An-Najah National University

Faculty of Graduate Studies

The Effect of the Electromagnetic Radiation from High Voltage Transformers on Students Health in Hebron District

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Dedication

To the source of inspiration for unwavering support and encouragement, during this study, to the precious soul of my father. I would like to thank my mother for her love and endless support. Special thanks to Ayman my life partner for his encouragement and support, and to my children (Ibrahim, Toqa, Shatha and Mohammed). Thanks to my sisters and my brothers for giving me the bravery to keep going, specially Fatima, special thanks to my brother Hazem for his help in measurement part. To all my family, and friends with love and respect.

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الاقرار

أنا الموقع أدناه مقدم الرسالة التي تحمل العنوان:

The Effect of the Electromagnetic Radiation from High Voltage Transformers on Students Health in Hebron District

أقر بأن ما اشتملت عليه هذه الرسالة ، انما هي نتاج جهدي الخاص ، باستثناء ما تمت الاشارة اليه حيثما ورد ، وأن هذه الرسالة ككل ، أو أي جزء منها لم يقدم من قبل لنيل أي درجة علمية أو بحث علمي لدى أي مؤسسة تعليمية أو بحثية أخرى .

Declaration

The work provided in this thesis, unless otherwise referenced, is the researcher's own work, and has not been submitted elsewhere for any other degree or qualification.

Student’s name: اسم الطالب:

Signature: التوقيع:

Date: التاريخ:

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List of Abbreviation

symbol	Abbreviation
a	After
a.m	Before midday
A_b	Absorbance
A/m	Ampere per meter
AM	Amplitude modulation
ANOVA	Analysis of Variance
b	Before
B	Magnetic flux density
dB(A)	Decibel(s) by a weighting Filter (A)
dB	Decibel(s)
DBP	Diastolic Blood Pressure
DOE	Department of energy
DNA	Deoxyribonucleic acid
E	Internal electric field
ELF	Extremely Low Frequency
EMF	Electromagnetic Field
EMR	Electromagnetic Radiation
EM SE	Electromagnetic Shielding Efficiency
EPA	Environmental Protection Agency
FDA	Food and Drug Administration
Fig	Figure(s)
FM	Frequency modulation
G	Gauss
GSM	Global System for Mobile Communication
H	Magnetic field strength
HPR	Heart Pulse Rate
Hz	Hertz
ICNIRP	International Commission on Non-Ionizing Radiation Protection
IRPA	International Radiation Protection Association
J	Current density
KVA	Kilo volt ampere
Max	Maximum
Min	Minimum
mG	Milli Gauss
nT	Nano Tesla
NIOSH	National Institute for Occupational Safety and Health
OSHA	Occupational Safety and Health Administration
p.m	After midday

pT	Pico Tesla
P	Power density
P-value	Probability
R	Pearson correlation coefficient
R_e	Reflectance
RICNIRP	Russia International Commission on Non-Ionizing Radiation Protection
RF	Radio Frequency
SAGE	Stakeholder Advisory Group on Extremely low frequency
SAR	Specific absorption rate
S	Schools
S1	Hebron Secondary Industrial School
S2	Dura Secondary School for Girls
S3	Al-Qadesya School for Girls and Boys
S4	Wad alsultan School for Girls and Boys
S5	Zaid bn haretha School for Girls and Boys
S.D	Standard Deviation
sec	Section(s)
S/m	Siemens per meter
SBP	Systolic Blood Pressure
SpO_2 %	Blood Oxygen Saturation
T	Tesla
T(℃)	Tympanic Temperature
T_r	Transmittance
TEPRSSC	Technical Electronic Product Radiation Safety Standards Committee
TV	Television
V/m	Volt per meter
W/kg	Watt per kilogram
W/m^2	Watt per meter square
WHO	World Health Organization
σ	Electrical conductivity
μ	Magnetic permeability
Ω	Ohm
ρ	Density
η	Field resistance

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Abstract

This study aims to investigate the effect of exposing students to extremely low frequency electromagnetic radiation from high voltage transformers (160 KVA and 250 KVA). The sample of this study was 142 students including 69 males and 73 females, with ages (16-18) years and (9-11) years. This research was carried out in five schools in Hebron District. Measurements were taken for student's tympanic temperature, blood oxygen saturation, heart pulse rate, arterial blood pressure (diastolic and systolic), three times at (8:00 – 8:30) a.m and three times at (12:30 – 1:00) p.m in September 2012. These measurements were recorded indoors of the studied schools: Hebron Secondary Industrial School, Dura Secondary School for Girls, Al-Qadesya School for Girls and Boys, Wad Al-Sultan School for Girls and Boys, and Zaid Bn Haretha School for Girls and Boys, in Hebron District. The power flux density was measured using spectran RF 6080, the highest value was in Dura Secondary School 604 nW/ m^2, and the lowest value was in Zaid Bn Haretha School for Girls and Boys 350 nW/ m^2. These values explain that the schools were in different locations from the transformers. The data were subjected to statistical analysis. The

results show that the measured values of power flux density were within slight concern limit. The effect of EMR on student's health resulted in increasing tympanic temperature, heart pulse rate, arterial blood pressure (systolic and diastolic). On the other hand, the blood oxygen saturation was decreased.

Chapter One

Introduction

1.1 Background

The last three decades have witnessed a tremendous growth in all aspects of modern technology such as cellular phones, wireless communication links, antennas, microwave ovens, and high voltage transformers which are sources of the electromagnetic radiations (EMR) (Shankar, 2002). Humans are continuously exposed to these sources of electromagnetic fields. Many of the electromagnetic waves at certain frequencies, power levels, and exposure durations can produce biological effects or injury depending on multiple physical and biological variables (Michaelson, 1972). The pollution caused by electromagnetic radiation is the biggest problem of the twenty first century (Dode Adilza, 2010). Electromagnetic fields generate an electro pollution phenomenon; while there have been many benefits from the use of Radio Frequency (RF) radiation, people now are concerned that long-term exposure could affect their body biological system and health. The United States Department of energy (DOE) with the International Commission on Non-Ionizing Radiation Protection (ICNIRP), and the World Health Organization (WHO) and others conducted numerous studies on the effect of exposure to EMR on biological systems and human health. That is helped to clarify the risks and provide increased understanding. Standards have been developed and promulgated for television set receivers, medical X-rays, cathode ray tubes, microwave ovens, and lasers. The Food and Drug

Administration (FDA) has been required to consult with the Technical Electronic Product Radiation Safety Standards Committee (TEPRSSC). Other federal agencies that are actively concerned with non-ionizing radiation hazards include the Occupational Safety and Health Administration (OSHA), the Environmental Protection Agency (EPA), the National Institute for Occupational Safety and Health (NIOSH) (Wilkening, 2001).

Electromagnetic Fields (EMFs) are invisible forces that exist wherever there is electric power and are emitted from almost all electrical devices. They are in different magnitudes, present in virtually every home, office, school and in the industrialized world (Orel, 2010).

Electromagnetic Radiation (EMR) is the flow of photons through space at speed of light; each photon contains a certain amount of energy, which increases with growing frequency. This energy spread out as it moves. There are two types of electromagnetic radiation:

a. Ionizing radiation: contains sufficient electromagnetic energy to strip atoms and molecules from tissue and alter chemical reactions in the body. X-ray and Gamma ray are two forms of ionizing radiation.
b. Non ionizing radiation: the lower part of the frequency spectrum is considered as non ionizing electromagnetic radiation (EMR) with energy levels below that required for effects at the atomic level. Examples of non ionizing radiations are:

- static electromagnetic fields from direct current (0 Hz)
- low frequency waves from electric power (50 – 60 Hz)

- extremely low frequency and very low frequency fields (ELF) (up to 300 kHz)
- Radio frequencies (Low Frequency, High Frequency, Very High Frequency, Ultra High Frequency), Infrared light, Visible light and Ultraviolet light (above 300 GHz) (Zamanian *et al*, 2005)

Electric power substations, distribution lines, high voltage transmission lines, electric appliances, high voltage transformers as well as industrial devices are some of the commonly known sources of electromagnetic field pollution of ELF magnetic fields in the environment (Tayebeh *et al*, 2012). The ionizing radiation and non ionizing radiation are shown in Fig. 1.1

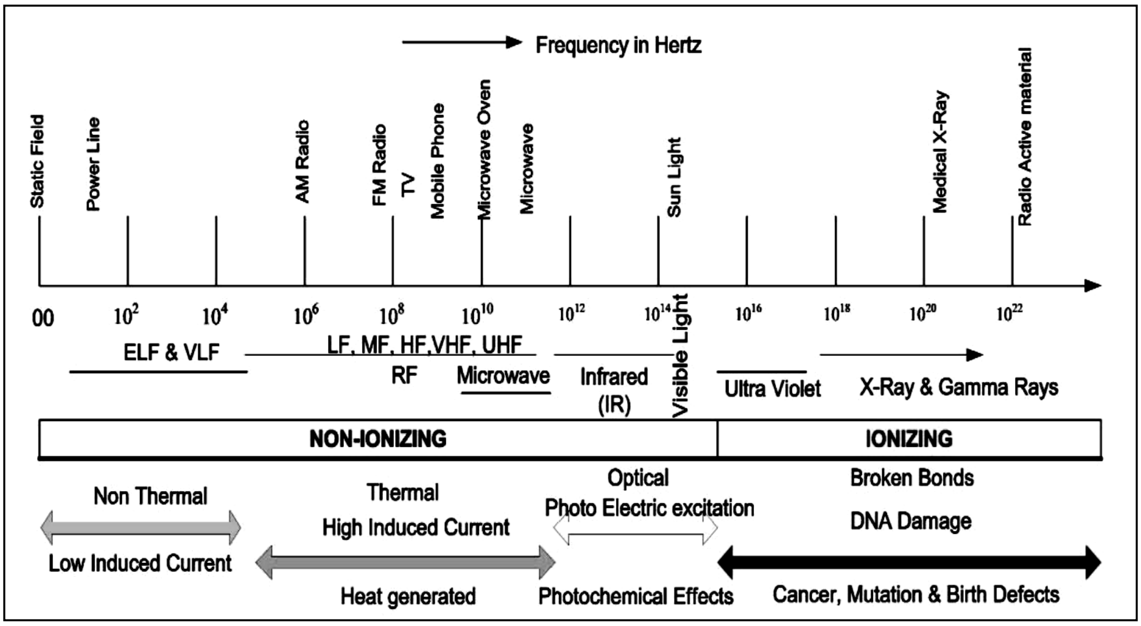

Fig. 1.1: Ionizing and non-ionizing electromagnetic radiation (Zamanian *et al*, 2005).

Instructions on use of microwave devices:

1. Minimize the time you speak on a phone, a few minutes enough.
2. Do not call when the signal is weak.

3. Hold the phone as far as possible from the body while calling.
4. Use safe headsets, use a loudspeaker phone.
5. Keep out of Wi-Fi fields, and use cable connection.
6. Avoid using cordless phones in your home.
7. Keep out of mobile phone towers, base station (Kumar, 2010).

1.2 Literature review

One could highlight the effects of exposure to electromagnetic radiation, by clarifying previous studies.

A study by Carl Blackman has shown that weak electromagnetic fields release calcium ions from cell membranes (Blackman *et al*, 1982).

Savitz and Loomis in 1994 had showed that the electric utility workers with the highest exposures to electromagnetic field radiation died from brain cancer at 2.5 times the rate of workers with the lowest exposure (Savitz *et al*, 1994).

An Australian research showed that children living near TV and FM broadcast towers had more than twice the rate of leukemia as children living more than seven miles away from these towers (Hocking *et al,* 1996).

A study by Om Gandhi and his group showed the percentage of radiation that penetrates the skull of an adult is 25%, ten years old is 50%, and five years old is 75%. The younger the child the deeper the penetration due to the fact their skulls are thinner and still developing, as shown in Fig. 1.2 (Om Gandhi *et al*, 1996).

