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Measurements of ELF Electromagnetic Fields in Jordan Exposure Limits and Recommendations

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ABSTRACT

In view of the public concern over the effect of extremely low frequency electrical and magnetic fields on the human health, it is necessary to measure the level encountered in Jordan at different locations in the vicinity of electrical appliances, switchgears, transformers, cables, transmission lines, and any electrical devices. The danger posed by these devices is assessed by comparing the measured values with the guideline limits as defined by international standards. Exposure limits are suggested at the country level and recommendations are made for the public and the occupational staff to avoid or at least minimize the risk of exposure to these fields.

Keywords: Electromagnetic Fields, Extremely Low Frequency, Exposure Limits.

1. INTRODUCTION

The invention of the incandescent lamp by Edison in the early 1880s sparked a series of inventions to utilize electrical energy easily and efficiently in domestic and industrial applications. Nowadays, electricity is inseparable from modern societies and it controls almost every aspect of their life. This persistent need for electricity led to the buildup of electrical power systems that are growing enormously in size and complexity. Generation, delivery, and utilization of electrical energy are accompanied by 50/60 Hz voltages in the range of 110/230/400V – 1500 KV range. Generated or load current may reach 10 KA while fault currents may exceed 100 KA at transient fault conditions.

The presence of these voltages and currents may be accompanied by excessive electric (E) and magnetic (B) fields. Prior to 1979, there was limited awareness of any potential adverse effects from the use of electricity aside from possible electrocution associated with direct contact or fire from faulty wiring. Recently there has been considerable concern and controversy about the effect of extremely low frequency (ELF) 0-300 Hz electromagnetic fields (EMFs) on the human health. There are reports of possible association between childhood cancer and proximity of homes to power transmission and distribution lines. These effects are outlined in section 2. It will be clear that there are many conflicting reports in the literature and care should be taken before drawing a conclusion from one or more researchers.

The ELF EMFs exposure limits as defined by the International Standards are outlined in section 3. It is evident that there is a wide range of limit guideline levels to which the human body may be exposed to without causing harm.

The results of the measurements of ELF EMFs in the vicinity of an assorted group of 230V home appliances, switchgears/cables/overhead lines in the 11 KV- 400 KV range are presented in section 4.

Conclusions are drawn in section 5 by comparing the measured values with the exposure limits as defined by the international standard. Exposure limits are suggested and recommendations are made for the public and occupational staff to minimise risk while dealing with appliances or working on the power systems.

2. Biological Effects of ELF EMFs on Human body

In theory, exposure to ELF EMF's without contact with a conductor can result in shock and burns. Current carrying conductors produce magnetic fields. The magnetic flux density at a point at a distance x meters from the centre

$$B_x = \frac{\mu I}{2\pi x} \quad wb/m^2$$

μ = permeability of the medium H/m

I = current (A)

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The electric field at the point

$$E_X = \frac{q}{2\pi \in x} \quad V/m$$

$q \, \alpha \, V =$ electric charge columb

$\in$ = permittivity of the space F/m

Fields above 15 mT (150 gauss) may cause faint flickering visual sensation due to the modulation of the activity of the cells of the retina. Fields above 500mT can cause ventricular fibrillation (Saunders 1991). However, these hazards require field strengths that are higher than those encountered in practice. Internal longitudinal currents are induced in the human body due to the interaction of the time varying electric fields with human body forming electric dipoles and reorienting the electric dipoles present in the tissues. The relative magnitudes of these currents, (international Commission on Non-Ionizing Radiation Protection. 1997) depend on the relative conductivity of the body according to the relation:

$$J = \sigma E$$

Where

J: current density A/m^2.

σ: electrical conductivity $(\Omega.m)^{-1}$.

E: electric field V/m.

The physical interaction of time varying magnetic fields with the human body results in induced circulating electric currents (Sowa P., 2012). The magnitude of these currents are proportional to the radius of the loop, the electrical conductivity of the tissue (σ), and the rate of change and magnitude of B. The internally induced currents produce internal fields in the marrow. The order of the amplitudes of E_{int} is 1 mV/m for magnetic fields of 100 µT (1 gauss) and 10mV/m for a body impeded in an electric field of 10 KV/m (Lillien, 2008). World health organization considers 10 mV/m as a basic minimum level for E_{int} able to potentially disturb the biological mechanism in the human body (Lillien, 2008). However, it should be noted that a contact current of 0.1 mA produces E_{int} up to 500 mV/m in the arm of an adult (Lillien, 2008).

