HUMAN CHROMOSOMAL ABERRATIONS CAUSED BY ELECTROMAGNITIC FIELD

RAFID ABDUL-WAHID
Department of Biochemical Engineering, College of Al-Khwarizmi, University of Baghdad. Baghdad – Iraq.

Abstract

Forty five volunteers aged between 25 and 65 years ,were exposed for at least 10 years to electromagnetic fields (EMFs) induced by transmission power lines in their residential area and 15 male of similar age unexposed, away from the transmission power lines as a control group were used in this study. The electromagnetic fields (with range of 50 to 60 Hertz) were beside the homes of the volunteers. This study carried out in three different region of Baghdad and included Al –Bladyat, Hay Al-Adel and Al-Dorra region, The groups of this study were divided into three sub-groups according to the distance away from the towers of transmission power lines, (1) range: from 1 to 25 meter (2) from 25 to 50 meter (3) from 50 to 75 meter. The results showed that there were structural and numerical chromosomal abnormalities in the lymphocytes of the exposure volunteers and the frequencies of chromosomal aberrations (chromosome lose, dicentric chromosome, ring chromosome, and chromatid breaks) were significantly ($P \leq 0.05$) higher than in the exposed volunteers in compare with the control group. And these aberrations increased with short distance from the transmission power lines .in all cites of this study .Additionally that we can get the high value of electromagnetic field with shorter distance from the towers of the transition power lines and this may lead to induced directly damage DNA strand and significant increase of chromosomal aberrations.

تأثير الأشعة الكهرومغناطيسية على التغيرات الكروموسومية في الأنسان

رافد عبد الواحد
قسم هندسة الكيمياء الاحيائية ، كلية هندسة الخوارزمي ، جامعة بغداد. بغداد - العراق.

الخلاصة

أجريت هذه الدراسة الدراسة الوراثية الخلوية على 60 عينة دم لمتطوعين تم اختيارهم بشكل عشوائي ,45 شخصا منهم متعرضين للمجال الكهرومغناطيسي الناتج من ابراج الضغط العالي لخطوط نقل الطاقة الكهربائيةالقريب من مناطق سكناهم .كما تم اختيار 15 شخصا غير متعرضين حيث تم اعتمادهم كمجموعة سيطرة. تم جمع النماذج من ثلاثة مناطق مختلفة من مدينة بغداد تضمنت منطقة البلديات وحي العدل ومنطقة الدورة .كما تم تقسيم كل منطقة الى ثلاثة مسافات من موقع ابراج الضغط العالي لخطوط نقل الطاقة الكهربائية وهي من 1−25 و25−50 و50−75 مترا. حيث زرعت خلايا الدم المحيطي للمتطوغين للكشف عن تأثير للمجال الكهرومغناطيسي على التغايرات الكروموسومية للمتطوعين، اضهرت النتائج وجود انحرافات كروموسومية عددية و انحرافات كروموسومية تركيبية وبمستوى معنوية $P\ value \leq 0.05$ للاشخاص المتعرضين للمجال الكهرومغناطيسي ولجميع المناطق قيد الدراسة عند المقارنة مع مجموعة السيطرة (الغير متعرضين) .وقد اشتملت هذة التغيرات على الفقدان, (8.3%) والكروموسومات ثنائية المركز(5%) والكروموسومات الحلقية (8.3 %) اضافة الى الكسور الكروماتيدية (3.3 %). وان هذه الزيادة كانت مترافقة مع شدة المجال الكهرومغناطيسي ولجميع المناطق قيد الدراسة .كما اشارت النتائج ان شدة المجال الكهرومغناطيسي تزداد مع نقصان المسافة من ابراج خطوط الضغط العالي الخاصة لنقل الطاقة الكهربائية.

Introduction

Both occupational and general exposure to extremely low frequency electromagnetic fields generated by electric power lines have dramatically increased over the past 20-year period .This has created social concerns about the possible adverse effects of electromagnetic fields (EMFs) on human health. To date, concerns about the potential health effects of exposure to ELF-EMFs have focused on damage to DNA, chromosome aberrations and mutations leading to diseases such as cancer [1].