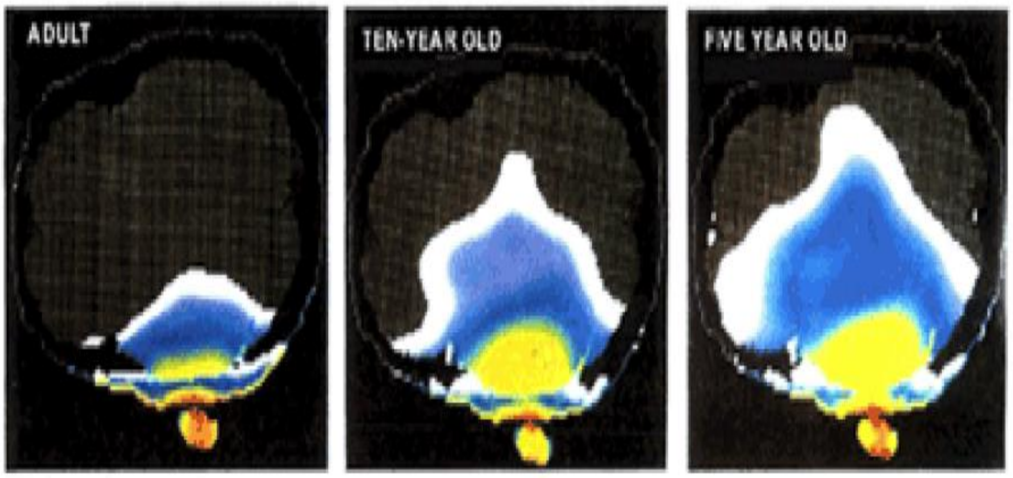

Fig. 1. 2: Absorption of electromagnetic radiation from a cell phone based on age (frequency GSM900MHz) (Om Gandhi *et al,* 1996).

A research done by Leszczynski and his group, on human cells exposed to 900 MHz GSM mobile phone microwave radiation, showed that very low-level frequency (ELF) and RF exposures could cause the cells to produce stress proteins. This further demonstrates that ELF and RF exposures can be harmful, and it happens at levels far below the existing public safety standards (Leszczynski *et al*, 2002).

The researchers who believe that humans can suffer from cancer and tumor when exposed to EMF radiation get their data from studies of people living near power stations but they fail to give proper justifications. The relation between EMF field strength and the possible risk associated with it or the mechanisms that can trigger processes like cancer and the creation of tumors are still unresolved (Shankar, 2002).

A study in France showed an increased incidence of tiredness among people living within 300m from the base station, of headache, sleep disturbance, discomfort within 200m, and of irritability, depression, dizziness, loss of memory within 100m. Women were found to complain significantly more often than men of nausea, headache, and loss of appetite, sleep disturbance, depression, discomfort and visual perturbations (Santini *et al*, 2002).

Another study reveals that workers who are in the highest 10% category for EMF exposure are twice as likely to die of prostate cancer as those exposed at lower levels (Charles *et al*, 2003).

Maternal Occupational exposure to extremely low frequency magnetic fields had showed an increased risk of childhood leukemia among children whose mothers were exposed to the highest occupational levels of ELF-MF during pregnancy (Claire *et al*, 2003).

David de Pomerai had shown that very weak microwave radiation can change the shape of proteins, prompting them to clump together, and the radiation can lead to the formation of long strands of proteins called fibrils (David, 2003).

Braune and his group reported that both systolic and diastolic blood pressure of volunteers were increased by about five mmHg by exposure for 35 minutes to the signals from a GSM mobile phone held close to the right ear (National Radiological Protection Board, 2004).

A Saudi Arabian study found a relationship between headache, fatigue, dizziness, tension and sleep disturbances in subjects exposed to mobile phones emissions (Al-Khlaiwi *et al*, 2004).

Electricity studies of workers exposed to strong electric and magnetic fields (60 Hz) from power lines provide no consistent evidence that these fields are damaging to DNA or that they are capable of causing mutations or cancer (Zamanian *et al*, 2005).

Living near mobile phone base stations are also at risk for developing neuropsychiatric problems as headache, tingling, nausea, alter reflexes, tremors, muscle spasms, numbness, memory loss, dizziness, muscle and joint paint, leg/foot pain, depression, and sleep disturbance (Abdel-Rassoul *et al*, 2006).

Exposure to electromagnetic fields has shown to be in connection with Alzheimer's disease, motor neuron disease and Parkinson's disease (WHO, 2007).

Scientists in Russia had done studies on EMF for decades, and reported that electric fields cause high blood pressure, changes in white and red blood cell counts, immune system dysfunction, chronic stress effects, increased metabolism, chronic fatigue disorders, and headaches (Havas, 2008).

An epidemiology study in Tel Aviv University by a physician Sadetzki, found that those who held a mobile handset against one side of their head for several hours a day had 50% more risk for tumor formation in the parotid gland (Sadetzki *et al*, 2008).

An experimental study on laboratory mice exposed to radio frequency radiation showed that the average white blood cells level increases as the samples were kept longer under the RF radiation, while the average red blood cells decreases (Rusnani *et al*, 2008).

Jonas Hardell suggested that the risk for developing brain tumors increases significantly for the people who used the phone more intensely and for more years. In addition, a significantly increased risk of brain cancer was observed on the same side as one held the phone; the risk was increased by 30% for developing Acoustic Neurinoma, a benign tumor in the brain on a nerve related to hearing that may cause permanent deafness (Hardell L *et al*, 2009).

A study in Iran about the effect of electromagnetic radiation from high voltage transmission lines showed that living under these transmission lines was considered to be more risky region than living near these transmission lines (Ahmadi H *et al*, 2010).

In Natanya city, a study showed an increase of 4.15 times the incidence of cancer among residents who lived within a radius of up to 350m of antennas of mobile phone (Dode Adilza, 2010).

A study of staff working near antennas transmitting high microwave power showed the effect on their thyroid gland processes (for example increase in body temperature and change the production of thyroid hormone)(Gavriloaia *et al*, 2010).

Another research performed in the common 60 Hz range demonstrated repeatedly that electromagnetic radiation could cause serious, sometimes fatal disease, changes in hormones, and major psychological and physical stress (Matt, 2010).

The Seletun Scientific Panel in Norway recommends for all new constructed residences, hospitals, and schools, there shall be one milli

Gauss for the magnetic flux density max 24 hour average exposure limit, from electrical power distribution (for example transmission lines and transformers) (Adamantia *et al*, 2010).

Iranian research showed that exposure to magnetic fields at high voltage (230 KV) substations can cause the intensifications of neurological, cardiac, mental, respiratory auditory disorders and gastrointestinal, despite that the exposure level was lower than occupational permissible limits from ICNIRP (Sharifi Mahdieh *et al*, 2010).

Indian scientists indicates that deafness (loss of hearing due to damage to sensors in inner ear) can occur in 25 – 30 % of people using mobile phones for more than two hours a day over a two-year period, besides causing burning sensation in the ear and headaches. In addition, DNA damage, low sperm count leading to infertility and reduction in testis size in rats has also been reported. The health minister in India therefore advices for not using mobile phones for more than one hour a day (Kumar, 2010).

A research in Poland showed that the mean temperature in the whole volunteers during continuous exposure to EMF emitted by mobile phone was significantly higher than during separate periods of exposure (Alicja *et al*, 2012).

Avandano and his group found that exposing to a Wi-Fi laptop for four hours gave a decrease in sperm motility and an increase in DNA fragmentation as compared with samples exposed to a similar computer with the Wi-Fi switched off (Avandano *et al*, 2012).

Another research by Tayebeh Barsam and his group, showed that exposure to extremely low frequency electromagnetic field from high voltage substations in Kerman city, had a negative effect on sleep quality for people living near these substations (Tayebeh Barsam *et al*, 2012).

1.3 Objectives of the study

In Palestine, there is a lack in information about electromagnetic radiation effects on humans. The wide spread of high voltage transformers everywhere, near homes, hospitals, and specially schools is the encouraging reason to conduct this study. As a result of this study, some suggestions and recommendations for students and teachers in schools are expected.

The aims of this study are:

1. Measuring the power density of the electromagnetic radiation near schools and calculating the electric field and the magnetic field strengths.
2. Measuring the blood pressure, heart pulse rate and blood oxygen saturation of selected students in each studied school.
3. Measuring of electromagnetic radiation in different locations. The results will be compared with the recommended EMF levels from International Commission on Non-Ionizing Radiation Protection, and Building Biology Institute Guidelines. Calculating the specific absorption rate (SAR) for human brain.
4. Giving some advices and recommendations to the students about the health risks, for exposure to EMR from high voltage transformers.

The reference levels for general public exposure to time varying electric and magnetic fields are shown in Table 1.1.

1.4 Reference levels

Table 1.1: Reference levels for general public exposure to time varying electric and magnetic fields (ICNIRP, 2010).

Frequency range	E-field strength (kV m^{-1})	Magnetic field strength H (A m^{-1})	Magnetic flux density B (T)
1 Hz − 8 Hz	5	$3.2\times10^4/f^2$	$4\times10^{-2}/f^2$
8 Hz − 25 Hz	5	$4\times10^3/f$	$5\times10^{-3}/f$
25 Hz − 50Hz	5	1.6×10^2	2×10^{-4}
50 Hz − 400 Hz	$2.5\times10^2/f$	1.6×10^2	2×10^{-4}

(Where f is the frequency)

Building Biology Institute in Germany provided the following guidelines for power flux density exposure, where the exposure levels are shown in Table 1.2 (Building Biology Institute, 2008).

Table 1.2: Reference levels for power flux density exposure (exposure levels in $\mu W/m^2$) (Building Biology Institute, 2008).

Power flux density ($\mu W/m^2$)	
< 0.1	no concern
(0.1 - 10)	slight concern
(10 - 1000)	severe concern
> 1000	extreme concern

The reference values for SAR are shown in Table 1.3

Table 1.3: Standard values for SAR in Europe and USA (David, 2005).

	Whole body SAR	Spatial peak SAR	Averaging time	Averaging mass
Europe	0.08 W/kg	2 W/kg	6 min	10 gm
USA	0.08 W/kg	1.6 W/kg	30 min	1 gm

Chapter Two

Theoretical Background

This chapter consists of six sections including, nature of electromagnetic fields (sec. 2.1), specific absorption rate (sec. 2.2), sources of non-ionizing electromagnetic radiation (sec. 2.3), the effect of EMR of high voltage transformers on human health (sec. 2.4), the interaction between electromagnetic fields and human body (sec. 2.5), and electromagnetic radiation shielding (sec. 2.6).

2.1 Nature of electromagnetic fields (EMF)

Electricity is usually delivered as alternating current that oscillates at (50 - 60) Hertz, putting these fields in the Extremely Low Frequency range (ELF). EMF with cycle's frequencies of greater than 3Hz and less than 3000 Hz is generally referred to as ELF (National Institute of Environmental Health Science, 1999).

Electromagnetic fields in the environment are usually characterized by their flux density. Magnetic field can be specified in two ways, magnetic flux density *B*, expressed in tesla (T), or as magnetic field strength *H*, expressed in ampere per meter ($A\ m^{-1}$).

For linear materials, the two quantities are related by the expression:

$$B = \mu H \tag{2.1}$$

Where μ is the constant of proportionality (the magnetic permeability) in vacuum or air, as well as in nonmagnetic (including biological) materials.

Human beings are complex electrochemical systems that communicate with the environment through electrical pulses.

Exposure to time-varying EMF results in internal electric fields in body currents and energy absorption in tissues that depend on the coupling mechanisms with the frequency involved. For ohmic materials, the internal electric field *E* and current density *J* are related by Ohm's Law:

$$\vec{J} = \sigma \vec{E} \qquad (2.2)$$

Where σ is the electrical conductivity of the medium (ICNIRP, 2010).

The Power density (P), which is the rate of flow of electromagnetic energy per unit surface area (usually expressed in W/m^2 or mW/cm^2), can be written as:

$$P = \frac{E^2}{\eta} \qquad (2.3)$$

or

$$P = EH \qquad (2.4)$$

or

$$P = \eta H^2 \qquad (2.5)$$

Where E is the electric field intensity and η is the field resistance taken as 377Ω for free space (in air) (Mousa Allam, 2009). The following Table shows List of orders of magnitude for magnetic fields (magnetic flux density).