Exposure to low-frequency EMFs normally results in negligible energy absorption and consequently no measurable temperature rise in the body. While exposure to EMFs at frequencies above 100 KHz can lead to significant absorption of energy and temperature increases.

Investigations on the effect of ELF EMFs on humans were based on epidemiological rather than biophysical or laboratory studies. Most laboratory studies were carried out on animals because it is not ethical to expose humans to the unknown consequences of EMFs. Epidemiological, studies have serious limitations in their ability to demonstrate a cause and effect relation whereas laboratory studies can clearly show that cause and effects are possible. The outcomes are summarized as follows:

2.a: Effect on Cancer:

Epidemiological studies (Mizrach S., 2001; Cherry N., 2004) Claimed to find a higher than normal incidence of childhood leukemia including acute lymphoctic leukemia in those houses close to electrical substations or power lines. Another study (Masateru I., 2010) showed a positive association between high level exposure above 0.4µT and the risk of childhood brain tumors. However laboratory studies on animals have shown that exposure to magnetic fields in the range of 1.3– 2200 µT has no effect on induced leukemia/lymphoma, (Saunders R., 1995). Three studies examined the risk of power company workers in U.S.A, Canada, France, of these one reported no increase in the risk of brain cancer while the other two reported an increase. (American Industrial Hygiene Association., 2002). A combined analysis of the data from the three studies found that the relative risk (RR) per 10 mT. Year was 1.09 for leukemia and 1.12 for brain cancer. The exposure in the studies was in the range of 15.7 – 18.8 µT. years. (RR = P_1/P_2 where P_1 is the probability of occurrence in a group exposed to EMF and P_2 is the probability of occurrence in a second not exposed group). It is expected that the more the exposure time, the more is the RR.

2. b: Effect of ELF EMFs on heart:

The heart is a very electrically dynamic organ. The heart muscle itself because of its electrical activity creates its own EMF (Pawluk W. 2004). The reaction of the cardiovascular system to ELF EMFs is complex and can increase the diameter of capillaries and greatly improve microcirculation systematically and locally in the heart itself. Conflicting studies have shown either an increase or decrease in the heart rate by 3-5 beats/min. due to the action of cardiovascular reflexes (World Health Organisation, 2007; Pawluk W., 2004). The exposure in these studies represented electrical and magnetic fields of 9 KV/m and 200µT respectively. Strong ELF fields cause electromagnetic interference in cardia pacemakers or other implanted electromagnetic devices.

Appendix 1

Table 1: Exposure limits as specified by different countries

Country/ organisation	ICNIRIP	IEE	Europe	Argentina	Australia	Austria	Belgium	Bulgaria	Cost Arica	Finland
(E) Public	5 KV/m	5 KV/m	5 KV/m	3 KV/m	5/10 KV/m	5 KV/m	5/7/10 KV/m	–	2/8 KV/m	5/15 KV
(E) Occup.	10 KV/m	20 KV/m under TL	10 KV/m	–	10-30 KV/m	10 KV/m	–	25 KV/m	–	–
(B) Public	1000 mG	9.04 G (min)	1000 mG	250 mG	1000 mG /10G	1000 mG	–	–	150 mG	5000 mG
(B) Occup.	5000 mG	27.1G	5000 mG	–	5000 mG	5000 MG	–	12G	–	–
Country/ organisation	**France**	**Germany**	**Hungary**	**Italy**	**Japan**	**Netherlands**	**Switzerland**	**UK**	**USA**	–
(E) Public	5 KV/m	5/10 KV/m	5/10 KV/m	5 KV/m	3 KV/m	8 KV/m	5 KV/m	5 KV/m	–	–
(E) Occup.	5 KV/m	5/10 KV	10/30 KV/m	–	ICNIRP	40 KV/m	–	10 KV/m	25 KV/m	–
(B) Public	1000 mG	1-2 mG	1/10 G*	1 G	–	1.2 G	1G	1 G	–	–
(B) Occup.	1000 mG	1-2 G	5/-50 G*	–	–	6 G	–	5 G	12G	-

* Short time

2. c: Effect of ELF EMFS on Human Behavior:

