactorial and the most commonly diagnosed cancer among women. Men are also suffer from this kind of cancer. The effectiveness of treatment depends on early detection of the disease. As the etiology and progression of breast cancer remain poorly

understood, novel routes of disease pathogenesis are important to consider.

Environmental factors for human breast cancer

The relationship between the occupational factors and the risk of human breast cancer need to be studied, especially in view of the large number of women and men exposed to EMF. MF exposure is hypothesized to increase the risk of breast cancer primarily by reducing production of melatonin by the pineal gland, which could alter the risk of breast cancer [12]. Studies on occupational exposures to MFs were insufficient. The aim of the review was to investigate the potential association of breast cancer risk with occupational EMF exposure.

The risk factors for human breast cancer include genetic mutations, lifestyle and reproductive status. On the other hand the evaluation of occupational factors for breast cancer (in the workplace) remains to be explained.

Currently popularity computer-aided diagnostic systems of cancer, including breast cancer, is growing. Selected types of material, e.g. obtained by needle biopsy, are analysed. The cell nuclei [13, 14, 15] analysis allows to classify lesions into types. These methods can be used in attempting to determine the biological effects from EMF's exposure.

A systematic summary of the selected studies and meta-analysis is available in Table 1 and Table 2. These studies or meta-analysis were published between 2001 and 2016 in English. All the considered materials research and the results of the analysis were obtained from US National Library of Medicine [1].

Table 1. The characteristics of included studies on the relationship between EMF exposure and breast cancer risk.

1st author (year of publication)	Study period	Sample Size(n) case/control or participants
Koc (2001) [16]	1990-2000	196
Van Wijngaarden (2001) [17]	1993-1995	843/773
Labrèche (2003) [18]	1996-1997	608/667
Schoenfeld (2003) [19]	1996-1997	576/585
Kliukiene (2004) [20]	1980-1996	1830
Forssen (2005) [21]	1976-1999	20400/111247
McElroy (2007) [22]	not specified	6213/7390
Peplonska (2007) [23]	2000-2003	2386/2502
Elliott (2013) [24]	1974-2008	29202/79507
Li (2013) [12]	1989-2000	1687/4702 (267400)
Grundy (2016) [25]	not specified	115/570

Table 2. The characteristics of included meta-analysis on the relationship between EMF exposure and breast cancer risk.

1st author (year of publication)	Year of published included research reports	Research reports/ database
Feychting (2006) [26]	1987-2005	26 studies
Davanipour (2009) [27]	2005, 2008	2 studies
Marcilio (2009) [28]	1998-2008	15 studies
Chen (2010) [29]	2000-2009	15 studies including 24,338 cases and 60,628 controls / Medline, PubMed, Embase, the Cochrane Library and Web of Science
Chen (2013) [30]	1990-2012	23 case-control studies
Sun (2013) [31]	1979-2012	7 case-control and 11 cohort studies was identified / Medline, PubMed, Embase, Cochrane Library, Web of Science, the Chinese National Knowledge Infrastructure
Zhao (2014) [32]	2000-2007	16 research reports of case-control studies
Zhang (2016) [33]	Publication data were not restricted	42 studies involving 13,259 cases and 100,882 controls / PubMed, EMBASE, ISI Web of Science, The Cochrane Library, ScienceDirect, EBSCO, Ovid, Wiley Online Library, and HighWire

Epidemiological and experimental studies demonstrated that ionizing and non-ionizing radiation exposure was defined environmental factors for breast cancer.

A summary of included studies' conclusions is available in Table 3.

The researchers reported that: (1) "occupational exposure to EMF may be linked to a slight elevation in breast cancer risk"; (2) "no evidence of an elevated risk of breast cancer associated with women working in occupations with high EMF exposures"; (3) "exposure to EMFs is important for women with estrogen-receptor positive breast tumors, particularly for premenopausal women who produce high levels of estrogens; (4) "increased circulating levels of estrogens and consequently enhanced proliferation of breast tissue cells have been observed"; (5) "have not suggested inhibition of melatonin generation in humans mediated by EMFs exposure" and on the other hand (6) "increased risk of breast cancer in men was observed for employment in jobs considered above the 0.3µT average MF exposure threshold for ≥30 years" and (7) "the women exposure to ELF-EMFs may be the risk factor of breast cancer when they are non-menopausal".