Table 2.1: List of orders of magnitude for magnetic fields (magnetic flux density) (Wikipedia, 2006).

Item	Magnetic field (Gauss)
Human brain magnetic field	(1 – 10) nG
Strength of earth's magnetic field at 0 latitude	310 mG
Strength of earth's magnetic field at 50 latitude	580 mG
The strength of a typical refrigerator magnet	50 G

2.2 specific absorption rate (SAR)

Specific absorption rate (SAR) is defined as the quantity used to measure how much RF is actually absorbed in a body. SAR is defined as the time derivative of the incremental energy δW, absorbed by or dissipated in an incremental mass that is contained in a volume element, δV of a density ρ. Therefore,

$$\text{SAR} = \frac{\delta}{\delta t}\left(\frac{\delta W}{\delta m}\right) = \frac{\delta}{\delta t}\left(\frac{\delta W}{\rho \delta V}\right) \tag{2.6}$$

SAR units are expressed as Watts per kilogram (W/kg) (Alberto, 2011). SAR should be considered an "absorbed dose rate" and is related to electric fields at a point by:

$$\text{SAR} = \frac{\sigma|E^2|}{\rho} \tag{2.7}$$

Where σ is the conductivity of the tissue (S/m), ρ is the mass density of the tissue (kg/m^3), and E is the rms electric field strength (V/m).

SAR can also be an estimated rate of temperature rise at a given point (David, 2005). Therefore, tissue heating is the principal mechanism of interacting between radio frequency energy and the human body. For example, we can find SAR for human brain using this relation:

$$\text{SAR} = \frac{\sigma|E^2|}{\rho_m} \qquad (2.8)$$

where, ρ_m is the mass density of the material in the human brain, and it is taken as 1700 kg/m^3, and the electrical conductivity σ is given by 0.7 S/m (Mousa *et al*, 2010). Other values of σ and ρ for human brain, are given 1.1531 S/m for the conductivity and 1030 kg/m^3 as the mass density of the tested tissue (Chiang *et al*, 2008). As an example of SAR, the Seletun Scientific Panel recommends for whole body exposure limit of 33 µW/ kg from microwave radiation. Another example for effects to be seen SAR level must exceed (0.5 – 1.0) mW/m^2 for whole body (Gerd Oberfeld, 2012).

2.3 Sources of non-ionizing electromagnetic radiation

This section describes various sources of electromagnetic radiation. They are transformers (sec. 2.3.1), overhead power lines (sec. 2.3.2), wireless internet (sec. 2.3.3), and microwave ovens (sec. 2.3.4).

2.3.1 High voltage transformers

Transformer is an electrical device used to transfer an alternating current or voltage from one electric circuit to another by means of electromagnetic induction. This device main function is to reduce the voltage level usually from 4000V to 440V/220V for domestic usage (Nostolgia A, 2010). The high voltage electrical transformer is shown in Fig. 2.1.

Fig. 2.1: High voltage electrical transformer

Transformers Types are:

1. Power Transformers
2. Distribution Transformers
3. Phase-Shifting Transformers
4. Rectifier Transformers
5. Constant Voltage Transformers (Harlow, 2004).

Since power transformers and high voltage overhead lines create strong magnetic fields, from here comes the importance of knowing the distance at which people can consider themselves safe living in surroundings.

2.3.2 Overhead power transmission lines

By increasing population of the world, many buildings construct near high voltage overhead power transmission lines. The increase of power demand has increased the need for transmitting huge amount of power over long distances. Large transmission lines configurations with high voltage and current levels generate large values of electric and magnetic fields stresses, which affect the human being.

Overhead power lines consist of three main components:

- Pylons (called towers).
- Lines (called conductors or wires).
- Transmission route.

The number of conductors on a circuit will depend on the operating voltage, and the load carried by a circuit. The overhead power lines are shown in Fig. 2.2.

Fig. 2.2: Overhead power lines

For living in safe region near overhead power lines, the International Radiation Protection Association (IRPA) recommends measuring the electric field and the magnetic field strength for evaluation of electromagnetic pollution from power lines.

2.3.3 Wireless internet

Wireless Fidelity (Wi-Fi): is defined as the network technology that uses radio waves to allow high-speed data transfer over short distances (usually less than 100m). The strength of RF fields is greater at its source and diminishes quickly with distance; Wi-Fi allows local area network (WLANs) to operate without cables and wiring, making it a popular choice for home, university, airports, schools and many public areas. The wireless router is shown in Fig. 2.3 (WHO, 2006).

Fig. 2.3: An example of a wireless router (Britannica, 2013).

Computers and laptops operate within the frequency range of (1000 - 3600) MHz, and most Wi-Fi systems and some cordless phones operate around 2450 MHz (Sage *et al*, 2009).

2.3.4 Microwave ovens

The microwave oven is one of the great inventions of the 20th century. They are also extremely efficient in their use of electricity, because a microwave oven heats only the food-nothing else. Microwave ovens use microwaves to heat food, microwaves are radio waves; the radio wave frequency is roughly 2,500 MHz. In this frequency range, radio waves have an interesting property they are absorbed by water, fats and sugars. When they are absorbed, they are converted directly into atomic motion - heat, another property they are not absorbed by most plastics, glasses or ceramics. (Instruction Manual for Microwave oven, 2007). A microwave oven is shown in Fig. 2.4.

Fig. 2.4: Microwave Oven (Instruction Manual for Microwave oven, 2007).

2.4 The effect of EMR of high voltage transformers on human health

The human body is composed of some biological materials like blood, brain, muscle, skin …etc. It contains free electric charges (largely in ion, rich fluids such as blood and lymph). Our body acts like an energy wave broadcaster and receiver in cooperating and responding to EMR. All living cells create electric fields, in general the strength of the electric field of the heart is up to 50 mV/m, and that of the brain and other vital organs up to 5 mV/m (Vladimir *et al*, 2012).

Environmental and occupational health risks are increasingly a focus of public concern, because all living organisms are exposed to electromagnetic radiation.

This work measures the effect of EMR on the following variables:

a) Heart pulse rate (HPR): is the number of heartbeats per unit time. The following are the average values of normal heart pulse rate for different ages:

Newborns (0 to 30 days old): 80 beats / min.

Children (1 month to 10 years): 100 beats / min.

Children over 10 years and adults: 80 beats/min (Bernstein D, 2007) .

Our heart pumps the blood to all parts of the body with some pressure.

b) Blood pressure (Systolic and Diastolic): is the pressure exerted by circulating blood upon the walls of blood vessels, during each heartbeat; blood pressure varies between a maximum (systolic) and a minimum (diastolic) pressure. Heart contracts to achieve a maximum blood pressure as required for proper circulation in our body. This pressure is called systolic blood pressure, after the systole cycle completed the heart comes in the relaxing position by exerting minimum blood pressure called diastolic blood pressure. The normal (systolic and diastolic) blood pressure is at or below 120/80 mmHg. The high blood pressure is considered at or above 140/90 mmHg (Nivedita *et al*, 2012).

c) Tympanic Temperature: one of the methods which is used to check body temperature in the ear. Tympanic temperature as formal name for the eardrum is the tympanic membrane (Elert *et al*, 2007).

d) Blood oxygen saturation SpO_2%: is the ratio of oxyhemoglobin to the total concentration of the hemoglobin present in the blood. The normal values for blood oxygen saturation are between (95 to 100) percent (Michael K, 2007).

2.5 The interaction between the electromagnetic fields and human body

ELF-EMFs induce currents in the human body, but various biochemical reactions within the body itself generate currents as well. Electric fields induced in tissue by exposure to ELF-EMFs will directly stimulate nerve fibers in a biophysically plausible manner, when the internal electric field strength exceeds a few volts per meter (Ahmadi *et al*, 2010). The forces exerted by electric fields on living cell can cause rotation, destruction, deformation of cells because of the conductivity of living tissues (Aliyu *et al*, 2012). There are three basic coupling mechanisms through which time-varying electric and magnetic fields interact directly with living matter: coupling to low-frequency electric fields, coupling to low-frequency magnetic fields and absorption of energy from electromagnetic fields. The interaction of time-varying low-frequency electric fields with the human body results in the flow of electric charges, the polarization of bound charge, and the reorientation of electric dipoles already present in tissue. The relative magnitudes of these different effects depend on the electrical properties of the body that is, electrical conductivity and permittivity (governing the magnitude of polarization effects). Electrical conductivity and permittivity vary with the type of body tissue and depend on the frequency of the applied field. Electric fields external to the body induce a surface charge on the body; this results in induced currents in the body, the distribution of which depends on exposure conditions, on the size and shape of the body, and on the body's position in the field. The physical interaction of time varying to low-frequency magnetic fields with the human body results in induced electric fields and circulating electric currents. The magnitudes of the induced field and the current density are proportional to the electrical conductivity of the tissue, and the rate of change and magnitude of the magnetic flux density (Vladimir *et al*, 2012).

2.6 Electromagnetic radiation shielding

Due to the tremendous development of technology and industry these days, the electromagnetic radiation exists wherever we go. To protect people from exposing to EMR, or at least minimize exposure to EMR, by using electromagnetic shielding which is the process of limiting the penetration of electromagnetic fields into a space, by blocking them with a barrier made of conductive material.

When electromagnetic radiations pass through a medium or an object, then these radiations will interact with the molecules of the medium or the object, these interactions include, absorption, reflections and internal reflections (Subhankar et al, 2013).

Electromagnetic Interference Shielding Efficiency (EMSE) is the ratio of the incident to transmitted power of the electromagnetic wave.

$$\text{EMSE} = 10 \log \left|\frac{P1}{P2}\right| = 20 \log \left|\frac{E1}{E2}\right| \qquad 2.9$$

EMSE value expressed in decibels, where P_1 (E_1) are the incident power (incident electric field), and P_2 (E_2) are the transmitted power (transmitted electric field). By measuring the transmittance (T_r) and the reflectance (R_e) of the material, the absorbance (A_b) can be calculated using this equation

$$A_b = 1 - T_r - R_e \qquad 2.10$$

Conductive polymers such as polyaniline, polyacetylene and polypyrrole, are applied to textile materials. These materials showed superior electrical property as electromagnetic shield (Subhankar *et al*, 2013). Other examples for good absorption materials, polystyrene, or electrolytic manganese dioxide and MnZn-ferrite (Pretorius *et al*, 2013).

Chapter Three

Methodology

3.1 Study Sample

This study was conducted on students in five schools, distributed in several locations in Hebron District: Hebron Secondary Industrial School, Dura Secondary School for Girls, Al- Qadesya School for Girls and Boys, Wad Alsultan School for Girls and Boys, and Zaid Bn Haretha School for Girls and Boys. The sample of this study was 142 students including 69 male and 73 female. Number of students with age (16 - 18) years are 85 students, and students with age (9 - 11) years are 57 students. The chosen students have no history of any disease. In order to select study sample from a random, the following formula was used (Cochran, 1977).

$$M = \frac{n}{1+\frac{n}{N}} \tag{3.1}$$

Where M is the correlation sample size that should be used, N is the actual sample number of students that found in each school, and n is the best value to select a random sample of students in each school, which is given by

$$n = \frac{Z^2\ P\ q}{\delta^2} \tag{3.2}$$

where Z = 1.96 (the abscissa of the normal curve that cuts an area of δ at the two tails, for population above 120), P = 0.9 (is the estimated proportion that one is trying to estimate in the population), q = 1- P = 0.1, (Pq the estimate of variance), and δ is the acceptable margin of error for proportion being estimated to be 0.065.

The number of examined students in each school is given in Table 3.1 below.

Table 3.1: Number of examined students in each school.