A survey (Mizrach S., 2001) of electric power workers found that there is a statistically greater incidence of suicide and depression among those workers who worked near electrical substations. A study (Saunders R., 1999) noted changes that affect the synthesis of melatonin (related to the day and night cycles) by the pineal gland (control the hormonal balances in the body). All vital organs including the brain, hypothalamus, central nervous system, lymph system, heart, lungs, liver, kidneys, uterus, and testes have melatonin receptors and hence are affected by melatonin reduction. There has been a number of case reports of mood changes and hypersensitivity thought attributable to ELF EMFs exposure manifested as psychological reaction, disturbed sleep, fatigue headaches, loss of concentration, dizziness, eye strain and skin problems (Health Goods., 2008).

2. d: ELF EMFs and Neurodegenerative Diseases:

The possible effects of EMFs on neurodegenerative diseases (Alzheimer and Parkinson) have been examined in epidemiological studies but there are very few relevant experimental investigations. There is no good ground that exposure to ELF EMFs can cause Parkinson disease and only very weak evidence to suggest that is cause Alzheimer (National Radiological Protection Board., 2001). The evidence that people employed in electrical occupations develop amyotrophic lateral Sclerosis is substantially stronger. However, this could be because they run an increased risk of having an electric shock than by the effect of exposure to fields (National Radiological Protection Board., 2001).

Some occupational studies show that ELF fields do damage to brain and produce an increase in Multiple Sclerosis in electricity works (Cherry N., 2004). It is advised (Australian Radiation Protection and Safety Agency, 2001) that on the basis of preventing harmful levels of induced currents in the tissues of the central nervous system, the magnetic field exposure should be limited to 100μT (1G). Exposure to 8 KV/m electric field has been found to show positive changes in the catecholamine and acetylcholine neurotransmitters in the brain (Mizrach S., 2001).

2.e: Other Effects of ElFEMFs on Human body:

Studies of the effect of power frequency electric fields up to 20 KV/m or magnetic field exposure up to 300 μT (3G) for hours had shown little effect on white or red blood cell count or on blood protein level (Saunders R. 1991). No convincing evidence currently exists that ELF fields cause damage to DNA by point mutations, gross chromosomal alterations, or micronuclei formations (Hulbert A. L., 1998).

3. ELF EMFS EXPOSURE LIMITS

World Health Organisation (WHO) strongly recommends that member states adopt international standards that limit both EMF exposures and emissions from devices (WHO 2007). In this study, the emphasis is on the exposure standards that refer to maximum levels to which whole or partial body exposure is permitted. Such standards have been developed by the Institute of Electrical and Electronics Engineers (IEEE), and Internal commission on Non-Ionizing Radiation Protection (ICNIRP), and many national authorities.

At the country level regulations for exposure can be broadly categorised as either voluntary or mandatory instruments. (National Institute of Environmental Health, 1998). Voluntary instruments include guidelines, instructions, and recommendations that are not legally mandated and generally have no legal force. International guidelines such as those developed by IEEE, ICNIRP and others provide guidance to national agencies. These guidelines (EMF Exposure stands, 2006) are outlined in table 1.

Table 1 in the appendix show that different bodies have set different guidelines restricting exposure to electric and magnetic fields. The limits for public are conforming with ICNIRP (E=5 KV/m, B = 1 G) for most countries, however the limits for B are set at the lowest value of 150 mG. A safety factor of 50 for the public and 10 for occupational staff has been taken into account by ICNIRP (International Commission on Non-Ionizing Radiation Protection, 1997).

4. MEASUREMENT OF MAGNETIC AND ELECTRIC FIELDS

3- axis EMFS were measured in the vicinity of many home appliances. In addition measurements at different locations under 11, 33, 13, 2, and 400 KV transmission lines, indoor and outdoor switchgears, transformers were taken at a height of one meter above the ground level. This level is usually adopted to represent the value of the EMF near the heart of a human being standing under the line or outdoor busbars. The ac milligauss meter used for measuring the electric field has an accuracy of ± 2% of the reading in the 40 Hz- 20 KHz measuring up to 20 KV/m. The meter used for measuring magnetic field measures true magnitude with an accuracy of ∓ 7% of the reading in the 45Hz–5KHz range measuring up to 2000 mG. Measurements were taken for many devices/ transmission lines/ switchgears/ transformers. The results are presented for those having median values from each category. Table 2 shows EMFS in the vicinity of home appliances/devices from which it is evident that EMFs exceeds the recommended exposure limits as will be discussed in section 5. Table 3 and 4 outline the EMFs under transmission lines and in switchgear rooms.

