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

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Abstract: ***This study aims to investigate the effect of exposing to extremely low frequency electromagnetic radiation from high voltage transformers (160 KVA and 250 KVA) on students. 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 on five schools in Hebron District. Measurements were taken for student's tympanic temperature, blood oxygen saturation, heart pulse rate, and arterial blood pressure (diastolic and systolic). The results showed that the measured values of power flux density were within slight concern limit. The effect of EMR on students health were explained as follows, there was increasing in tympanic temperature, heart pulse rate, arterial blood pressure (systolic and diastolic), on the other hand the blood oxygen saturation was decreased.***

Keywords: Electromgnetic radiation,

1. Introduction

The last three decades have witnessed a tremendous growth in all aspects of modern technology (Shankar, 2002), such as cellular phones, wireless communication links, antennas, microwave ovens, and high voltage transformers are sources of the electromagnetic radiations (EMR). 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 nowdays 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. They are in different magnitudes, present in virtually every home, office, school and in the industrialized world (Orel, 2010).

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).

2. Literature Review:

A study by Carl Blackman has shown that weak electromagnetic fields release calcium ions from cell membranes (Blackman *et al*, 1982).
David and his group in 1993 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 (Philip Heying, 1995).
A study in France showed an increase in 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).
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).
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).

A study of staff working near antennas transmitting high microwave power showed the effect of their thyroid gland processes (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)(Cook *et al*, 1992).

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).

Another research by Tayebeh 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 *et al*, 2012).

Objectives of the Study:

The aims of this study are:

1. Measuring the power flux density of the electromagnetic radiation near schools, and calculating the electric field and the magnetic field strength.
2. Measuring the blood pressure, heart pulse rate and blood oxygen saturation of selected students in each studied school.
3. Calculating specific absorption rate SAR.

3. Theoretical Background:

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:

$$B = \mu H \quad (1)$$

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.

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:

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

or

$$P = \eta H^2 \quad (3)$$

Where E is the electric field intensity and η is the field resistance taken as 377Ω for free space (in air) (Mousa Allam, 2009).

Specific Absorption Rate (SAR):

Specific absorption rate (SAR): is the quantity used to measure how much RF is actually absorbed in a body

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 appoint by:

$$SAR = \frac{\sigma |E^2|}{\rho} \quad (4)$$

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

4. Methodology:

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 (16 - 18years) are 85 students, and for students (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).

$$M = \frac{n}{1+\frac{n}{N}} \quad (5)$$

Where, M: correlation sample size that should be used.

N: the actual sample number of students that found in each school.

n: is the best value to select a random sample of students in each school.

Previous studies show that there is a considerable impact of noise on the blood pressure and other parameters.[20-24](Abdei-Ali *et al*, 2003; Abdel-Raziq *et al*, 2003; Qamhieh *et al*, 2000; Sadeq *et al*, 2013; Dana *et al*, 2013) Therefore, the schools are chosen to be in areas of noise level ($L_p < 50$ dB).

The number of examined students in each school is given in Table 1 below.

Table 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

5. Measurements and Instrumentation:

The instruments and tools were used in performing our test and measurements are

Spectran of radio frequency (RF) 6080, Pulse Oximeter, Automatic Blood Pressure and Pulse rate, Ear Thermometer, Sound pressure level meter, and Hioki 3423 - lux Hitester Meter.

Statistical Analysis:
The gathered data were digitalized in a database developed with Microsoft excel and SPSS programs. Pearson correlation coefficient (R) and the Probability (P) were used to measure the strength correlation between the EMR pollution and the dependent variables, before and after exposure to EMR.

6. Results:

Measurements of power flux density:
Measurements of power flux density of each studied school were taken by spectran RF 6080.

SAR values in Table 2 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 2: Average values of power flux density, electric field, magnetic field strength, magnetic flux density, and SAR for human brain, for selected schools

School	P× 10^{-9} (W/m^2)	E×10^{-4} (V/m)	H×10^{-5} (A/m)	B×10^{-9} (G)	SAR*×10^{-8} (W/kg)	SAR**×10^{-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.1.