Indeed, DNA damage has been correlated with carcinogenicity, cell death, aging, and neurodegenerative diseases. It has been reported that 50 to 60- Hertz EMF exposures may indirectly causing strand breaks of DNA molecule and chromosomal aberrations, and induces a significant increase of micronuclei [2]. Chromosomal aberrations that result in the rearrangement of the sequence of genetic code carried by the chromosome can have profound effects on the cell. These aberrations are associated with certain malignancies [3].

Most literatures evaluated the effects of electromagnetic fields on chromosomes by investigating whether there were chromosomal aberrations, including sister chromatid exchange and chromosomal breaks after exposure to electromagnetic fields between 0.1 - 0.3 mT [4].

In laboratory studies, EMFs have been shown to disrupt biological rhythms, brain functions, chromosomes and lower immune system function. Nordenson and his collages. Used the comet assay to detect strand breaks and oxdated DNA bases and chromosomes aberration in human lymphocytes exposed to a 50 Hz, 1-100 μT magnetic fields for 18 hours [5].

In Children born in homes located 200 to 600 meters from high-voltage transmission power line, they observed increased risk of leukemia and brain tumors or other cancers [6]. Results for all cancers combined showed relation to the distance. For both leukemia and brain cancer results at two distances are noteworthy: for the 50-100 meters category an excess of leukemia and a deficit for brain tumors was observed. For the 500-600 meters category the results showed a modest excess for both leukemia and brain tumors [7].

Kyong and his colleagues investigated the effect of electromagnetic fields (50 Hz) on the induction of micronuclei (MN) and chromosomal aberrations in cultured human fibroblasts, and they found that EMF radiation resulted in a time dependent increase of micronuclei, which became significant after 10 h of intermittent exposure at a flux density of 1 mT. After approximately 15 h a constant level of micronuclei of about three times the basal level was reached. In addition, chromosomal aberrations were increased up to 10-fold above basal levels. The data of this study is strongly indicated a clastogenic potential of low-frequency electromagnetic fields, which may lead to considerable chromosomal damage in dividing cells [8]. Some genotoxic effects were reported in fibroblasts, granulosa cells and HL60 cells. Cells responded to EMFs exposure between 0.3 and o.2 mt/kg with a significant increase in single and double strand DNA breaks and in micronuclei frequency [9].

Chromosomal aberrations in fibroblasts were also observed after exposure. Down regulation of the expression of neuronal genes in neuronal precursor cells and up regulation of the expression of early genes in p53-deficient embryonic stem cells were observed at 1.5 mt/kg [10].

A number of laboratory experiments have been carried out on Big Blue mouse to assess possible genotoxic effects of a broad range of different EMFs frequencies .Many of the experiments found strong evidence for direct genotoxic or mutagenic effects of EMFs fields at different power densities. These include DNA breaks, damage to chromosomes, induction of sister chromatid exchanges (SCE), induction of micronuclei, cell transformation and mutation [11].

Subjects, Material, methods

Subjects

This study included 45 healthy volunteers aged between 25 and 65 years, and they were at least 10 years exposed to electromagnetic fields (EMFs) induced by transmission power lines in their residential area.

The EMFs were (with range about (50 to 60 Hertz) beside their homes, the study was carried out in three different regions of Baghdad, which included Al –Bladyat, Hay Al-Adel and Al-Dorra regions during Feb. 2008.

They were divided into three sub-groups according to distance from the towers of transmission power lines, [1] from 1 to 25 meter [2] from 25 to 50 meter and [3] from 50 to 75 meter . Another 15 males of a similar age (apparently healthy with smoking habits)

unexposed away from the transmission power lines about 500 meter were compared as a control group.