Table 2: Measured 50 Hz EMFs in the Vicinity of Home Appliances Devices

Device	3 axis Electric Field (V/m) at a distance (cm)				3 axis Magnetic Field (mG) at a distance (cm)			
	0	10	30	50	0	10	30	50
Washing Machine	4000	480	175	110	450	18	3.2	1
Refrigerator	900	34	≈ 0	≈ 0	240	20	3	1.48
Light Switch	2200	65	5	≈ 0	12	≈ 0	≈ 0	≈ 0
Florescent lamp	1100	175	42	5	1100	40	1.5	5
Incandescent lamp	700	75	≈ 0	≈ 0	3.32	≈ 0	≈ 0	≈ 0
Microwave oven (mains side)	1950	180	10	≈ 0	1600	345	65	24
Instant water heater	440	41	≈ 0	≈ 0	350	44	6.6	2.1
Vacuum cleaner	445	107	31	≈ 0	1160	133	14	4
Iron	600	23	≈ 0	≈ 0	110	7	≈ 0	≈ 0
Hair dryer (2000w)	2000	400	70	5	>2000	105	9	2.5
TV screen	9800	1600	760	300	340	153	38	8.2
Fan	1100	99	≈ 0	≈ 0	1600	24	1.3	0.7
Computer case (Front side)	2600	215	158	50	8.2	2.48	1.52	1.11
Computer monitor (Front side)	5000	600	220	93	20	6.5	1.45	0.96
Blender	1150	124	54	19	1800	122	11	3.4
Electric saw	3500	287	66	25	1670	96	6	2
Induction Machine	3900	440	81	5	>2000	280	15	8.2

Table 3: Measured 50 Hz EMF’s Under H. V. Transmission Lines

Transmission	3 axis Electric Field (V/m) at a distance from the center line (m) 1 m above ground level				3 axis Magnetic Field (mG) at a distance from the center line (m) 1 m above ground level			
	0	10	30	50	0	10	30	50
South Amman- East Amman 400 KV OHL	2040	921	320	98	7.2	4.86	1.63	0.82
North Amman – Syria 400 KV OHL	2072	973	356	102	17.4	12.9	7.5	3.7
South Amman- Salt 132 KV OHL	1464	478	25	≈ 0	7.51	4.2	.8	≈ 0
*South Amman- Queen Alia Airport 132 KV OHL	533	369	12	≈ 0	3.2	1.37	.22	≈ 0
Shafa Bardan- Cymetry 33 KV OHL	672	438	42	≈ 0	9.41	3.34	.22	≈ 0
Bereen – Zarqaa Road 33 KV OHL	589	436	39	≈ 0	4.32	2.61	.13	≈ 0
Yajooz – Elzarqaa Street 11 KV OHL	302	132	≈ 0	≈ 0	3.07	1.62	≈ 0	≈ 0
El-Koom 11 KV OHL	337	135	≈ 0	≈ 0	3.12	1.02	≈ 0	≈ 0

*** This line has an extension of 9 m above standard height**

Table 4: Measured 50 Hz EMFs in Switchgear Rooms

Location	3 axis Electric Field (V/m) at a distance (cm)				3 axis Magnetic Field (mG) at a distance (cm)			
	0	**10**	**40**	**100**	**0**	**10**	**40**	**100**
132 KV indoor switchgear. Single core cables to 132 cable end box Tareq S/S (Trans. 1 I_L = 150 A)	≈ 0	≈ 0	≈ 0	≈ 0	> 2000	1680	495	82
33 KV indoor switchgear. Single core cables to 33 KV cable end box Tareq S/S (Trans.1 I_L = 600 A)	≈ 0	≈ 0	≈ 0	≈ 0	> 2000	> 2000	1935	459
33 KV switchgear, 3 core, 33 KV cable end box	≈ 0	≈ 0	≈ 0	≈ 0	161	153	141	109
11 KV Switch gear 3 core cable end box	≈ 0	≈ 0	≈ 0	≈ 0	28.1	21	19.7	13.2