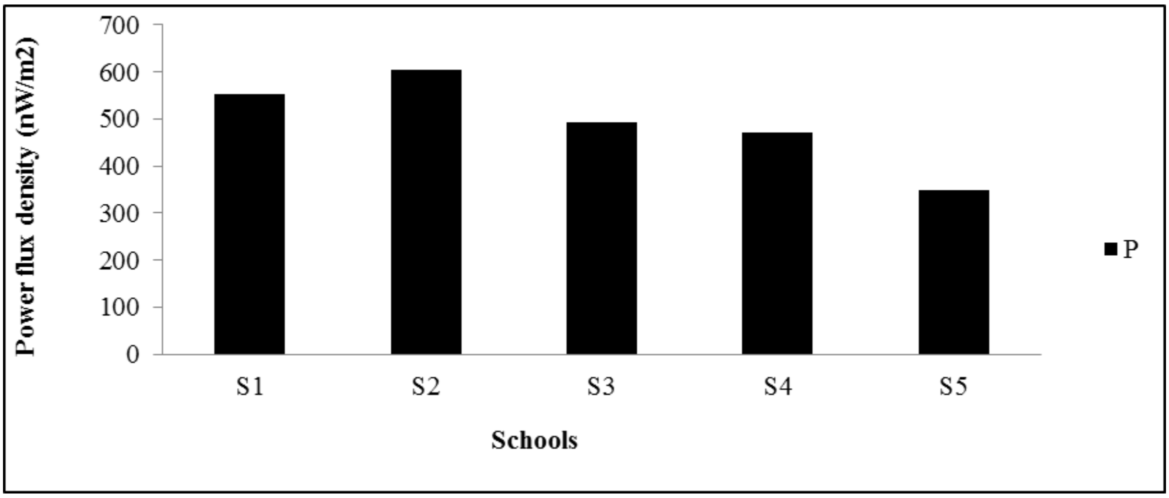

Fig. 1: Average values of the measured power flux density levels for high voltage transformers, in studied schools.

Measurements of health effects of the EMR pollution from high voltage transformers:
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 3 and Table 4.

Table 3: 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)		SpO2%		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: 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 3 and 4, it can be observed that all students male and female are suffering from exposure to EMR from high voltage transformers.

Table 5: 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 (°C)	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 6: 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 (°C)	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

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 students are represented in Fig. 2 and Fig. 3.

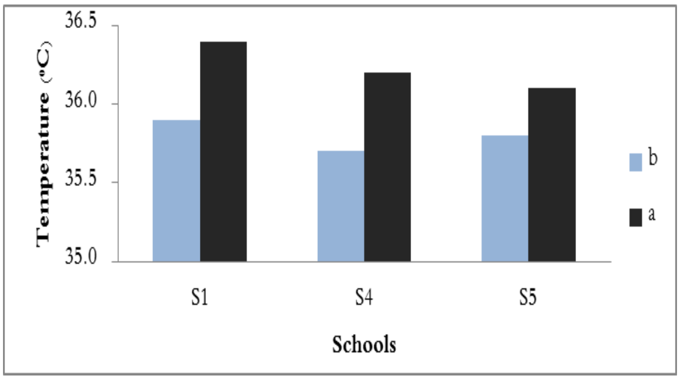

Fig. 2: Average values of tympanic temperature for male students in each studied school before (b) and after (a) exposure to EMR from high voltage transformers.

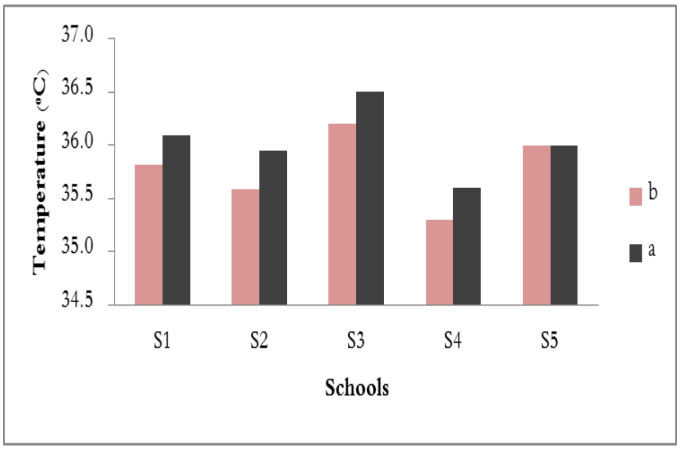

Fig. 3: Average values of tympanic temperature for female students in each studied school before (b) and after (a) exposure to EMR from high voltage transformers.

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 and Fig 5.