Cytogenetic analysis

Peripheral blood lymphocyte culture was carried out according to the standard protocol [12] .with slight modifications. Five ml of blood from each subject (exposed and control group) was incubated in complete lymphocyte culture medium (RPMI 1640; Sigma,), supplemented with 10% of fetal calf serum (Sigma). To initiate the cultures 0.3 ml of phytohaemagglutinin (Sigma) was added to the culture. The cultures were incubated at 37 o C in CO 2 incubator for 72h. Metaphases were harvested by adding colcemid(Sigma) to the cultures to arrest the cell division at metaphase stage, followed by hypotonic KCl treatment and fixation,. For each individual, a minimum of 30 metaphases were counted and at least five cells were karyotyped after standard G-banding that described by [13]. With slight modifications, as the routine banding method.

Measurement of ELF Frequency

The electromagnetic fields were measured in the three sub-sections according to distance from the tower of transmission power lines by using Gauss Meter in micro Tesla (μT).

Statistical Analysis:

Experimental data were analyzed using a statistical software (SPSS 10.0).A Significance differences between means of control and samples was determined using Student's t-test. P value $\leq$ 0.05 was considered statistically significant.

Results

The results of measurement electromagnetic field by Gauss meter for different sites from the towers of transmission power line showed significant reduction with the distance The values of Gauss meter reading reduced when the distance increased from the towers regression, and we can get the highest value under the towers of power line 1.01, 0.987 ,and 1.142 μT in Al-Bldyat Hayal-Adel and Al- Dora Respectively and the lowest value 0.34 ,0.43, 0.61 μT in 75 meter away from the towers of transmission power line in Al-Bldyat ,Hayal-Adel and Al- Dora respectively, Table (1).

Table 1: Measurement of EMF output in different site from the towers in the regions of study.

Distance (meter)	Measurement of the frequency of electromagnetic field in *micro(tesla* μT)		
	Al-Bldyat	Hayal-Adel	Al- Dora
0-25 meter	0.1.01	0.987	1.142
25-50 meter	0.725	0.716	0.822
50-75 meter	0.346	0.435	0.611

The Results showed that the electromagnetic fields (ELMFs) induced by transmission power lines have significant effects ($P \leq 0.05$) on the chromosomes of the exposed lymphocytes in comparison with control group. Cytogenetic analysis for all volunteers (exposed and unexposed) in the study is summarized in table (2).

Table 2: Cytogenetic analysis for all volunteers in the study.

sex	Age	Frequency	Percentage	chromosomes aberrations
M	50-55	2	3.3%	Chromatide breaks
M	40-64	5	8.3 %	Ring chromosome
M	44-30	3	5 %	Dicentric chromosomes
M	35-55	5	8.3%	Lose
M	24-29	12	18.3 %	Un separated chromosomes.
M	52-76	18	40 %	No metaphase
M	20-55	15	16.6%	Normal
-	-	60	100 %	Total

Most cases (58.3 %) failed to show a producible cultures either without metaphase (40 %) or we did not have separated chromosomes (18.3%), and (16.6 %) of the cases showed normal karyotype, while the remained cases(25%) showed different chromosomal aberrations Figure (2).

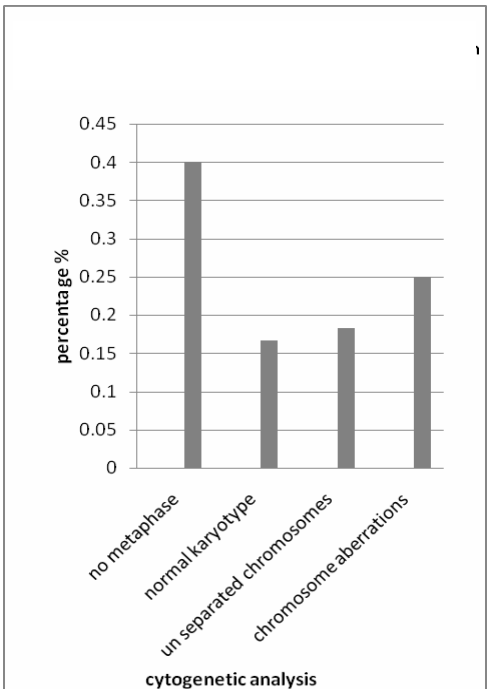

Figure 1: percentage of chromosomes of analysis in all volunteers of the study.