5. DISCUSSIONS AND RECOMMENDATIONS

For home appliances, the measured values of E and B in the vicinity of many appliances are given in table 2. High levels are obtained at a close distance to most of the devices. Some measurements are available at a distance 30 cms from the device and compare well with the findings of this paper (Federal Office for Radiation Safety- Germany 1999). It can be concluded that electric and magnetic fields drop to a very small value at 50 cms distance from the appliance. Fig. (5.1) portrays the relation between EMF and distance from a hair dryer as an example. Appliances containing motors produce a very high magnetic field. For the hair dryer. E and B at zero distance from the device is 2 KV/m and exceeds 2 G respectively. Since hair dryers are used very close to the head and very frequently, it is evident that it poses a high risk and this is why some consultants recommend that hair dryers should not be used on children. The same conclusions apply for all appliances utilizing motors, such as fans, blenders, saws, washing machines, vacuum cleaners… etc.

Another source of concern is the electric blanket as the electric field at a touching distance from the blanket is 2.2. KV/m which exceeds the recommend exposures limit. Hence care should be taken to switch off the supply if the user is in contact with the blanket.

Computer printers produce a relatively high magnetic fields. While the computer monitors and TV sets produce high electric fields. Fluorescent lamps produce a very much higher electric and magnetic as compared with incandescent lamps.

High electric (3.9 KV/m) and magnetic (> 2G) fields were measured in the vicinity of induction and synchronous motors in the machines laboratory and students or staff should keep a distance from these machines and limit the exposure time.

The electric field at zero distance from the centerline of 400 KV transmission lines just exceeds the adopted limit of 2 KV/m in the research and drops to approximately 100 V/m at 50 m distance from the centerline. The maximum magnetic field under the centerline of south Amman- East Amman 400 KV OHL is 7.2 mG and drops to 0.82 mG at a distance of 50 m from the centerline. Fig. (5.2) shows the relation between EMF and distance from the centre line of a 400 KV OHL. It was noted during the process of measurements that the electric field depends on the voltage, conductor size and height, lateral distance from the centerline, and the geometric configuration of the line. The electric fields are strongly attenuated by metal casings, buildings, and other objects including the human body. Magnetic fields from OHLs are usually low at 1 m above ground level compared to single core cables terminating a transformer or switchgear. The magnetic field depends on the height of the line and the line current and are weakly attenuated by nearby objects.

People living in the vicinity of 400 KV/33 KV/ 11 KV substations or transmission lines may be exposed to magnetic fields of few milligauses and electric fields of few hundreds of volts per meter. These values are very much reduced at a distance of 0.5 – 15 meters depending on the voltage level.

The ELF EMFs can be effectively attenuated if the line height is increased. This conclusion could be clearly seen by comparing the values of these EMFs under south Amman – Queen Alia Airport 132 KV line (which has an extension of 9 m above standard height) with the values for south Amman-Salt 132 KV line (standard height). Therefore it is very important that utilities should adopt a policy of increasing lines heights (within practical limits) whenever they approach a residential area. On the other hand, special care should be excercised by occupational staff working at a very close distance on the maintenance of live transmission lines where the magnetic field B may exceed 5 G.

As for indoor 132/33/11 KV substations, the electric fields in the vicinity of busbars, C.Ts, and V.Ts shielded by metal enclosures are negligible. While magnetic fields are noticeable especially near the single core cables terminating the cable end boxes where the magnetic fields may exceed 2G, hence the work time in the vicinity of these 1-C cables should be limited. The magnetic field in the vicinity of 3-core 33 KV and 11 KV cables is usually low.

In outdoor 400/132 KV substations the electric field at the head level reached 6.06 KV/m under the 132 KV busbars and 12.31 KV/m under the 400 KV busbars. Hence extended work under these busbars may pose a health risk for the occupational staff. However, magnetic fields in these locations are found to be less than 100 mG. Therefore, wherever there are sources of high ELF fields like outdoor substations, transformers … etc., unauthorized access to the public should be restricted by fences, barriers, and danger marks.