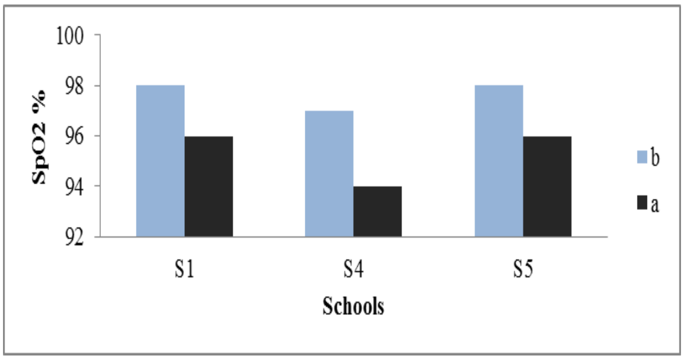

Fig. 4: Average values of blood oxygen saturation SpO_2 % for male students in each studied school before (b) and after (a) exposure to EMR from transformers.

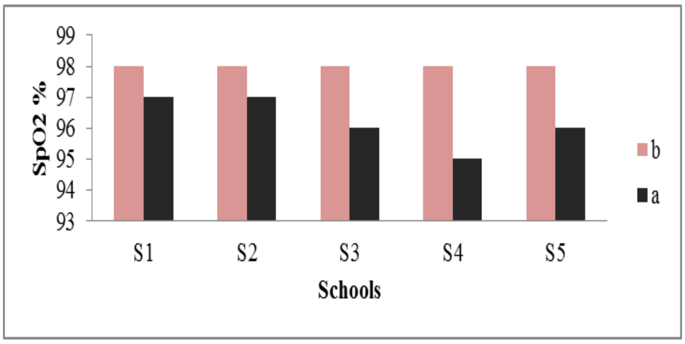

Fig. 5: Average values of blood oxygen saturation SpO_2 % for female students in each studied school before (b) and after (a) exposure to EMR from high voltage transformer.

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 6 and Fig 7.

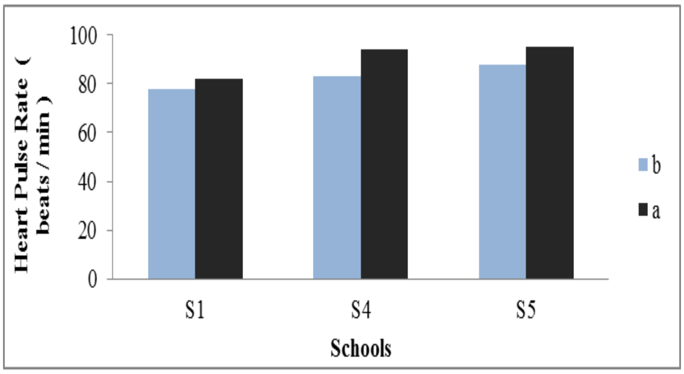

Fig. 6: Average values of heart pulse rate for male students in each studied school before (b) and after (a) exposure to EMR from high voltage transformers

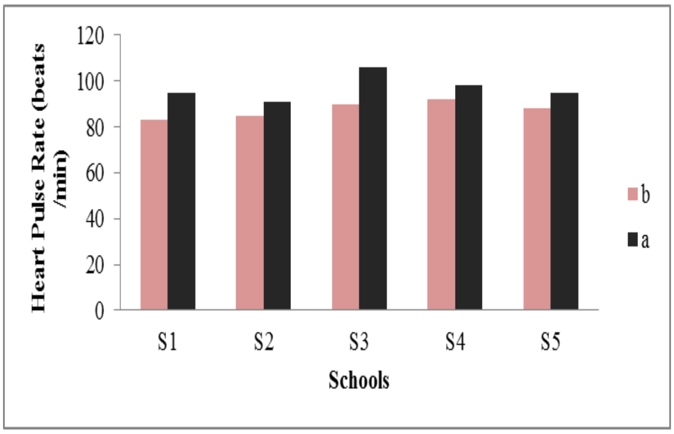

Fig. 7: Average values of heart pulse rate for female students in each studied school before (b) and after (a) exposure to EMR from high voltage transformers.

7. 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 8 – 11.