The conclusions presented in Table 3 are related to people diagnosed with breast cancer and exposure of that people to EMF was indicated. The reported impact of electromagnetic fields on people covered by the researches was different in terms of time and exposure. The conclusion that ELF magnetic fields are possibly carcinogenic is still valid. For breast cancer recent research has indicated that an association is likely. Most new ELF-EMFs studies have been looking into breast cancer or brain tumour risk. Breast cancer caught particular interest because of experimental results suggesting that melatonin synthesis was related to ELF field exposure. The melatonin might play an important role in the development of breast cancer. Several studies also reported an increased breast

cancer risk among subjects with elevated ELF-EMFs exposure.

Nowadays, the biological effects induced by ELF-EMFs on human health have become a cause for concern.

Table 3. The results of included studies on the relationship between EMF exposure and breast cancer risk.

Conclusions / Exposure details	Association between EMF and breast cancer
"...we demonstrated a close relation between exposure to EMFs and light at night and male breast carcinoma in eastern Turkey. We also supposed that not only exposure to EMFs but also the duration of the exposure could affect the risk of development of male breast carcinoma." [16]	Yes
"These findings give little support to the hypothesis that electromagnetic fields cause cancer of the female breast." [17]	Yes
"There appears to be a small increased risk for breast cancer among postmenopausal women exposed occupationally to ELF-MF." [18]	Yes
"...results agree with other recent reports of no association between breast cancer and residential EMF exposures." [19]	No
"...our results show an association between exposure to magnetic fields and the risk of breast cancer and a more important role for residential exposure than for occupational exposure, in particular in the last 5 years before diagnosis." [20]	Yes
"The findings give no support to the hypothesis that magnetic field exposure increases the risk of female breast cancer." [21]	No
"Our findings... suggest that exposure to EMF in the workplace may be associated with a slight elevation in breast cancer risk." [22]	Yes
"...we found few associations for breast cancer and occupations or industries. The suggestive findings for the electronic and electric equipment manufacturing industry and for the occupations with potential exposure to magnetic fields deserve further evaluation." [23]	Needs further evaluation
"Our results do not support an epidemiologic association of adult cancers with residential magnetic fields in proximity to high-voltage overhead power lines." [24]	No
"The findings do not support the hypothesis that MF exposure increases the risk of breast cancer." [12]	No
"Our analysis, in one of the largest case-control studies of breast cancer in men conducted to date, provides limited support for the hypothesis that exposure to MF increases the risk breast cancer in men." [25]	Limited support for hypothesis

A summary of meta-analysis conclusions is available in Table 4. The selected meta-analysis [26, 27, 28, 29, 30, 31, 32, 33] included 157 research reports in terms of years 1979-2012. In studies with people-volunteers [12, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25] in the years 1976-2008, the analysis covered almost 534000 people. Relationship of exposure to EMF with an increased risk of breast cancer in men and women was analysed multi-contextually. Some studies estimated exposition on PEM for some part of the country or region. Kliukiene [15] carried out a case-control study of female breast cancer within a nationwide cohort in Norway. Women living in a residence within a defined corridor near high-voltage power lines (ranged from 40 m for 33 kV lines to 300 m for 420 kV lines) were participated investigation. Occupational exposure was

estimated on a scale from 1 to 3. One means < 4 h exposure at > 0.1 μ T per week), three means > 24 h exposure at > 0.1 μ T per week. Van Wijngaarden [17] give results of a case-control study of occupational exposures to magnetic fields. Occupational exposure to magnetic fields was estimated from the time-weighted average. The risk estimates mostly showed a similar pattern by latency of exposure, whether pre- or post-menopausal and by estrogen receptor status. Generally higher risks were found for pre-menopausal women. 20400 cases of breast cancer (woman) identified by regional cancer registry was included to study [16]. Information about magnetic field exposure was obtained from a job-exposure matrix. Measurements were made using monitor carried on for 24 hours by volunteers. Zhang [28] selected studies by: evaluated the associations between ELF-EMF and cancer risk, studied humans, confirmed the disease, had a case-control design. Studies involving multiple diseases were separated by disease. The study locations were categorized as Asia, Europe or North America. Van Wijngaarden [17] occupational exposure to magnetic fields estimated focusing on the time-weighted average. A convenience sample consisting of 800 participants who had not been asked previously about occupational or environmental exposures as part of previous epidemiological studies of this study population were identified. The association of breast cancer with exposure to magnetic fields was initially examined using occupational categories. Breast cancer risks were considered for office workers and industrial workers, two common occupations in this study population. Authors of meta-analysis [25] reported that exposure groups were often confirmed by using electric heating equipment such as electronic blanket or not, work duty or measuring and assessment of working environment, distance from the high voltage power lines or combining some above factors. The analysed publications were selected by: a population epidemiology study on the association between ELF-EMF exposure and breast cancer in females, the papers must offer the size of the samples, number of exposed and non-exposed individuals in cases and controls and report is published in English.

