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Assessment of Extremely Low Frequency Effects on human body

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ABSTRACT

In this paper, we discuss about probable biological effects on human body caused by the electromagnetic fields at low frequency (power frequency). Mechanisms of interplay between human tissues and extremely low frequency fields are represented. Some of the standards are being sampled and some advices are consulted around the decrement of biological effects and keeping safe from these fields.

Keywords: *ELF field, Electric & Magnetic fields, Human tissues, Biological effect*

1. INTRODUCTION

Electromagnetic spectrum is divided to ionizing and non-ionizing waves. Also it divided into Extremely Low Frequency (ELF), Very Low Frequency (VLF), visual, X-ray, δ and etc. This paper is limited to ELF (extremely low frequency field specially 50/60 Hz). All of the electrical devices such as computers, TV are ELF field sources. The human bodies nervous are connected to each other and transfer electrical pulses from sensors of pressure, temperature, light, sound, etc., to the brain and returns control signals to muscles and other tissue. Since many years ago it is well known that electric currents can affects the nervous system and other tissues of human.

Because of electrical properties of human tissues, the electromagnetic fields can interact with them at both high and low frequency. Thus the electrical currents from extremely low frequency fields can cause some biological effects.

2. The energy of power frequency field

At power frequency fields (50/60 Hz) the energies are very small to break the body tissues chemical bonds. Table 1 shows the comparison of energies in various frequencies. These values are found by Eq.1 where h is the plank constant and f is frequency.

Table1. Comparison of Particle Energies at Different Frequencies [1]

	Wave length ( )	Energy(ev)
X- ray	= 1.2nm	1000
Visible light (green)	= 0.5 μm	2.5
Far-infrared	= 30 μm	0.04
Transmission(50Hz)	= 6000km	10-13

Table 2 shows the energies of chemical bonds. At 50Hz wavelength is 6,000km and at 60Hz is 5,000km. These frequencies do not have sufficient energy to break the chemical bonds (from Tables 1 and 2). For instance at 50Hz 10^{-13} 1.43eV (O-O)

Table2. Examples of Energies of Chemical Bonds [1]

Bond type	Energy(eV)
O-O	1.43
O=O	5.16
Hydrogen bond	0.1
ATP hydrolysis	0.3

3. Electrical properties of tissues at ELF frequencies

Electrical properties of biological tissues are conductivity (σ), permittivity (Ɛ) and permeability (μ). Permeability of human tissues is equal to air i.e. = 4π 10-7. But conductivity and permittivity change with frequency. These properties vary with age, environment condition, exposure source and etc. For more information see [2 -5]

For example Table 3 shows the tissue properties at low frequencies.

Table1. The conductivity of tissues at low frequencies [6], [7]

Tissues	σ(S/m)	f(Hz)
Whole body	0.22	50
Head	0.25	50
Arm	0.19	50
Leg	0.2	50
Cartilage	0.2	0-100
Bone	0.02	0-100
Dry Skin	0.00002	0-100
Wet skin	0.2	0-100

4. Mechanism of interaction between human body and electric and magnetic ELF field

Because of the human tissue electrical properties, the electromagnetic fields can interact with it, so, in this section the possible mechanisms are introduced. According to [8-15] these mechanisms are Magnetite, Free radical, Cell membrane,

Cell nuclei, Heat shock proteins, Blood-brain barrier, Field induction, Energy, Corona.

Describing all mentioned above requires a book to be written.

In the cellular levels the interactions are Membrane changes, Ionic effects, Nucleic acid and gene expression, enzymatic activity, Biorhythms and Hormones, Genotoxic effects.
Mechanisms for Electric and Magnetic Fields are included Fields and Currents, Thermal Noise, Shot Noise, Endogenous Fields.

In other word we can divide this mechanism into two categories. "Electric" field effects and "Magnetic" field effects. [9]

4-1- Electric field effects

Because of electrical properties of biological tissues it includes polarization of Bound Charges, Orientation of Permanent Electric Dipoles, Drift of Conduction Charges, Pearl-Chain effects and electro rotation.