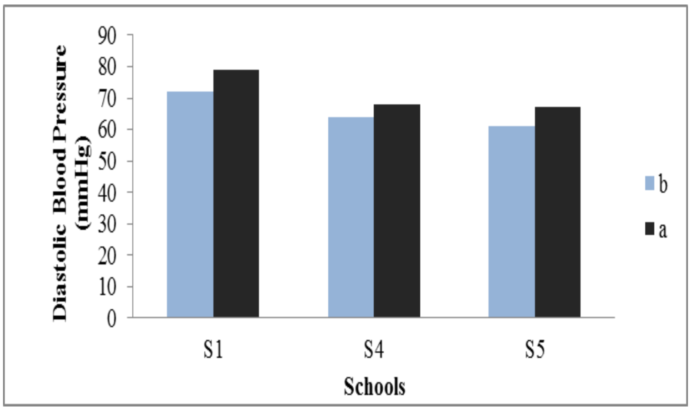

Fig. 8: Average values of diastolic blood pressure for male students in each studied school before (b) and after (a) exposure to EMR from high voltage transformers

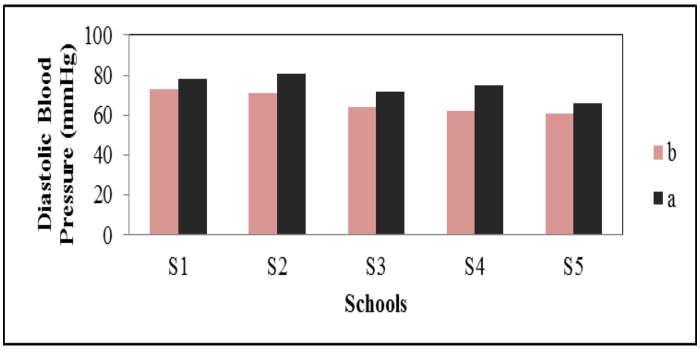

Fig. 9: Average values of diastolic blood pressure for female students in each studied school before (b) and after (a) exposure to EMR from high voltage transformers

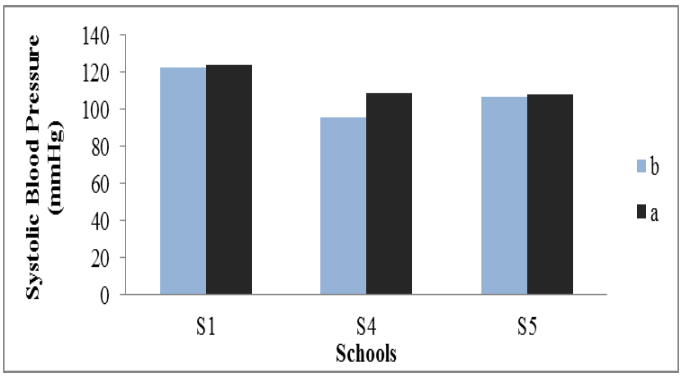

Fig. 10: Average values of systolic blood pressure for male students in each studied school before (b) and after (a) exposure to EMR from high voltage transformers

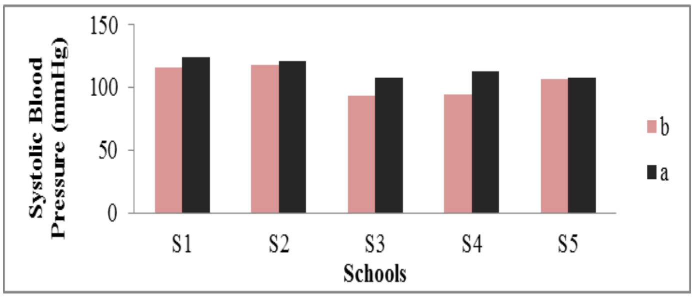

Fig. 11: Average values of systolic blood pressure for female students in each studied school before (b) and after (a) exposure to EMR from high voltage transformers

8. Discussion:

According to guidelines of Building Biology Institute, measurements of power flux density in Table 2 are in the range of (0.1 - 10) μW/m^2, where the highest value is 0.6 μW/m^2 and lowest value is 0.35 μW/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 0.02mW/m^2 in urban area and 0.05mW/m^2 in the rural area (Tayebeh *et al*, 2012). Human brain magnetic flux density is in the limit of (1 - 10) ×10^{-9} G. According to Table. 2, the highest value of the magnetic flux density is in Dura School (S2) is 5× 10^{-9} G. This value is within the allowed value of the human brain magnetic flux density.

The highest value of SAR is 0.2549 μW/kg, comparing with whole body exposure limit from microwave radiation, it's much below this value 33 μW/kg (Gerd Oberfeld, 2012). It was clear that results of this research were much below the standard levels. The electric field, magnetic field strength and magnetic flux density in Table.2 are much below than the reference levels. 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).

9. 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 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. Advise officials about building schools for using a plaster cement form as pre-manufactured tiles, to shield these schools effectively from outside electromagnetic interference.
7. Using one of these materials in addition to cement for good absorption, such as polystyrene or electrolytic manganese dioxide and MnZn-ferrite.

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