School	School's name	Students ages (years)	Number of examined students
S1	Hebron Secondary Industrial School	16 – 18	40 male, 15female
S2	Dura Secondary School for Girls	16 – 18	30 female
S3	Al- Qadesya School for Girls and Boys	6 – 12	11 female
S4	Wad Alsultan School for Girls and Boys	6 – 14	14 male, 9 female
S5	Zaid Bn Haretha School for Girls and Boys	6 - 16	15 male, 8 female

The transformers power and the distances between the transformers and the schools are given in Table 3.2 below.

Table 3.2: The distance between the transformers and schools, in addition to transformers power.

School	Distance between the schools and transformers	Transformers Power (KVA)
S1	30m and 5m	250 and 160
S2	10m	250
S3	5m	160
S4	50m	160
S5	150m	250

In this study the Transformers height above the ground level are (9 - 10) meters.

3.2 Sites of the schools

Hebron Secondary Industrial School (S1) is in Hawooz area in Hebron. This school consists of two separate buildings. The first consists of two floors and the second for the practical application. This school is surrounded by a wall from the inside around the stadium, and from the outside around the school, and the school is surrounded by homes from two sides.

Dura Secondary School for Girls (S2) is located in an area surrounded by trees on one side, and surrounded by a wall from all other sides. It consists of two buildings, one of them has two floors, the distance between the school playground and the high voltage transformer is almost 4 meters. Beside the school there is building of the training center.

Al-Qadesya School for Girls and Boys (S3) is in Wad Sood in Dura city. It is located under a mosque (it consists of one floor under the ground). There is no fence around it, but it is surrounded by houses from all sides.

Wad Alsultan School for Girls and Boys (S4) is a school in Ramadeen area in Dura city. It consists of one floor, there are no trees, walls surrounding it, and the houses are far from school.

Zaid Bn Hartha School for Girls and Boys (S5) is located on the top of a hill in Afiqiqays area near Dura city; the homes are far from the school. A fence and trees surrounds it from all directions.

3.3 Stages of study

This study was conducted in September 2012. Field measurements were carried out in each school in order to fulfill the objectives of this study.

Several stages were performed:

1. Visiting the Electricity Company (Hebron Southern Company) in Dura city to take a permission for helping to find the suitable schools for the study, the nearest from the transformers.
2. Discussing the nature of these transformers near these schools with electric engineers in the company, taking into considerations that the distance between the transformers and the schools is less than 200m.
3. Choosing the schools in quiet areas (50 – 60 dB) from the environment (far away from main streets, industries).
4. Taking a permission from the Ministry of Education in southern Hebron, to visit these schools.
5. Visiting the selected schools to inform them about the nature of the study. And taking the permission for doing the measurements on students.
6. Measuring the power flux density of the electromagnetic radiations in these schools.
7. Regular visits to these schools at 8:00 a.m, and before the students leave the schools at 12:30 p.m, in order to measure several health parameters. The tested parameters are:
   a- Tympanic temperature;
   b- Blood oxygen saturation;
   c- Heart pulse rate;
   d- Arterial blood pressure (systolic and diastolic);

Measurements of these parameters were taken three times for each student during (8:00 – 8:30) a.m and three times during (12:30 – 1:00) p.m. The average values of these measurements will be considered in the analysis part. In Palestine it is worth noting that a 50 Hz is used for transformers and transmission lines.

3.4 Measurements and Instrumentation

Several instruments and tools were used in performing our test and measurements. These instruments are briefly described in the following subsections, spectran of radio frequency (RF) 6080 is described in sec 3.4.1, pulse oximeter is described in sec 3.4.2, automatic blood pressure and pulse rate is described in sec 3.4.3, ear thermometer is described in sec 3.4.4, sound pressure level meter is described in sec 3.4.5, and Hioki 3423-lux Hitester meter is described in sec 3.4.6.

3.4.1 Spectran of radio frequency (RF) 6080

Radio frequency 6080 is used to make precision measurements to establish human safety, particularly in workplace environments. It measures the power flux density in the selected schools, and the field strengths (the strongest signal). It is composed of spectran HF device, antenna. The spectran devices offers four different operation modes:

- Spectrum analysis;
- Exposure limits calculation;
- Audio output;
- Broad band –Detector (power meter);

In this study, the operation mode was exposure limits calculation.

Spectran RF 6080 is shown in Fig. 3.1 and has an accuracy of ± 3dB. Spectran RF was placed in different locations in the schools, in order to get the signal. The average of these readings was taken three times during (8:00 – 8:30) a.m and three times during (12:30 – 1:00) p.m.

Fig. 3.1: Spectran RF 6080 (Instructions manual for spectran RF 6080, Aaronia AG, Germany, 2007).

3.4.2 Pulse oximeter

Pulse oximeter is used to measure the blood oxygen saturation three times for each student during (8:00 – 8:30) a.m and three times during (12:30 – 1:00) p.m. Pulse oximeter LM-800 (Finger- Oximeter) has an accuracy of ± 1 %, which is shown in Fig. 3.2.

Fig. 3.2: Pulse Oximeter LM-800 (Instructions manual for pulse oximeter, 2012).

3.4.3 Automatic blood pressure and pulse rate meter

The blood pressure (systolic and diastolic) and heart pulse rate were measured for each selected student three times during (8:00 – 8:30) a.m and three times during (12:30 – 1:00) p.m. By automatic digital electronic wrist blood pressure monitor (model WS-300) with accuracy ± 1 mmHg, and ± 1 % for reading heart pulse rate. The automatic digital electronic wrist blood pressure meter is shown in Fig. 3.3. (Instruction manual for automatic digital electronic wrist blood pressure, 1998 a).

Fig. 3.3: Arterial Blood Pressure and Heart Pulse Rate Meter, model WS- 300 (Instructions manual for Automatic Digital Electronic Wrist Blood Pressure, 1998a)

3.4.4 Ear thermometer GT-302

This instrument is used to measure the human body temperature through the tympanic temperature of the ear for each selected student three times during (8:00 – 8:30) a.m and three times during (12:30 – 1:00) p.m; the display temperature range is 32°C to 42.9°C, with accuracy range ± 0.01°C. The ear thermometer is shown in Fig. 3.4.

Fig. 3.4: GT- 302 Ear thermometers

3.4.5 Sound pressure level meter

Sound Level Meter is used to measure the sound levels of selected schools. It has an accuracy of ± 0.5 dB (A), with precision of 0.1dB (A).The sound pressure level meter which is used in this study is shown in Fig. 3.5 (Instructions manual for sound level meter, 1998b).

Fig. 3.5: Sound pressure level meter model 2900 type 2 (Instructions manual for sound level meter, 1998b).

3.4.6 Hioki 3423 lux hitester digital illumination meter

This instrument is used to measure the light intensity. It measures a broad range of luminosities from the low light provided by induction lighting up to a maximum intensity of 199,900 lux. In this study, the light was kept constant around 400 lux or less. The lux hitester digital meter is shown in Fig. 3.6.

Fig. 3.6: Hioki 3424 lux hitester digital illumination.

3.5 Statistical analysis

The gathered data were digitalized in a database developed with Microsoft excel and SPSS programs. The measurements were analyzed statistically as the following.

Pearson correlation coefficient (R) and the Probability (P) were used to measure the strength correlation between the EMR pollution and the dependant variables, before and after exposure to EMR. The Pearson correlation coefficient (R) reflects the degree of linear relationship between two variables. It ranges from -1 to +1. +1 is a perfect positive (increasing linear relationship), while -1 is a perfect negative (decreasing linear relationship). If R is zero then no correlation exists between studied variables. The strength of the correlation using the guide that Evans (1996) suggests for the absolute value of R as follows:

- $0.00 \leq R \leq 0.19$, very weak correlation
- $0.20 \leq R \leq 0.39$, weak correlation

- $0.40 \leq R \leq 0.59$, moderate correlation
- $0.60 \leq R \leq 0.79$, strong correlation
- $0.80 \leq R \leq 1.0$, very strong correlation (Brown *et al*, 1998).

The (P) values ranged from zero to one as follows:

- Values with $P = 0.050$, the threshold of statistical significance.
- Values with $0.000 \leq P \leq 0.050$, strong significance.
- Values with $0.050 \leq P \leq 1.000$, no significance (William *et al*, 2007).

- Analysis of variance (ANOVA) test was used in this work to detect association between power flux density, as independent variable, and temperature, blood oxygen saturation, heart pulse rate, and arterial blood pressure (diastolic and systolic), as dependant variables.

Chapter Four

Results

This chapter represents the results of this study. Measurements of power flux density, the electric and magnetic fields, and SAR is calculated and explained in sec. 4.1. Measurements of health effect of the EMR pollution from transformers is shown in sec. 4.2. Data analysis of dependant variables and power flux density levels is shown in sec. 4.3.

4.1 Measurements of power flux density

Measurements of power flux density of each studied school were taken by spectran RF 6080. The highest value of power density was in Dura Secondary School S2. The values were taken in the second floor in the school; there was a clear line of sight with the high voltage transformers from this position. The lowest value was in Zaid Bn Hartha School S5. This school is in the far field region. The electric and magnetic fields, magnetic flux density, were calculated using equations 2.1, 2.2, and 2.4.

Specific absorption rate for human brain was calculated, using equation 2.8. The results are tabulated in Table 4.1 for all selected schools.

SAR values in Table 4.1 were calculated according to ρ and σ values as follows. In SAR*, ρ = 1030 kg/m^3 and σ = 1.1531 S/m (Chiang *et al*, 2008), while in SAR** σ = 0.7 S/m, and ρ = 1700 kg/m^3 (Gerd Oberfeld, 2012).

Table 4.1: Average values of power flux density, electric field, magnetic field strength, magnetic flux density, and SAR for human brain, for selected schools.

School	$P\times 10^{-9}$ (W/m^2)	$E\times10^{-4}$ (V/m)	$H\times10^{-5}$ (A/m)	$B\times10^{-9}$ (G)	SAR*$\times10^{-8}$ (W/kg)	SAR**$\times10^{-8}$ (W/kg)
S1	552	144.27	3.83	4.81	23.30	8.57
S2	604	150.89	4.00	5.03	25.49	9.37
S3	494	136.46	3.62	4.55	20.85	7.66
S4	470	133.11	3.53	4.44	19.83	7.29
S5	350	114.87	3.05	3.83	14.77	5.43

The average values of the measured power flux density levels for transformers, of studied schools are shown in Fig. 4.1.a.

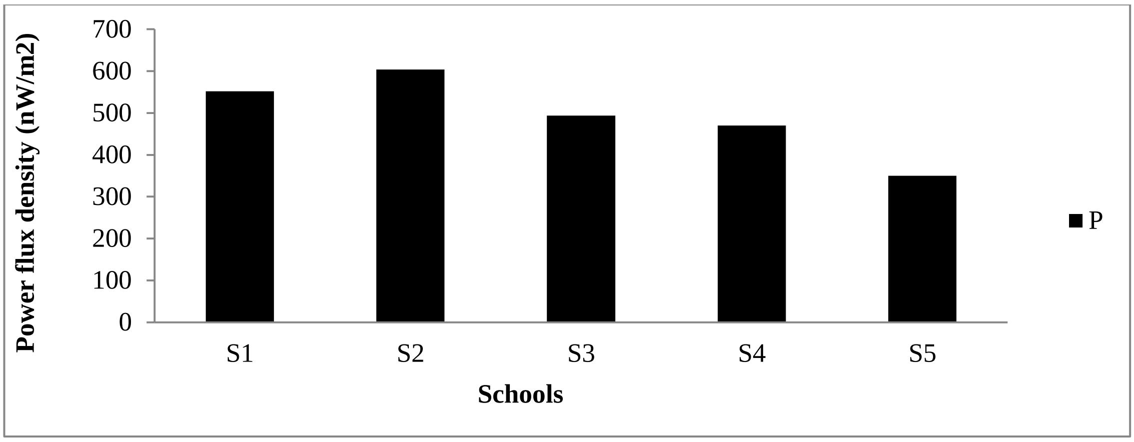

Fig. 4.1.a: Average values of the measured power flux density levels for high voltage Transformers, in studied schools.

4.2 Measurements of health effects of the EMR pollution from high voltage transformers

In this section, the health effects on some dependant variables such as: tympanic temperature, blood oxygen saturation SpO_2 %, heart pulse rate, and blood pressure levels (systolic and diastolic) are discussed.