As a general rule, the public must avoid unnecessary proximity to high intensity EMF sources and turn off any electrical devices or computers whenever they are not in use. It is wise to keep a distance from these sources when in use and a distance of 0.5 -1 m is considered reasonable. Sleeping beside an electric clock may be more harmful than sleeping under a H.V. power line. It is sometimes useful to rearrange all home appliances so that they are placed against outside walls thus avoiding creation of EMFs in adjoining rooms. Designers of new electrical schemes or new equipment should keep in mind that wherever possible their designs should ensure minimum exposure to ELF EMFS.

6. CONCLUSIONS

It is evident from section 2 that there is no strong scientific evidence that exposure to ELF EMFs poses any health risk. The strongest evidence for health effects comes from the association observed in many epidemiological studies with two forms of cancer: childhood leukemia and chronic lymphocytic leukemia in occupationally exposed adults. However, the lack of full scientific uncertainty should not be used as a reason for relaxing measures on exposure to these ELF EMFs and it is necessary to define the maximum safe exposure levels. Aggressive regulatory action may not be needed at this stage, but it is wise to educate the public and the occupational staff and create an understanding of the possible adverse effects. At the meantime laboratory studies should be encouraged to investigate the cause-effect relationship between human health and ELF EMFs and provide clear evidence whether a relationship exists or not.

A revision of the guideline levels imposed by many countries as summarized in table 1 reveals that for the public the range of electric field E is from 2-15 KV/m and the magnetic field B is from 150 mG-10G, while for the occupational staff the range is 5 – 40 KV/m and 1 – 27.1 G respectively.

In the absence of any local study or any firm world specification for the levels, it is logical to adopt the lowest specified levels, i.e for the public, the recommended levels are E = 2 KV/m and B =150 mG, while for the occupational staff the levels are E = 5 KV/m and B = 1 G. Occupational staff exposure levels are higher than the public because the former are familiar and aware of the hazards involved while working and are able to take appropriate precautions or limit the exposure time if necessary. These levels are not considered aggressive compared with the levels defined by many other countries, e.g. the American conference of Governmental Industrial Hygienists limits the exposure levels for the public to 250V/m and 100 mG. In Sweden a much severe limit of 2mG is adopted for the magnetic field and the construction of houses within 330 feet (100m) from HV lines is banned. In U.K. homes should be built at least 150 m from overhead power lines. In California, the Department of Education stipulated boundary limits between schools and overhead lines: 100 feet (30 m) from the edge of basement for 100 – 110 KV lines, 150 ft (45m) for 220-230 KV lines and 250 ft (75m) for 345 KV lines.