Cytogenetic analysis of the exposed volunteers revealed that chromosomal aberrations occurred in 15 cases out of 60 (25 %). These aberrations were mostly presented by numerical changes (losing), which were present in 5 cases of the exposed volunteers (8.3 %), and structural changes (dicenteric chromosome) were present in 3cases of the exposed volunteers. (5 %) Also, ring chromosomes were present in 5 cases of the exposure volunteers (8.3 %). Furthermore chromatid breaks were present in 2 cases of the exposed volunteers (3.3 %). Figure (2).

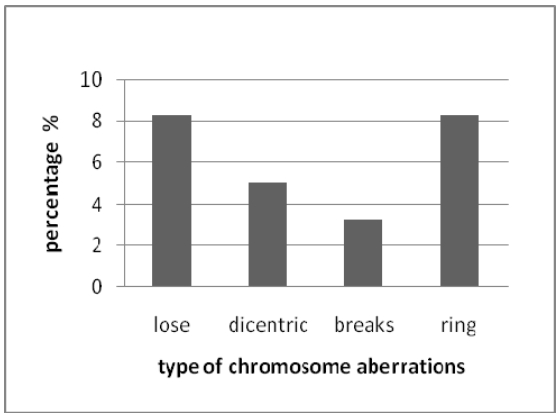

Figure 2: Percentage of chromosomes aberrationsh in 15 cases.

Two types of chromosomal aberrations were observed, numerical and structural aberrations in lymphocytes of the volunteers .who lived near the tower of transmission power lines in all distance of this study, from the other hand the results indicated that the four types of aberration were observed in each of Al-Baldyat and Hay Al-Adel regions respectively, while in Al-Dora region seven types of chromosome aberrations were observed. . Also the result was showed that the frequency of chromosomes aberration was dependent on the value of the electrom-agnetic field in the different site from the towers of transmission power lines. (Tables 3, 4 and 5).

Table 3: The chromosomes aberrations in deferent sectors in Al-Adel region.

Sample groups	Samples No	Numerical Aberrations	frequency	STRUCTURAL ABERATION	Frequency
From 1 to 25 meter	5	Loss of 1	1	Ring Chromosome	2
From 25 to 50 meter	5	Normal	0	Chromatide Breaks	1
From 50 to 75 meter	5	Normal	0	Normal	0
Control group	5	Normal	0	Normal	
TOTAL	20		1		3

Table 4: The chromosomes aberrations in deferent sectors in Al-Bldyat region.

Sample groups	Samples No	Numerical Aberrations	frequency	STRUCTURAL ABERATION	Frequency
From 1 to 25 meter	5	Loss of 7	1	Ring Chromosome	1
From 25 to 50 meter	5	Loss of 2	1	Dicentric Chromosome 45,XY, dic(10:6)	1
From 50 to 75 meter	5	Normal	0	Normal	0
Control group	5	Normal	0	Normal	0
TOTAL	20		2		2

Table 5: The chromosomes aberrations in deferent sectors in Al-Dora region.

Sample groups	Samples No	Numerical Aberrations	frequency	STRUCTURAL ABERATION	frequency
From 1 to 25 meter	5	Loss of 7	1	Ring Chromosome	2
From 25 to 50 meter	5	Loss of 8	1	Dicentric Chromosome 45,XY, dic(11:9),(2,5)	2
From 50 to 75 meter	5	Normal	0	Chromatide breaks	1
Control group	5	Normal	0	Normal	0
TOTAL	20		2		5

DISCUSSION

Several studies have demonstrated that EMF has genotoxic effects on human and animals. For example, significant increases in the numbers of chromosome aberrations and micronuclei have been found in human peripheral lymphocytes exposed to 75-µT and 150-µT EMF at 32 Hz in vitro [14]. It is possible that certain cellular processes, such as DNA repair, are altered by exposure to EMF, which could indirectly affect the structure of DNA causing strand breaks and other chromosomal aberrations, [15]. The result of measurement of electromagnetic field by Gauss meter showed significant increased with the distance and the value of reading increased when the distance reduced from the towers of power lines , All the values in all distance is more than the safety values that determined by ICNIRP/ WHO the International Commission on Non-Ionizing Radiation and Protection's (ICNIRP's) guidelines and this values is more than 3-4 *mG* (milli gauss) can cause health risks including childhood leukemia, adult brain cancer, causing strand breaks and other chromosomal aberrations, [16] .