The average values of the tympanic temperature, blood oxygen saturation, heart pulse rate, and blood pressure levels (systolic and diastolic), for males and females in each studied school before (b) and after (a) exposure to EMR from high voltage transformers are shown in Table 4.2 and Table 4.3.

Table 4.2: Average values of the tympanic temperature, blood oxygen saturation, heart pulse rate, diastolic and systolic blood pressure levels for males in each studied school.

variables	T(°C)		SpO_2%		HPR beats/min		DBP mmHg		SBP mmHg	
school	b	a	b	a	b	a	b	a	b	a
S1	35.9	36.4	98	96	78	82	72	79	123	124
S4	35.7	36.2	97	94	83	94	64	68	96	109
S5	35.8	36.1	98	97	88	95	61	67	107	108

Table 4.3: Average values of the tympanic temperature, blood oxygen saturation, heart pulse rate, diastolic and systolic blood pressure levels for females in each studied school.

variables	T(°C)		SpO_2%		HPR beats/min		DBP mmHg		SBP mmHg	
school	b	a	b	a	b	a	b	a	b	a
S1	35.8	36.1	98	97	83	95	73	78	115	124
S2	35.6	36.0	98	97	85	91	71	81	118	121
S3	35.3	35.6	98	95	92	98	62	75	94	113
S4	36.2	36.5	98	96	90	106	64	72	93	108
S5	36.0	36.0	98	96	88	95	61	66	107	108

From Tables 4.2 and 4.3, it can be observed that all students male and female are suffering from exposure to EMR from high voltage transformers.

Minimum, maximum, and standard deviation of the dependant variables temperature, blood oxygen saturation, heart pulse rate, blood pressure (diastolic and systolic) before (b) and after (a) exposure to EMR from high voltage transformers for male and female students in selected schools are presented in Tables 4.4 – 4.12.

Table 4.4: Min, Max, and S.D values of studied variables for male students in Hebron Secondary Industrial School (S1), before (b) and after (a) exposure to EMR from high voltage transformers.

variables	Min	Max	S.D
T (°C) (b)	34.2	36.4	0.55
T (°C) (a)	35.1	37.0	0.42
SpO_2 % (b)	95	99	0.94
SpO_2 % (a)	95	99	1
HPR beats / min (b)	52	110	13
HPR beats / min (a)	50	120	14
DBP mmHg (b)	51	102	12
DBP mmHg (a)	64	104	10
SBP mmHg (b)	80	145	13
SBP mmHg (a)	111	143	8

Table 4.5: Min, Max, and S.D values of studied variables for female students in Hebron Secondary Industrial School (S1), before (b) and after (a) exposure to EMR from high voltage transformers.

variables	Min	Max	S.D
T (°C) (b)	34.9	36.6	0.14
T (°C) (a)	35.2	36.9	0.60
SpO_2 % (b)	93	99	3
SpO_2 % (a)	95	99	1
HPR beats / min (b)	65	97	9
HPR beats / min (a)	85	110	7
DBP mmHg (b)	64	85	7
DBP mmHg (a)	63	88	8
SBP mmHg (b)	99	130	9
SBP mmHg (a)	104	131	8

Table 4.6: Min, Max, and S.D values of studied variables for female students in Dura Secondary School for Girls (S2) before (b) and after (a) exposure to EMR from high voltage transformers.

variables	Min	Max	S.D
T (°C) (b)	33.2	37.2	0.81
T (°C) (a)	35.2	37	0.48
SpO_2 % (b)	91	99	1.77
SpO_2 % (a)	93	99	1.62
HPR beats / min (b)	55	130	15.43
HPR beats / min (a)	66	130	15.10
DBP mmHg (b)	55	83	10
DBP mmHg (a)	69	93	8
SBP mmHg (b)	102	134	9
SBP mmHg (a)	90	145	16

Table 4.7: Min, Max, and S.D values of studied variables for female students in Al-Qadesya School for Girls and Boys (S3), before (b) and after (a) exposure to EMR from high voltage transformers.

variables	Min	Max	S.D
T (°C) (b)	34.6	35.9	0.48
T (°C) (a)	34.7	36.3	0.54
SpO_2 % (b)	96	99	1
SpO_2 % (a)	85	98	4
HPR beats / min (b)	82	100	6
HPR beats / min (a)	82	110	9
DBP mmHg (b)	53	70	7
DBP mmHg (a)	68	95	10
SBP mmHg (b)	83	102	8
SBP mmHg (a)	96	132	11

Table 4.8: Min, Max, and S.D values of studied variables for male students in Wad Alsultan School for Girls and Boys (S4), before (b) and after (a) exposure to EMR from high voltage transformers.

variables	Min	Max	S.D
T (℃) (b)	34.3	36.5	0.58
T (℃) (a)	34.8	36.6	0.58
SpO_2 % (b)	95	99	1
SpO_2 % (a)	81	98	5.76
HPR beats / min (b)	74	91	5.53
HPR beats / min (a)	83	105	6.22
DBP mmHg (b)	57	78	7
DBP mmHg (a)	58	91	10
SBP mmHg (b)	71	115	13
SBP mmHg (a)	98	126	10

Table 4.9: Min, Max, and S.D values of studied variables for female students in Wad Alsultan School for Girls and Boys (S4), before (b) and after (a) exposure to EMR from high voltage transformers.

variables	Min	Max	S.D
T (℃) (b)	34.8	36.8	0.7
T (℃) (a)	36.2	36.7	12
SpO_2 % (b)	95	99	1.31
SpO_2 % (a)	89	99	3.39
HPR beats / min (b)	82	97	7
HPR beats / min (a)	84	120	13
DBP mmHg (b)	51	76	9
DBP mmHg (a)	53	85	12
SBP mmHg (b)	85	97	5
SBP mmHg (a)	99	117	7

Table 4.10: Min, Max, and S.D values of studied variables for male students in Zaid Bn Hartha School for Girls and Boys (S5), before (b) and after (a) exposure to EMR from high voltage transformers.

variables		Max	S.D
T (°C) (b)	34.8	36.4	0.44
T (°C) (a)	35.8	36.4	0.26
SpO_2 % (b)	97	99	0.63
SpO_2 % (a)	92	99	2
HPR beats / min (b)	70	110	12
HPR beats / min (a)	83	115	12
DBP mmHg (b)	41	88	14
DBP mmHg (a)	37	103	20
SBP mmHg (b)	76	133	23
SBP mmHg (a)	70	148	24

Table 4.11: Min, Max, and S.D values of studied variables for female students in Zaid Bn Hartha School for Girls and Boys (S5), before (b) and after (a) exposure to EMR from high voltage transformers.

variables	Min	Max	S.D
T (°C) (b)	34.5	36.2	0.65
T (°C) (a)	35.1	36.3	0.42
SpO_2 % (b)	94	99	2
SpO_2 % (a)	85	99	4
HPR beats / min (b)	75	120	15
HPR beats / min (a)	84	120	13
DBP mmHg (b)	44	77	9
DBP mmHg (a)	36	85	16
SBP mmHg (b)	75	114	14
SBP mmHg (a)	87	128	13

The net change of tympanic temperature, blood oxygen saturation, heart pulse rate, blood pressure (diastolic and systolic), before and after exposure to EMR from high voltage transformers, for all students male and female, are measured and shown in Tables 4.13 and 4.14.

Table 4.12: Net change of tympanic temperature, blood oxygen saturation, heart pulse rate, blood pressure (diastolic and systolic), before and after exposure to EMR for males from high voltage transformers.

Differences between averages	S1	S4	S5
T (℃)	0.6	0.5	0.3
SpO_2 %	1	3	2
HPR beats / min	10	11	7
DBP mmHg	7	4	5
SBP mmHg	8	13	1

Table 4.13: Net change of tympanic temperature, blood oxygen saturation, heart pulse rate, blood pressure (diastolic and systolic), before and after exposure to EMR for females from high voltage transformers.

Differences between averages	S1	S2	S3	S4	S5
T (℃)	0.3	0.4	0.3	0.3	0
SpO_2 %	1	1	3	2	2
HPR beats / min	12	7	6	16	7
DBP mmHg	5	10	14	8	5
SBP mmHg	9	3	19	15	1

4.2.1 Tympanic temperature results

The tympanic temperature of selected students was measured three times for each student by using Ear Thermometers, during (8:00 - 8:30) a.m and three times during (12:30 - 1:00) p.m.

The effect of the electromagnetic radiation on the tympanic temperature for studied males and females schools are represented in Fig. 4.1 and Fig 4.2.

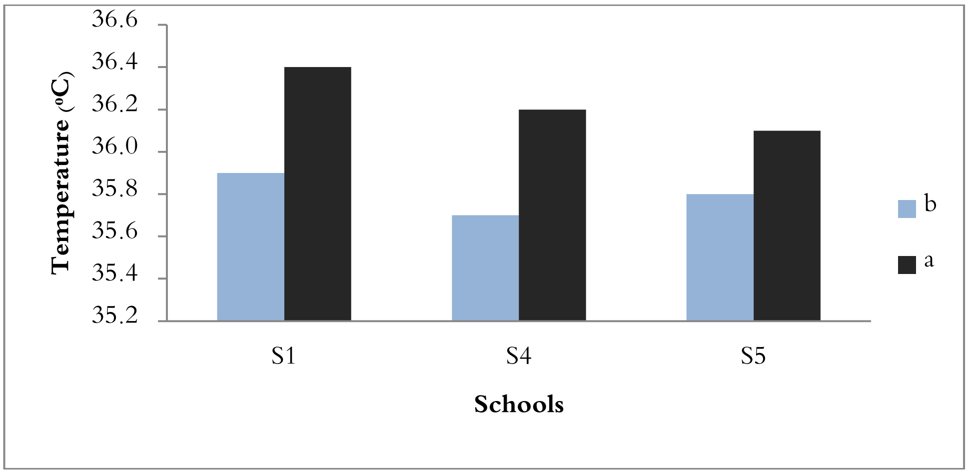

Fig. 4.1: Average values of tympanic temperature for male students in each studied school before (b) and after (a) exposure to EMR from high voltage transformers.

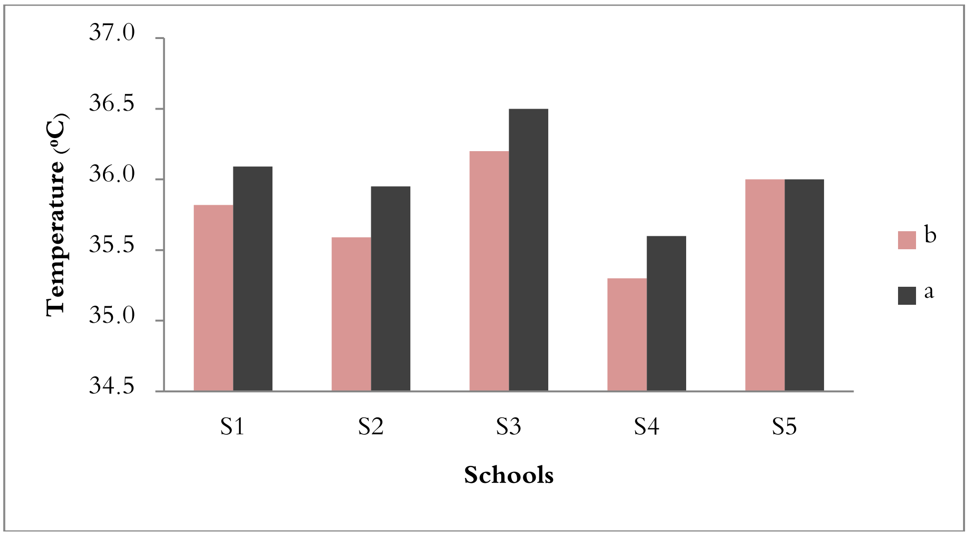

Fig. 4.2: Average values of tympanic temperature for female students in each studied school before (b) and after (a) exposure to EMR from high voltage transformers.