4-2- Magnetic field effects

Because of magnetic properties of biological tissues it includes Induced Currents, Magnetic Bio substances, Radical pairs, Cell Membrane and the Chemical Link. We introduce some of these mechanisms.

4-3- Induced fields and Currents

The external electric and magnetic fields can induce the currents and fields in human body, the figures 4-1-a, 4-1-b show these.

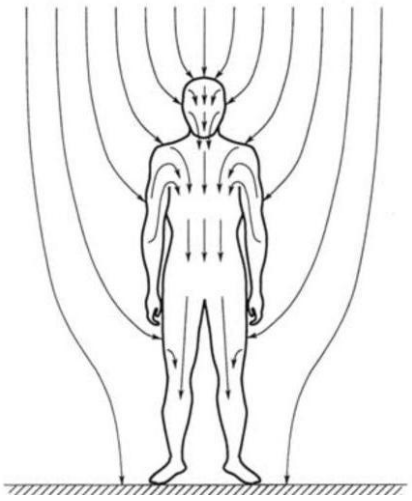

Figure 4-1-a- external electric field induces the internal currents [1]

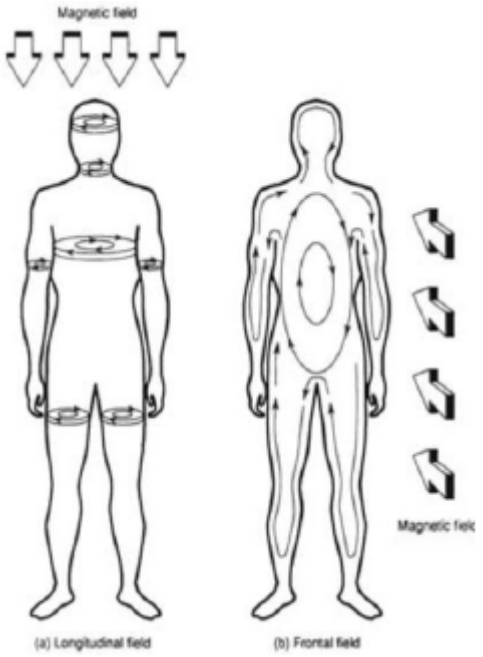

Figure 4-1-b- external magnetic field induces the internal currents [1]

4-4- Free radicals

Free radicals are atoms or molecules with at least one unpaired electron. Unpaired electrons are very unnatural, unstable, and hazardous because electrons normally come in pairs. These odd, unpaired electrons in free radicals cause them to collide with other molecules so they can steal electrons from them, which change the structure of other molecules and causes them to also become free radicals. They just exist for very short periods (typically less than 1 ns), but their effect is extreme in terms of cell aging and various kinds of cancer because of the damage they do to DNA, cells, and tissues. The experiments show that ELF fields can cause free radicals.

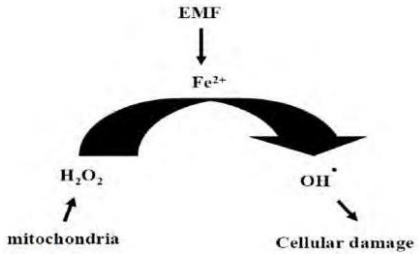

Figure2. Free radical formation [14]

4-5- Orientation of permanent electric dipoles

Permanent dipoles tend to align with an applied E

field (Figure 3). The net alignment of permanent dipoles produces new fields.

The drift of conduction charges in an applied E field occurs because these charges are free to move substantial distances in response to E fields. The movement of conduction charges is called drift. A large drift means high conductivity.