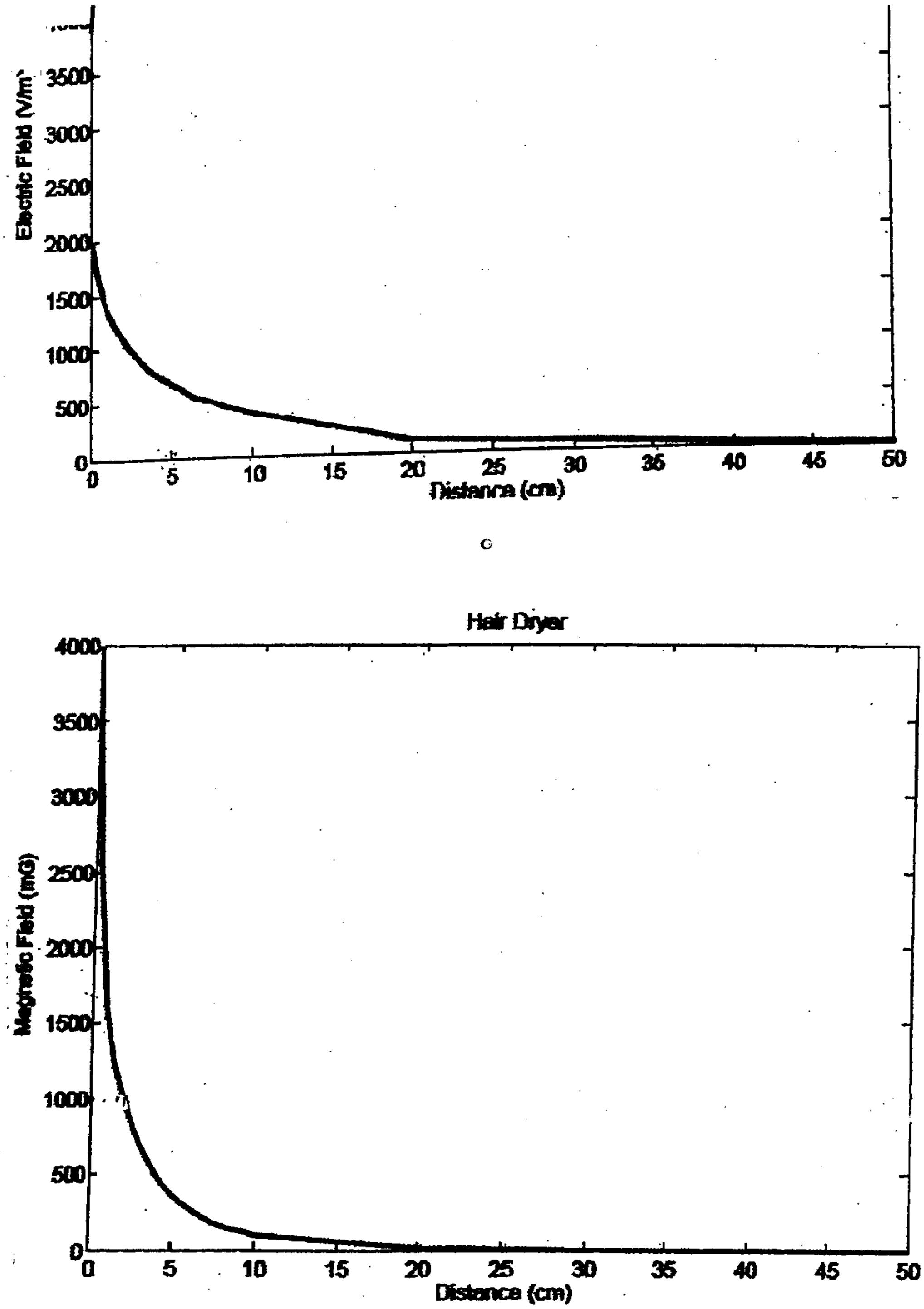
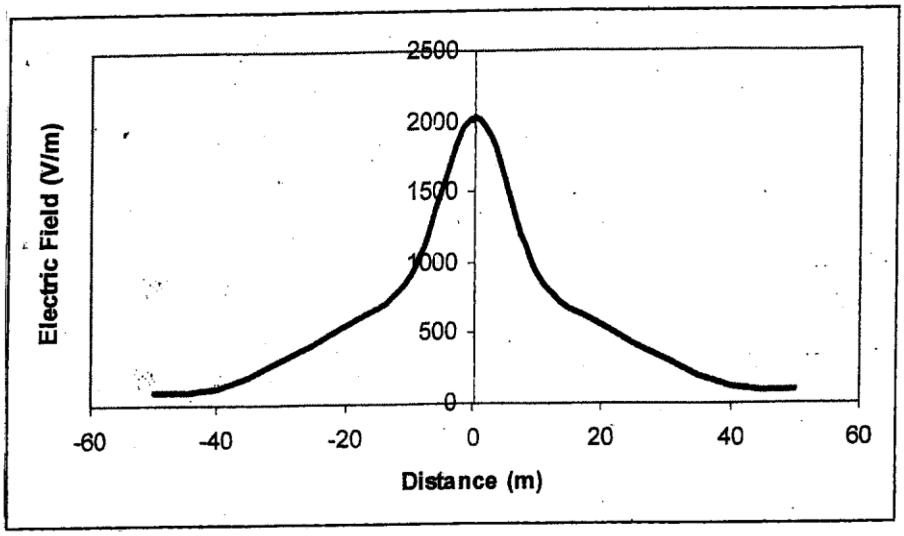