Figs 4.1 and 4.2 show that there is a significant shift of student's temperature after exposure to EMR from high voltage transformers.

4.2.2 Blood oxygen saturation (SpO_2 %) results

Pulse oximeter LM-800 was use to measure the blood oxygen saturation three times of selected students during (8:00 – 8:30) a.m and three times during (12:30 – 1:00) p.m. The average values of blood oxygen saturation for male and female students, before (b) and after (a) exposure to EMR from transformers, are shown in Fig 4.3 and Fig 4.4.

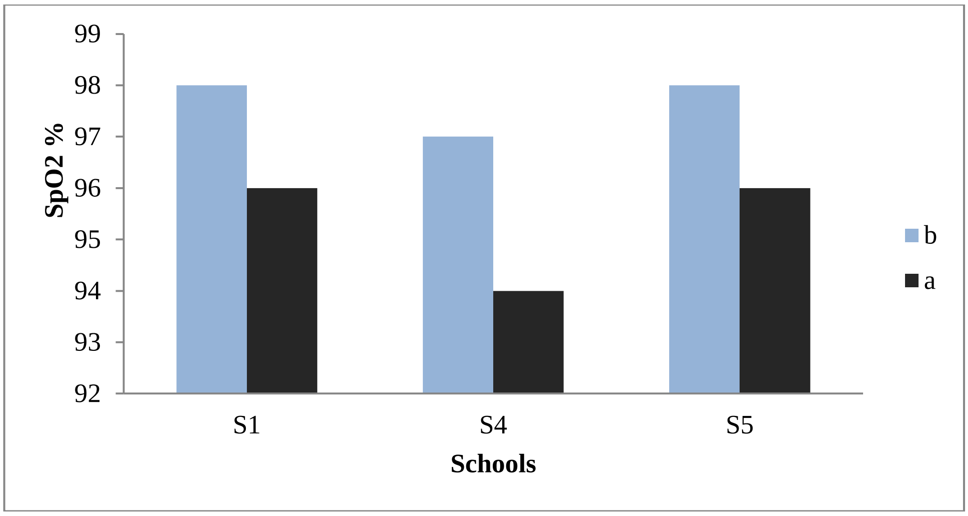

Fig. 4.3: Average values of blood oxygen saturation SpO_2 % for male students in each studied school before (b) and after (a) exposure to EMR from transformers

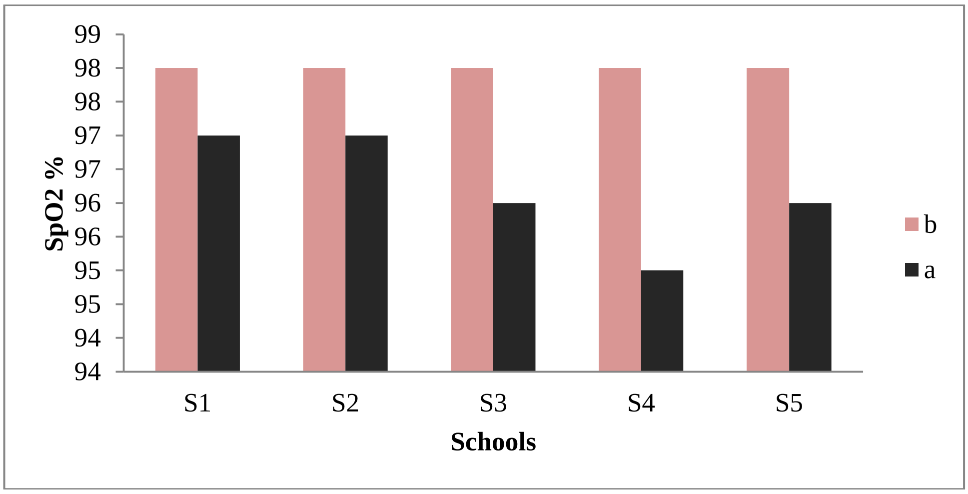

Fig. 4.4: Average values of blood oxygen saturation SpO_2 % for female students in each studied school before (b) and after (a) exposure to EMR from high voltage transformer.

From Figs 4.3 and 4.4, it can be observed that average values of blood oxygen saturation of selected students are decreased in all studied schools after exposure to EMR.

4.2.3 Heart Pulse Rate Result

The Automatic Digital Electronic Wrist Blood Pressure Meter, was used three times for each student during (8:00 – 8:30) a.m and three times during (12:30 – 1:00) p.m. The average values of heart pulse rate for male and female students in each studied school before (b) and after (a) exposure to EMR from high voltage, transformers are shown in Fig 4.5 and Fig 4.6.

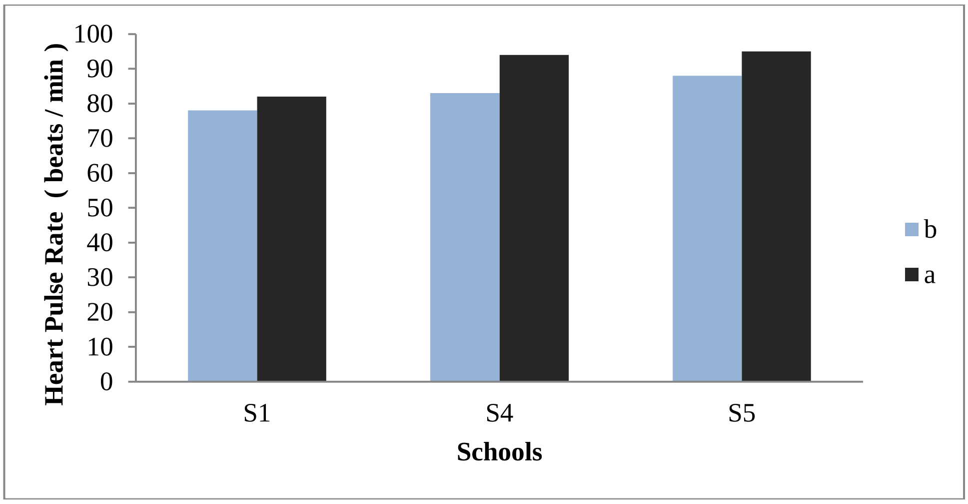

Fig. 4.5: Average values of heart pulse rate for male students in each studied school before (b) and after (a) exposure to EMR from high voltage transformers

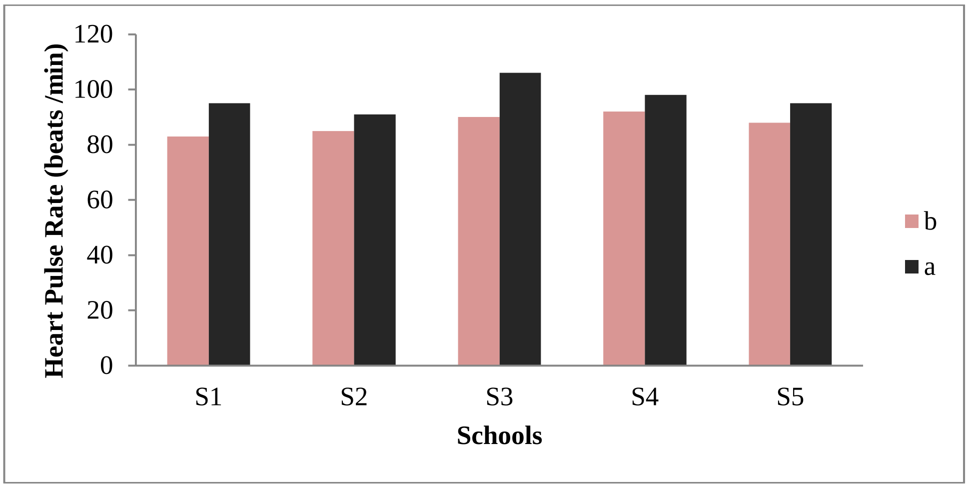

Fig. 4.6: Average values of heart pulse rate for female students in each studied school before (b) and after (a) exposure to EMR from high voltage transformers.

Fig 4.5 and Fig 4.6 show a clear increase of heart pulse rate values that occur when students male and female were examined during exposure to EMR from high voltage transformers in the studied schools.

4.2.4 Diastolic and Systolic blood pressure results

The measured values of diastolic and systolic blood pressure of selected students were recorded by using automatic digital electronic wrist blood pressure meter, three times for each student during (8:00 – 8:30) a.m and three times during (12:30 – 1:00) p.m.

The average values of diastolic and systolic blood pressure, for male and female students in each studied school, before (b) and after (a) exposure to EMR from high voltage transformers, are represented in Figs 4.7 – 4.10.

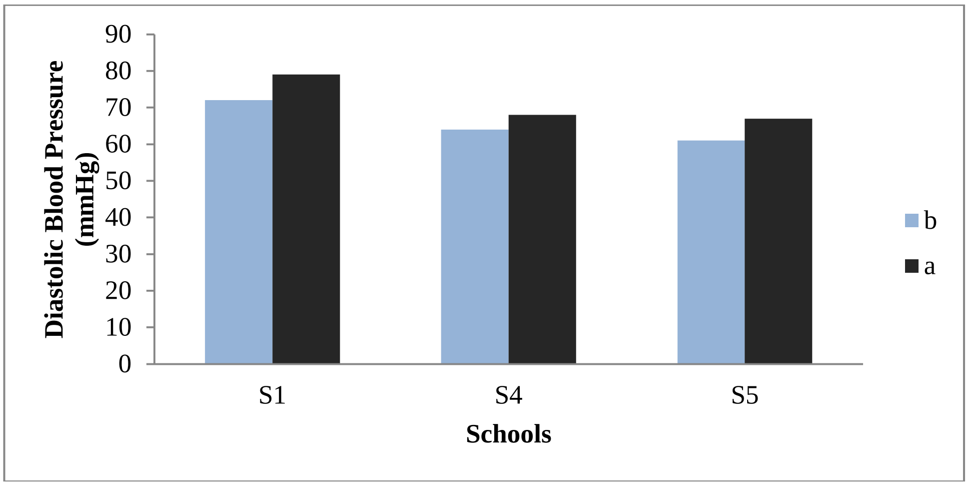

Fig. 4.7: Average values of diastolic blood pressure for male students in each studied school before (b) and after (a) exposure to EMR from high voltage transformers

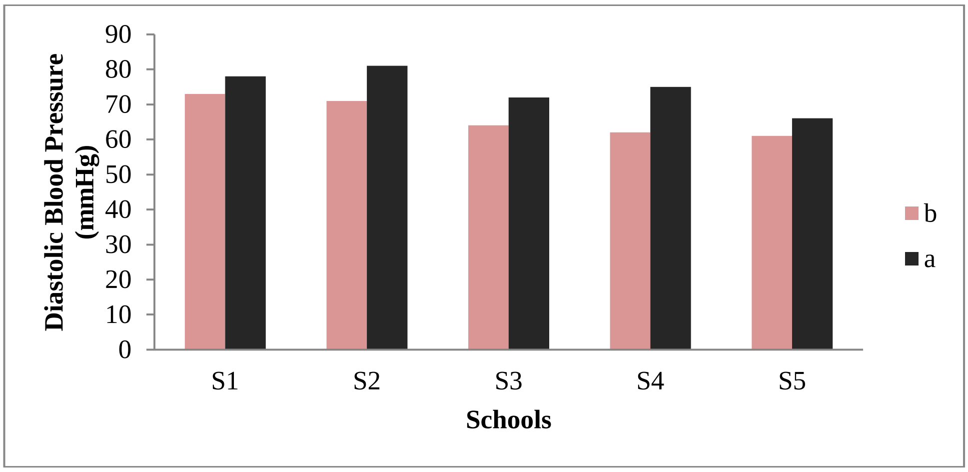

Fig. 4.8: Average values of diastolic blood pressure for female students in each studied school before (b) and after (a) exposure to EMR from high voltage transformers