From the results we can conclude that ,the safety distance to homes and people to live is more than 75 meter from the towers of transmission power lines to avoid the side effects of electromagnetic field pollution as demonstrate in several recent studies [17].

Our data strongly indicate a clastogenic potential of intermittent low-frequency electromagnetic fields, which may lead to considerable chromosomal damage in dividing cells."(18).We can hypothesd that EMF may activate several groups of genes that play a role in cell division, cell proliferation and cell differentiation, In addition, chromosomal aberrations.We also concluded that there were alterations in gene and/or protein expression in some human cells types exposed to EMFs and these changes were dependedent on the distance

from the towers of transmission power linen and the frequency of electromagnetic field [19].

The only biological hypothesis which has been epidemiologically investigated to explain the relationship between EMFs exposure and chromosomes aberration is that high EMFs exposure can lower melatonin production, and melatonin is a potent scavenger of free radicals that cause DNA damage, reduced melatonin causes higher concentrations of free radicals which produce more DNA strand breaks from EMFs frequencies [20].

Also reduced melatonin causes higher changes in the various biological systems which melatonin influences, including increased estrogen production and subsequent deleterious interactions with DNA, [21] , and decreased anti proliferative, antioxidant, DNA repair, and immune response capabilities. Thus lowered melatonin production can be expected to lead to increased risk of chromosomal aberrations [22].

The low energies needed to perturb DNA in the EMFs range suggest that the mechanism involves electrons, probably in the H-bonds that hold the two chains of DNA together. Electrons have very high charge to mass ratio and are most likely to be affected even by weak electric and magnetic fields. Here are many indications that electrons are involved in EMF reactions with DNA. The displacement of electrons in DNA would charge small groups of base pairs and lead to disaggregation forces overcoming H-bonds, separating the two chains and enabling transcription. [23].

Only the measurements in al- Dora region showed significant increase in frequency of EMFs in compare with other cities in this study, also the results of cytogenetic analysis showed that the chromosomal aberration is more than the other regions in all distance in this study We think that in Al- Dora city that the radio frequency radiation from a cell phone tower was re-radiating from the nearby high voltage transmission lines. It was also re- radiating from the electrical power station surrounded the sectors of study in Al- Dora region. in addition that the chemical sewage gas from al-Dora factory for oil and benzene my increase the pollution and this type of co-effects of other magnetic fields interferences my produce hot spots that are not normally calculated in [24] and this may lead to induced directly DNA damage and a significant. Increase of chromosomal aberrations [25].

References

1. Zhou C, Li Z, Diao H, Yu Y, Zhu W, , Yang J,**2006**. DNA damage evaluated by gammaH2AX foci formation by a selective group of chemical/physical stressors. *Mutat Res.* **604**:8-18.
2. Van den Bosch M, Bree RT, Lowndes NF, **2003.** The MRN complex: coordinating and mediating the response to broken chromosomes. EMBO Rep. **4**:844-84
3. Stronati L, Testa A, Villani P and Marino C, **2004**. Absence of genotoxicity in human blood cells Exposed to 5 magnetic fields as assessed by comet assay, chromosome aberration,micronucleus and sister chromatid exchange analyses. *Bioelectromagnetics.* **25**(1):41-48
4. Neri M, Ugolini D, Bonassi S, Fucic A and Holland N. **2006**. Children's exposure to environmental pollutants and biomarkers of genetic damage. *Mutation Research*- **612**:14-39.
5. Nordenson I, Hansson Mild K, Järventaus H, Hirvonen A, and Norppa H. **2001**. Chromosomal Aberrations in peripheral lymphocytes of train engine drivers. *Bioelectromag-netics*. **22**(5):306-315.
6. Draper G. **2005**. Childhood cancer in relation to distance from high voltagepower lines in England and Wales: a case-control study, BMJ.1290-1293.
7. Connelly JM. and Malkin MG. **2007**. Environmental risk factors for brain tumors. *Curr Neurol Neurosci Rep* **7**:208-14.
8. Kyong H. Nam Ph.D. and P. Eng. **August 1. 2005**. Chromosomal damage in human diploid fibroblasts by intermittent exposure to extremely low frequency electromagnetic fields, Omega-news, omega.twoday.net/ stories /885698/ p.1.
9. Ivancsits S, Diem E, Jahn O, Rüdiger H. **2003**. Intermittent extremely low frequency electromagnetic fields cause DNA damage in a dose dependent way. *Int Arch Occup Env Health*,**76**:431-436.
10. Czyz J, Guan K, Zeng Q, Nikolova T and Meister A**. 2004**. High frequency electromagnetic fields affect gene expression levels in tumor suppressor p53-