Fig. 5.1: Electric and magnetic fields Vs. Distance from a hair dryer



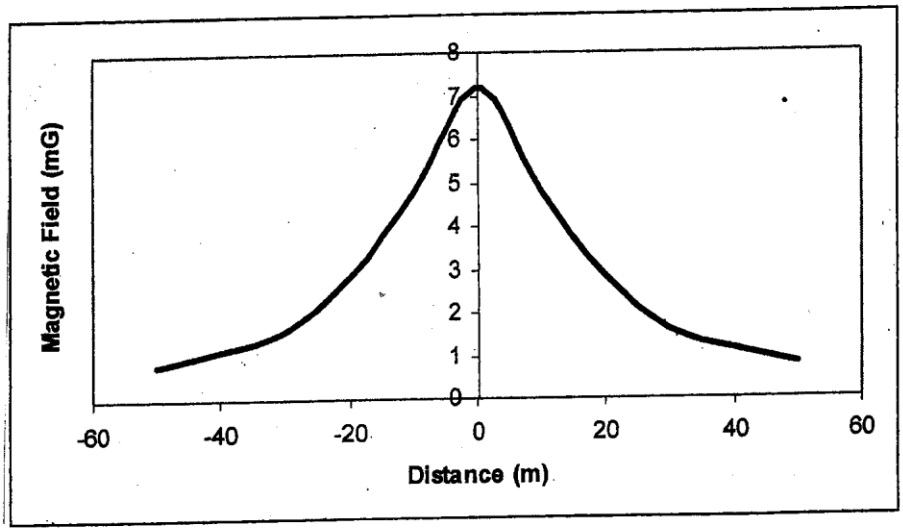


Fig. 5.2: Electric and magnetic fields Vs. Distance from the centerline of the 400 KV South Amman – East Amman OHL.

(The measurement is taken at 1 m above ground level)

REFERENCES

American Industrial Hygiene association. 2002. White Paper on Extremely Low Frequency Fields.

Australian Radiation Protection and Safety Agency. 2001. Does Electricity Cause Cancer?

Cherry N. 2004. Edvidence that Electromagnetic Fields from High Voltage Power Lines and Buildings are Hazardous to Human Health, Linclolin University, New Zealand.

EMF Exposure Standars (Applicable in Europe and Elsewhere). 2006.

Federal Office for Radiation-Germany. 1999.

Health Goods. 2008. Do Electric and Magnetic Fields Pose a Health Risk?

Hulbert A. L. 1998. Biological Response to Electromagnetic Fields.

IEEE Committee on Man and Radiation. 1999. Possible Health Hazards for Exposure to Power-Frequency Electric and Magnetic Fields.

International Commission on Non-Ionizing Radiation Protection. 1997. Guidelines for Limiting Exposure to Time Varying Electric, Magnetic, and Electromagnetic Fields (up to 300 GHz).

Lilien, J. L. 2008. Effects of Extremely Low Frequency Electromagnetic Fields on Human beings: An Electrical Engineer Viewpoints. Gastartikel, 124 (3): 34-50.

Masateru I. et al. 2010. Commission k: Electromagnetics in Biology and Medicine-Japan.

National Radiological Protection Board. 2001. ELF Electromagnetic Fields and Neurodegenerative Diseases.

National Institute of Environmental Health. 1998. Assessment of Health Effects from Exposure to Power – Line Frequency Electric and Magnetic Fields.

Mizrach S. 2001. Electromagnetic Effect on Human Behavior.

Pawluk W. 2004. Electromagnetic Fields and the Heart: Basic Science and Clinical Use.

Saunders R. D. Sienk Lewicz Z.J., and Qwalczuk CIK. 1991. Biological Effect of Electromagnetic Fields and Radiation. *J. of Radial Protection*, 11 (1): 27-42.

Sowa P. 2012. Identification of Impact of Electromagnetic Fields at Low and High Frequency on Human Health, Int. *J. of Electronics and Electrical Engineering*.

Saunders. R. 1995. Laboratory Studies on Static and ELF Fields.

World Health Organization. 2007. Guidelines of Exposure to Electromagnetic Field.

تأثير المجالات المغناطيسية على صحة الإنسان
قياسات موقعية وتوصيات

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ملخص

في ضوء الاهتمام المتزايد بأخطار المجالات الكهرومغناطيسية ذات الترددات المنخفضة على صحة الإنسان، فإنه من الضروري قياس مستويات هذه المجالات في الأردن، قرب الأجهزة المنزلية والمحولات والكابلات وخطوط النقل ومحطات التحويل الكهربائية، ومن ثم مقارنتها بالحدود العليا المسموح بها في المواصفات العالمية لتقدير مدى هذه الأخطار. وللعاملين في مجال الأنظمة الكهربائية لتجنيبهم اخطار التعرض لهذه المجالات أو الحد منها على الأقل.

الكلمات الدالة : المجالات الكهرومغناطيسية، الترددات المنخفضة للغاية، حدود التعرض.

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