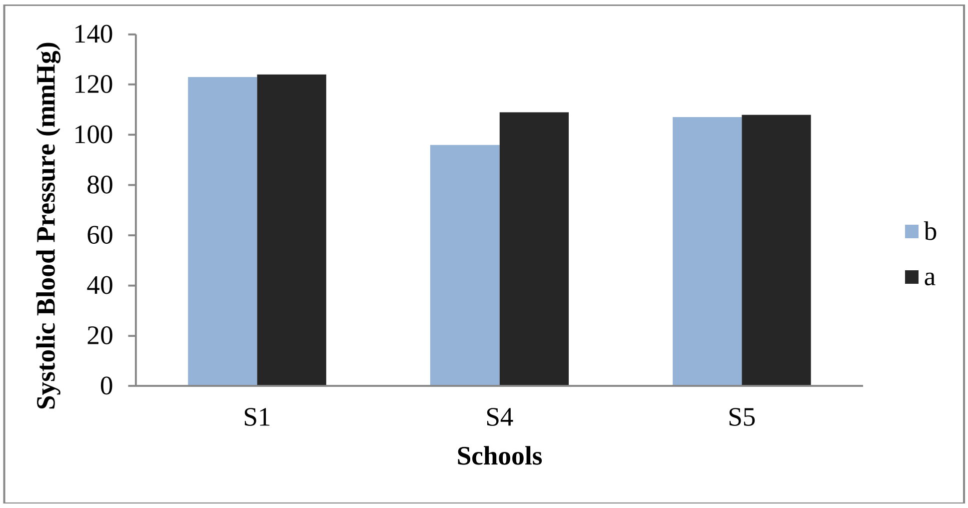

Fig. 4.9: Average values of systolic blood pressure for male students in each studied school before (b) and after (a) exposure to EMR from high voltage transformers

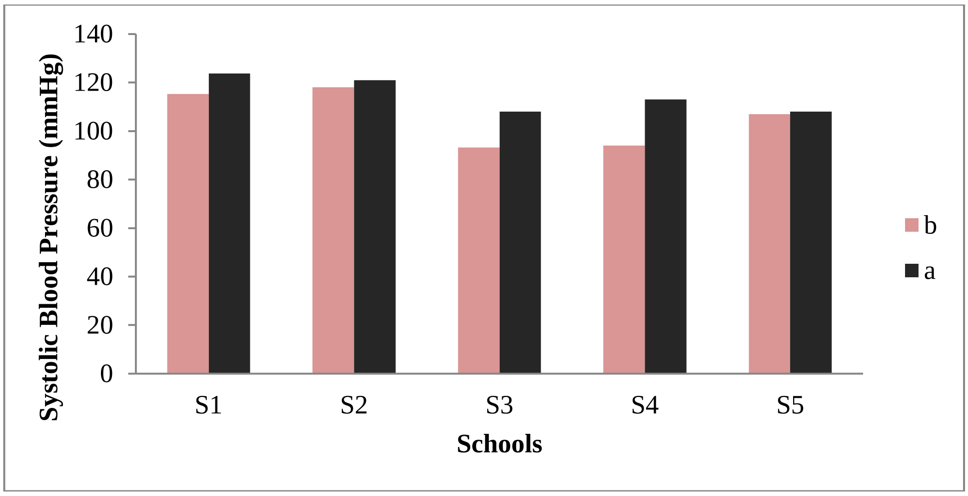

Fig. 4.10: Average values of systolic blood pressure for female students in each studied school before (b) and after (a) exposure to EMR from high voltage transformers

Figs 4.7 - 4.10 show that there are significant an increment shifts, in diastolic and systolic blood pressure of student's male and female, before and after four hours of exposure to EMR from high voltage transformers.

4.3 Data analysis of dependant variables and power flux density levels in the studied schools

Paired sample tests of dependant variables and power flux density as independent variable, all of these relationships are presented in Tables 4.14 – 4.20.

The dependent and independent variables, the correlation coefficient (R) and the probability (P-value) in all studied schools (for male and female students) are given in Tables 4.14 – 4.20. The data were analyzed as follows: for all the schools, comparing between males and females students, comparing between males and females students according to their age from 16-18 years and 9-11 years, comparing the results from all the schools with each other.

Table 4.14: Pearson correlation coefficients (R) and the Probability (P) for males of the studied variables from age 16 - 18 years.

Paired variables	Pearson correlation coefficient (R)	Probability (P)
P (nW/m^2) and T (°C) (b)	0.149	0.366
P (nW/m^2) and T (°C) (a)	0.506	0.306
T (°C) (b) and (a)	0.605	0.000
P (nW/m^2) and SpO_2 % (b)	0.438	0.385
P (nW/m^2) and SpO_2 % (a)	0.487	0.405
SpO_2 % (b) and (a)	- 0.069	0.674
P (nW/m^2) and HPR beats / min (b)	0.242	0.644
P (nW/m^2) and HPR beats / min (a)	0.130	0.806
HPR beats / min (b) and (a)	0.758	0.000
P (nW/m^2) and DBP mmHg (b)	0.211	0.688
P (nW/m^2) and DBP mmHg (a)	0.208	0.693
DBP mmHg (b) and (a)	0.450	0.011
P (nW/m^2) and SBP mmHg (b)	0.116	0.826
P (nW/m^2) and SBP mmHg (a)	0.119	0.588
SBP mmHg (b) and (a)	0.696	0.000

Table 4.15: Pearson correlation coefficients (R) and the Probability (P) for females of the studied variables from age 16 - 18 years.

Paired variables	Pearson correlation coefficient (R)	Probability (P)
P (nW/m^2) and T (°C) (b)	0.272	0.078
P (nW/m^2) and T (°C) (a)	0.244	0.111
T (°C) (b) and (a)	0.601	0.000
P (nW/m^2) and SpO_2 % (b)	0.315	0.074
P (nW/m^2) and SpO_2 % (a)	0.030	0.866
SpO_2 % (b) and (a)	-0.396	0.022
P (nW/m^2) and HPR beats / min (b)	0.029	0.848
P (nW/m^2) and HPR beats / min (a)	0.082	0.592
HPR beats / min (b) and (a)	0.489	0.001
P (nW/m^2) and DBP mmHg (b)	0.091	0.694
P (nW/m^2) and DBP mmHg (a)	0.208	0.329
DBP mmHg (b) and (a)	0.048	0.835
P (nW/m^2) and SBP mmHg (b)	0.119	0.570
P (nW/m^2) and SBP mmHg (a)	0.053	0.782
SBP mmHg (b) and (a)	0.474	0.019

Table 4.16: Pearson correlation coefficients (R) and the Probability (P) for males of the studied variables from age 9 - 11 years.

Paired variables	Pearson correlation coefficient (R)	Probability (P)
P (nW/m^2) and T (°C) (b)	0.003	0.987
P (nW/m^2) and T (°C) (a)	0.053	0.806
T (°C) (b) and (a)	0.329	0.117
P (nW/m^2) and SpO_2 % (b)	0.533	0.015
P (nW/m^2) and SpO_2 % (a)	0.226	0.339
SpO_2 % (b) and (a)	-0.116	0.635
P (nW/m^2) and HPR beats / min (b)	0.306	0.137
P (nW/m^2) and HPR beats / min (a)	0.014	0.947
HPR beats / min (b) and (a)	0.144	0.492
P (nW/m^2) and DBP mmHg (b)	0.042	0.864
P (nW/m^2) and DBP mmHg (a)	0.018	0.942
DBP mmHg (b) and (a)	0.320	0.898
P (nW/m^2) and SBP mmHg (b)	0.275	0.254
P (nW/m^2) and SBP mmHg (a)	0.088	0.727
SBP mmHg (b) and (a)	0.045	0.859

Table 4.17: Pearson correlation coefficients (R) and the Probability (P) for females of the studied variables from age 9 - 11 years.

Paired variables	Pearson correlation coefficient (R)	Probability (P)
P (nW/m^2) and T (°C) (b)	0.076	0.701
P (nW/m^2) and T (°C) (a)	0.026	0.898
T (°C) (b) and (a)	0.754	0.000
P (nW/m^2) and SpO_2 % (b)	0.076	0.724
P (nW/m^2) and SpO_2 % (a)	0.150	0.483
SpO_2 % (b) and (a)	- 0.282	0.182
P (nW/m^2) and HPR beats / min (b)	0.035	0.876
P (nW/m^2) and HPR beats / min (a)	0.003	0.996
HPR beats / min (b) and (a)	0.360	0.092
P (nW/m^2) and DBP mmHg (b)	0.279	0.234
P (nW/m^2) and DBP mmHg (a)	0.283	0.226
DBP mmHg (b) and (a)	0.371	0.107
P (nW/m^2) and SBP mmHg (b)	0.142	0.552
P (nW/m^2) and SBP mmHg (a)	0.429	0.041
SBP mmHg (b) and (a)	0.374	0.105

Table 4.18: Pearson correlation coefficients (R) and the Probability (P) for all males of the studied variables.

Paired variables	Pearson correlation coefficient (R)	Probability (P)
P (nW/m^2) and T (°C) (b)	0.105	0.415
P (nW/m^2) and T (°C) (a)	0.075	0.560
T (°C) (b) and (a)	0.488	0.000
P (nW/m^2) and SpO_2 % (b)	0.156	0.229
P (nW/m^2) and SpO_2 % (a)	0.033	0.801
SpO_2 % (b) and (a)	-0.210	0.110
P (nW/m^2) and HPR beats / min (b)	0.143	0.287
P (nW/m^2) and HPR beats / min (a)	0.147	0.274
HPR beats / min (b) and (a)	0.653	0.000
P (nW/m^2) and DBP mmHg (b)	0.235	0.101
P (nW/m^2) and DBP mmHg (a)	0.205	0.142
DBP mmHg (b) and (a)	0.384	0.006
P (nW/m^2) and SBP mmHg (b)	0.069	0.666
P (nW/m^2) and SBP mmHg (a)	0.049	0.763
SBP mmHg (b) and (a)	0.376	0.015

Table 4.19: Pearson correlation coefficients (R) and the Probability (P) for all females of the studied variables.

Paired variables		Pearson correlation coefficient (R)	Probability (P)
P (nW/m^2) and T (℃)	(b)	0.159	0.188
P (nW/m^2) and T (℃)	(a)	0.114	0.346
T (℃) (b) and (a)		0.661	0.000
P (nW/m^2) and SpO_2 %	(b)	0.167	0.220
P (nW/m^2) and SpO_2 %	(a)	0.221	0.096
SpO_2 % (b) and (a)		- 0.274	0.039
P (nW/m^2) and HPR beats / min	(b)	0.147	0.241
P (nW/m^2) and HPR beats / min	(a)	0.062	0.622
HPR beats / min (b) and (a)		0.513	0.000
P (nW/m^2) and DBP mmHg	(b)	0.411	0.008
P (nW/m^2) and DBP mmHg	(a)	0.436	0.003
DBP mmHg (b) and (a)		0.361	0.020
P (nW/m^2) and SBP mmHg	(b)	0.271	0.072
P (nW/m^2) and SBP mmHg	(a)	0.278	0.044
SBP mmHg (b) and (a)		0.503	0.000

Table 4.20: Pearson correlation coefficients (R) and the Probability (P) for all males and females students of the studied variables.

Paired variables		Pearson correlation coefficient (R)	Probability (P)
P (nW/m^2) and T (℃)	(b)	0.011	0.897
P (nW/m^2) and T (℃)	(a)	0.015	0.862
T (℃) (b) and (a)		0.586	0.000
P (nW/m^2) and SpO_2 %	(b)	0.031	0.741
P (nW/m^2) and SpO_2 %	(a)	0.053	0.569
SpO_2 % (b) and (a)		-0.245	0.008
P (nW/m^2) and HPR beats / min	(b)	0.016	0.856
P (nW/m^2) and HPR beats / min	(a)	0.032	0.725
HPR beats / min (b) and (a)		0.599	0.000
P (nW/m^2) and DBP mmHg	(b)	0.182	0.084
P (nW/m^2) and DBP mmHg	(a)	0.158	0.121
DBP mmHg (b) and (a)		0.383	0.000
P (nW/m^2) and SBP mmHg	(b)	0.133	0.221
P (nW/m^2) and SBP mmHg	(a)	0.066	0.529
SBP mmHg (b) and (a)		0.455	0.000

Chapter Five

Discussion

It has been proposed that the central nervous system is sensitive to ELF electromagnetic fields (Cook MR *et al*, 1992). In this study, a suggestion was set on the effect of EMR pollution on tympanic temperature, blood oxygen saturation, heart pulse rate, and arterial blood pressure (diastolic and systolic), in selected schools in Hebron District.