Research [12, 19, 21, 24] carried out with the participation of 508,000 people showed no association between EMF exposure and increased incidence of breast cancer. Reports [16, 17, 18, 20, 22, 23, 25] showed an association between EMF exposure on the risk of breast cancer. They were carried out with the participation of more than 20,000 people. Two scientific reports [23, 25] indicate the need for further research or limited support the hypothesis. Meta-analysis [27, 32, 33] indicate no association between exposure to EMF and the risk of breast cancer. These analyses included 60 research reports. Analysis [26, 28, 29, 31] cover 73 scientific reports. Two studies [29, 30] indicated the need for further research.

In general a number of reports have been published concerning the risk of female and male breast cancer associated with extremely low frequency magnetic field exposure. With these studies [18, 26, 29, 30, 31], the evidence for an association between ELF-EMFs exposure and the risk of breast cancer support an association.

World Health Organization formulated recommendation for research. For laboratory studies, priority should be given to reported responses that are potentially relevant to carcinogenesis. For existing animal studies, the weight of evidence is that there are no carcinogenic effects of ELF magnetic fields alone. High priority should be given to in vitro and animal studies in which ELF magnetic fields are evaluated as a carcinogen.

Table 4. The results of meta-analysis to the relationship between EMF exposure and breast cancer risk.

Conclusions	Association between EMF and breast cancer
"ELF-EMFs may be increase the risk of human breast cancer. The women's exposure to ELF-EMFs may be the risk factor of breast cancer when they are non-menopausal" [26]	Yes
"The results showed no significant association between ELF-EMF exposure and female breast cancer risk in total analysis... and in all the subgroup analyses by exposure modes, menopausal status, and estrogen receptor status." [27]	No
"This meta-analysis suggests that EMF exposure may be associated with the increase risk of male breast cancer despite the arguments raised." [28]	Yes
"ELF-EMFs might be related to an increased risk for female breast cancer, especially for premenopausal and ER+ females." [29]	Yes. It's necessary to undertake better epidemiologic researches.
"The evidence indicates that long-term significant occupational exposure to ELF MF may certainly increase the risk of both Alzheimer's disease and breast cancer.... It is important to mitigate ELF and RF MF exposures through equipment design changes and environmental placement of electrical equipment, e.g., AC/DC transformers." [30]	Further research is required
"Our meta-analysis suggests that ELF-EMFs are associated with cancer risk, mainly in the United States and in residential exposed populations." [31]	Yes
"Breast cancer does not seem to show augmented risk due to MF exposure." [32]	No
"A recent very large occupational study with improved exposure assessment and enough statistical power also for subgroup analyses found no indications of increased risks in any subgroups." [33]	No

Conclusion

The objective was to evaluate human occupationally exposed to electromagnetic fields and breast cancer risk. The review summarizes the occupational risk factors and the associated mechanisms involved in breast cancer. The author suggests additional research is required on this topic to establish the effect of EMFs on initiating breast cancer. Analysis of the results of research and results indicated in the meta-analysis allows to formulate a general conclusion that the problem of correlation of increased risk of breast cancer and exposure to EMF requires further research.

The World Health Organization is undertaking a health risk assessment of extremely low frequency electromagnetic fields, published

The investigations different occupational exposure risks among associated with breast cancer development are requirement. Over the last two decades there have been numerous epidemiological studies on breast cancer in both men and women, although this relationship remains controversial. Many of these studies, however, report that ELF exposures are related to increased risk of breast cancer. Although, the biological effects of EMFs are still controversial, in general, the negative effects should not be ignored.

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