deficient embryonic stem cells. *Bioelectromagnetics* **25**:296-307.
11. Takahashi, S., Inaguma, S., Cho, Y. M. and Imaida, K. **2002**. Lack of mutation induction with exposure to 1.5 GHz electromagnetic near fields used for cellular phones in brains of big blue mice. *Cancer Res*. **62**:1956–1960.
12. Hungerford, DA.**1965**.Leucocytes cultured from small inocula of whole blood and the preparation of metaphase chromosomes by treatment with hypotonic KCl. *Stain Technol*, **40**:333-338.
13. Verma, Sun NC, Chu CH and Chang CC. **1973**. Staining method for banding patterns of human mitotic chromosomes. *Caryologia;* **27:**315-322.
14. Lixia S, Yao K, Kaijun W., and Deqiang L, **2006**. Effects of 1.8GHz radiofrequency field on DNA damage andexpression of heat shock protein 70 in human lens epithelial cells. *Mutat Res***. 602**:135-142.
15. Mckenzie DR., Yin Y. and Moler S. **2005.** Chromosomal damage in human diploid fibroblasts by intermittent exposure to extremely low frequency electromagnetic fields, Omega-news,*health physics, August 1, p.1 omega.twoday.net/stor*ies/885698.
16. Gurny. JG, Mueller BA, Davis. S Schwartz, SM. **1996**. Childhood brain tumor occurrence in relation to residential power line configurations. Electric heating sources and electric appliance use. *Am. J. Epide Miol.* **143**:120-128.
17. Moulder J.E. **2005**. Electromagnetic fields and human health, *Medical College of Wisconsin,* pp.2-5.
18. Remondini D, Nylund R, Reivinen J, Poulletier de Gannes F. **2006**. Gene expression changes in human cells after exposure mobile phone microwaves. *Proteomics.* **6**(17):4745-4754.
19. Ivancsits S, Diem E, Rüdiger H. and Jahn O. **2002**. Induction of DNA strand breaks by exposure to extremely-low-frequency electromagnetic fields in human diploid fibroblasts. *Muta. Res.,* **519**:1-13.
20. Schernhammer ES, Hankinson SE.**2005** Urinary melatonin levels and breast cancer risk. *J. Natl. Cancer Inst*.; **97:1084**-1087.
21. Tan DX, Manchester LC, Terron MP,kFlores LJ, Reiter RJ. **2007** .One molecule, many derivatives: Anever-ending interaction of melatonin with reactive oxygen and nitrogen species. *J. Pineal Res*.; **42**:28-42.
22. Blank M. **2005**. Electromagnetic fields Interact with electrons Na KATPase. *Bioelectromagnetics*. **26**: 677-683.
23. Xing H, Wilkerson DC, Mayhew CN, Lubert EJ and Skaggs HS. **2005**. Mechanism of hsp70i Gene Bookmarking. *Sci***., 307**: 421-423.
24. Goheen SC., **2004**. Corona discharge Influences ozone concentrations rats, *Bio-electromag*, **25**:107-113.
25. Gadhia et al. **2003**. Reported a significant increase in dicentric chromosomes in blood cells among mobile users who were smoker – alcoholic as compared to nonsmoker nonalcoholic. *Electromag Biol Med*. **22**:149-159.