The obtained results from measurement and statistical analysis are explained as follows:

5.1 The effect of EMR pollution on tympanic temperature

Average values of tympanic temperature of selected students are increased after exposure to EMR from high voltage transformers as shown in Figs 4.1 and 4.2, based on Table 4.2 and Table 4.3. Comparing the results of the tympanic temperature for the studied schools with each other, it was clear that Pearson correlation coefficient between the power flux density and tympanic temperature after exposure to EMR (where $R > 0.5$), is in Wad Alsultan school $R = 0.522$. By comparing the results of tympanic temperature for males students with females, Pearson correlation coefficient between the power flux density and tympanic temperature for students after exposure to EMR is $R = 0.159$. It means that females are more affected from EMR than males students. Comparing males schools with females schools according to their age, it was found that students with age 16 - 18 years are more affected (where $R = 0.506$). Refereeing to Table

4.12 and Table 4.13 the difference between the tympanic temperature before and after exposure to EMR for 4 hours is in the range of 0℃ – 6℃ where Pearson correlation coefficient is R = 0.586 and the Probability is 0.000. A study performed on the effect of mobile phone on human tympanic temperature showed that after exposure to microwave radiation for one hour the volunteers temperature was higher about 0.03℃ (Alicja *et al*, 2012, Gavriloaia G *et al*, 2010, Aliyu *et al*,2012).

5.2 The effect of EMR pollution on blood oxygen saturation SpO_2 %

Average values of blood oxygen saturation SpO_2 % are decreased after the students exposed to EMR from high voltage transformers as shown in Figs 4.3 and 4.4. The strength of the results is good as can be understood from Pearson correlation coefficient and the probability between power flux density and blood oxygen saturation. The most affected students were from Wad Alsultan school (R = 0.747 and P- value = 0.033), then from Zaid Bn Hartha school (R = 0.612 and P- value = 0.107). Female students R = 0.221 are more affected than males R = 0.033. According to the students age, the younger students (9 - 11 years) are more affected R = 0.533. For all the students males and females R = 0.053. The difference between values of blood oxygen saturation before and after exposed to EMR is 1 - 3 %. Comparing this result with study on laboratory mice, exposed to RF radiation, after exposure the red blood cells decreased, which means that the blood oxygen saturation decreased either, so there is a good agreement with this study (Rusnani *et al*, 2008, Havas Magda, 2008).

5.3 The effect of EMR pollution on heart pulse rate

Results of heart pulse rate for the selected student showed an increase of HPR values as shown in Figs 4.5 and 4.6. The most affected students are from Zaid Bn Hartha school where Pearson correlation coefficient is R = 0.577 and the P- value = 0.134. Adults males (16 - 18 years) are more affected than females R = 0.147. For all the selected students R = 0.032. HPR values increased about (6 - 16) beats / min after the student's exposure to EMR for at least 3 hours. A study done on volunteers exposed to electric field (20 kV/m), and magnetic fields (50 G), under controlled laboratory condition showed changes in heart rate (Dermot Byrne, 2007).

5.4 The effect of EMR pollution on arterial blood pressure (Diastolic and Systolic)

Referring to Table 4.2 and Table 4.3 average values of diastolic blood pressure are increased after the students exposed to EMR as shown in Figs 4.7 and 4.8. Wad Alsultan school is the most affected school, where Pearson correlation coefficient is R = 0.659. Females are more susceptible from EMR than males R = 0.436. Young students suffer more from EMR R = 0.283. Pearson correlation coefficient R = 0.158 between the power flux density and diastolic blood pressure for all the selected students. There is a good agreement with the result of increase in diastolic blood pressure after volunteer's exposed to microwave radiation (about 5 mmHg) (Havas Magda, 2008, National Radiological Protection, 2004). In this study, the diastolic blood pressure increased by 4 - 14 mm Hg.

There is noticeable increase in systolic blood pressure average values as shown in Figs (4.9 – 4.10). AlQadesya school R = 0.680 and Zaid Bn Hartha school R = 0.643 are the most affected schools. Females are more affected than males students R = 0.278. Young students (9 - 11 years old) are more susceptible to electromagnetic radiation than adult students R = 0.429. Pearson correlation coefficient for all students who have been exposed to ELF electromagnetic radiation is R= 0.066. There are studies that showed exposure to microwave radiation will increase the systolic blood pressure by about five mmHg (Havas Magda, 2008, National Radiological Protection, 2004). In this study, the difference between average values of systolic blood pressure before and after exposure to EMR range of 1 - 19 mmHg.

Pearson correlation coefficient between the power flux density as independent variable and arterial blood pressure as dependant variable are R = 0.158 for DBP and R = 0.066 for SBP. Because of the strong relation between heart mechanism and arterial blood pressure, these variables were affected more than the tympanic temperature. The behaviors of blood oxygen saturation as dependant variables showed continuous decrease with power flux density. Students in Wad Alsultan school are the most affected from the high voltage transformers electromagnetic radiation, as was concluded from R values between power flux density and tympanic temperature R = 0.522, blood oxygen saturation R = 0.747, and diastolic blood pressure R = 0.659. The second school is Zaid Bn Hartha School, where R > 0.5, is found between power flux density and blood oxygen saturation, heart pulse rate, and systolic blood pressure. In this study, female students are more affected from EMR pollution than male students, for the dependant variables (tympanic temperature, blood oxygen saturation, arterial blood pressure), this result is instead of Pearson correlation coefficient for the last variables, except for heart pulse rate where male students are more affected. The results from dependant variables (SpO_2%, DBP and SBP) indicate that young students are more affected from EMR pollution compared with adult's students. On the other hand, results from dependant variables (temperature, heart rate) for adult students indicate that they are more affected.

According to guidelines of Building Biology Institute, measurements of power flux density in Table 4.1 are in the range of 0.1 - 10 $\mu W/m^2$, where the highest value is 0.6 $\mu W/m^2$ and lowest value is 0.35 $\mu W/m^2$. This means that slight concern is necessary in this situation. A research done in Iran found that the average power flux density from the base station was $0.02 mW/m^2$ in urban area and $0.05 mW/m^2$ in the rural area (Tayebeh *et al*, 2012). Human brain magnetic flux density is in the limit of $(1 – 10) \times 10^{-9}$ G. According to table 4.1, the highest value of the magnetic flux density is in Dura School (S2) ($B = 5 \times 10^{-9}$ G), this value is within the allowed value of the human brain magnetic flux density. Comparing the results of SAR values in Table 4.1 with the standard values of SAR in Table 1.3. It is clear that results of SAR values in this research were much below the standard levels, where the highest value of SAR is 0.2549 µW/kg. According to Table 4.1, the electric field, magnetic field strength and magnetic flux density are much below than the reference levels in Table 1.2. Where the highest value of E = 0.0151 V/m, H = 40 μA/m, and B = 5.03 nG. A study in Iran showed that exposure to EMR from high voltage substations affect human health, despite that exposure level was lower than ICNIRP limits (Sharifi Mahdieh *et al*, 2010).

The Russian Commission on Non Ionizing Radiation Protection (RCNIRP) recommended to halt the use of wireless technologies in the school classrooms, and to replace wireless with wired internet (Gerd Oberfeld, 2012).

Chapter Six

Recommendations

The following are some suggestions and recommendations, which can be carried on to reduce the effect of EMR from high voltage transformers on student's health.

1. Constructing schools in locations must be far away from high voltage transformers at least 200m.
2. Plant trees around the schools, to reduce the EMR pollution inside the schools.
3. Making a proposal to the Electricity Company in Dura to help for changing the locations of high voltage transformers, specially the one beside Al-Qadesya School.
4. Avoid sitting under the pillars of high voltage transformers in the street, because of its risks.
5. Explain the results of the EMR risks on student’s health to the teachers of the selected schools, and recommended them to spread these information to other students in different schools.
6. Give advice to Wad Al - Sultan School to build a fence around the school, and plantation.
7. Advise officials about building schools for using a plaster cement form as pre-manufactured tiles, to shield these schools effectively from outside electromagnetic interference.

8. Using one of these materials in addition to cement for good absorption, such as polystyrene, or electrolytic manganese dioxide and MnZn-ferrite.
9. The measurement of power flux density should be carried out for different sources to ELF, in other parts of the country, for risk management and comparative analysis.
10. More devices need to measure the power flux density from ELF electromagnetic radiation for example:

a) "HI-3604 ELF survey meter", to measure the magnetic flux density and electric field intensity for frequency range of (30 - 2000 Hz) (Tayebeh Barsam *et al*, 2012).

b) "Extech 480826 Triple axis EMF Tester", to measure the magnetic flux density and electric field intensity for frequency range from (30 Hz to 300 Hz) (Ahmadi. H *et al*, 2010).

11. Besides high voltage transformers, there are many appliances and sources that produce EMR such as high voltage transmission lines, copy machine, wireless from laptops, and imaging machines in libraries, microwave oven, and televisions that need to be studied.

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جامعة النجاح الوطنية

كلية الدراسات العليا

تأثير الاشعاع الكهرومغناطيسي من محولات الجهد العالي على صحة الطلاب في محافظة الخليل

اعداد

ايمان جبارة احمد الفقيه

اشراف

أ.د عصام راشد عبد الرازق

د. محمد ابو جعفر

قدمت هذه الاطروحة استكمالا لمتطلبات درجة الماجستير في الفيزياء بكلية الدراسات العليا في جامعة النجاح الوطنية في نابلس – فلسطين

2013

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الملخص

ألقت هذه الدراسة الضوء على تأثير التعرض للإشعاع الكهرومغناطيسي من محولات الجهد العالي (160)KVA و 250 KVAعلى طلاب المدارس في محافظة الخليل. كانت عينة الدراسة 142 طالبا من بينهم 69 من الذكور و 73 من الاناث، وكانت أعمارهم تتراوح بين (16-18) سنة و (9-11) سنة. وقد أجريت هذه الدراسة على خمسة من المدارس في محافظة الخليل. تم أخذ عدد من القياسات لدرجة حرارة الجسم عن طريق الاذن، ونسبة الأكسجين في الدم ومعدل نبض القلب، وضغط الدم الشرياني (ضغط الدم الانبساطي والانقباضي)، ثلاث مرات من الساعة (8:00 الى 8:30) صباحا وثلاث مرات من الساعة (12:30 الى 01:00) ظهرا في شهر ايلول 2012. تم تسجيل هذه القياسات في داخل المدارس التالية (الخليل الثانوية الصناعية، مدرسة دورا الثانوية للبنات، مدرسة آلقادسية للبنات والبنين، مدرسة واد السلطان للبنات والبنين، ومدرسة زيد بن حارثة للبنات والبنين)، في محافظة الخليل. وهدف هذا البحث ايضا لقياس كثافة تدفق الطاقة باستخدام جهاز spectran RF 6080 في مواقع مختلفة، حيث كانت أعلى قيمة في دورا الثانوية 604 نانوواط/م^2، وأقل قيمة كانت في مدرسة زيد بن حارثة للبنات والبنين 350 نانوواط/م^2، وكانت المدارس في مواقع مختلفة بالنسبة للمحولات، تم تحليل البيانات بالاعتماد على برنامج SPSS الإحصائي. وأظهرت الدراسة أن القيم المقاسة من كثافة تدفق الطاقة كانت ضمن الحد (تأثير طفيف). وتم شرح تأثير EMR على صحة الطلاب على النحو التالي، كان هناك زيادة في درجة الحرارة ، ومعدل ضربات القلب ، وضغط الدم الشرياني (الانقباضي والانبساطي)، من ناحية أخرى فقد لوحظ انخفاض في نسبة الأكسجين في الدم.