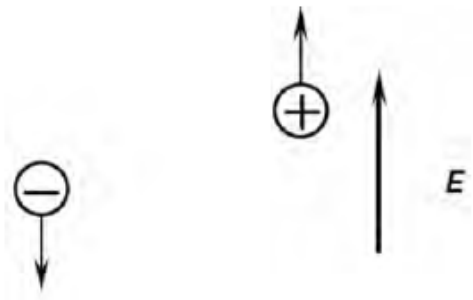

Figure3. The orientation of permanent electric dipoles.[9]

5. Biological effects of ELF fields

Many researchers all of the world try to determine the bio effects of ELF fields. The effects include thermal and non thermal effects. The energy of ELF field is very small to produce heat and cause ionization (for 50Hz the energy is equal to 10^{-13} eV). But these fields can affect the cell structure and cause the human adverse health effects. These effects are Genotoxic effects, Single and double DNA strand breakage, chromosomal problem, micronucleus formation, calcium current, Cell Proliferation, effect on melatonin, enzyme activities. Shock and micro shock, electrical activity, cardiovascular diseases, behavioral effects. Also free radicals can cause various kinds of cancer because of the damage they do to DNA, cells, and tissues. [16 -20]

6. Standards and recommendations for human health and safety against ELF fields

ICNIRP is an international commission of scientific experts in the area of biological and health effects of electric and magnetic fields. The purpose of the IEEE standard is to define an exposure levels to protect against adverse effects from exposure to electromagnetic fields from 0 - 3 kHz. Many standards are established to protect human against electromagnetic fields. For example ICNIRP and IEEE. These two types of standards are to establish guidelines for limiting exposure (occupational and general public exposures) to protect human against electric and magnetic all established adverse effects.

Occupational exposure refers to people who work at workplace for example power line workers. The exposure levels are known in these places. General public exposure refers to people who don't know the exposure levels of electromagnetic.

For establish the standard at low frequency the Electric field strength (V/m) and Magnetic flux densities (μT) are applied. [21-24]

Table4. Presents the relevant ICNIRP reference levels for 50Hz

ICNIRP levels	Electric field strength(V/m)	Magnetic flux density(μT)
General public	5000	200
Occupational exposure	10000	1000

Table5. Maximum permissible exposures levels for 50 Hz in IEEE.

Tissue	Electric field strength(kV/m)	Magnetic flux density(μT)
Head	5-10	904
Arm & leg	5-10	75800

6-2- recommendations for human health and safety against ELF fields

6-2-1- Reducing the level of ELF exposure

With regard to occupational exposure there may be localized sources of magnetic fields in the workplace such as electrical substations in the basement, power cables in the walls or floor and distribution lines close to the building. The magnitudes of both electric and magnetic fields decrease rapidly with increasing distance from the source. The easiest way to reduce exposure to these fields may simply be to move areas where people spend a lot of time (for example, chairs, beds) away from electrical appliances and facilities by rearranging room layouts. In addition:

1. Determine sources of ELF fields. 2. Use bundled and twisted power cable drops to reduce field generation. 3. Keep the drop, meter, service panels, and subpanels away from normally occupied rooms.4. Keep high-load wiring from the main panel to a subpanel or to high-current appliances away from frequently used spaces. 5. Place high-load appliances such as electric dryers and electric hot water heaters away from bedrooms, kitchens, etc.

6. Avoid using devices such as alarm clocks or electric blankets near the bed. 7. As a last solution, use shielding techniques to reduce the level of fields.

7. Conclusion

The biological effects of electromagnetic fields are an

interesting subjects for researchers the entire world. Many parameters influence the field's effects. For example [25-28]. The paper introduces the probable bio effects on human body. Cell, membrane and other organism of human have electrical properties i.e. conductivity and permittivity, thus they can interact with ELF fields. The possible mechanisms between electric and magnetic (at power frequency fields) are included induced field and current effects on cell structure (section 4).
The standard levels have been established to protect human against electromagnetic fields. At extremely low frequency fields the values of standards level are established by electric and magnetic field strength. For example according to ICNIRP the restriction value for general public at 50Hz are 5000 V/m and 200 μT. The effects of ELF at cell levels are Single and double DNA strand breakage, chromosomal problem micronucleus formation, calcium current, Cell Proliferation, effect on melatonin, enzyme activities and etc. Also in this paper some recommendation for human health protection against ELF fields have been proposed.

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H.Ghobadi received his B.Sc. degree in electrical and electronics engineering from Qazvin branch of Islamic Azad University, in 2011. His research interests include bioelectric systems and software development. Currently, he is working in numerous national projects focused on new methods in education as a software developer.