High Voltage Transformers and Elecrtomagnetic Emissions: Consequence on Students' Health in Apata, Ibadan, Nigeria

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Abstract
The last decade has witnessed a remarkable growth in all aspects of modern technology such as mobile phones, wireless communication links, antennas, microwave ovens, and high voltage transformers which are sources of electromagnetic radiations (EMR). This research work investigates the effect of exposing building occupants to electromagnetic emission from high voltage transformers. The sample of this study is 150 students comprising 78 males and 72 females. Spectra RF3040 was used to measure magnetic flux density in the five schools used for this research. Measurements were also taken to determine the effects of electromagnetic emission on student's tympanic temperature, blood oxygen saturation, heart pulse rate and arterial blood pressure (diastolic and systolic). Tests on health situations were done indoor four times at (9:00 – 9:30) a.m. and four times at (1:30 – 2:00) p.m. each day. The results show from analysis that the measured values of power flux density were within slight concern limit. The gradual increase in tympanic temperature, heart pulse rate, and arterial blood pressure is an indication that EMR has adverse health effects on building occupants within 200m distance from such transformers. Recommendations were given.
Keywords: High voltage, Transformer, Electromagnetic, Emission, Health effect.

1.0 INTRODUCTION

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 (Zamanian *et al*, 2005). This energy spread out as it moves. 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).

Modern technology such as cellular phones, wireless communication links, antennas, microwave ovens, and high voltage transformers which are sources of the electromagnetic radiations (EMR) have grown tremendously in the last ten years (Shankar, 2002). Exposure of electromagnetic fields to humans is on the increase. Biological effects or injury depending on multiple physical and biological variables can be produced by electromagnetic waves at certain frequencies, power levels, and exposure durations (Michelson, 1972). The pollution caused by electromagnetic radiation is the biggest problem of the twenty first century (Dode, 2010).

Although there have been many benefits from the use of Radio Frequency (RF) radiation however many people are of the opinion that long-term exposure could affect their body biological system and health. The study conducted by the International Commission on Non-Ionizing Radiation Protection (ICNIRP), and the World Health Organization (WHO) helped to shed light on the risks and provide increased understanding.

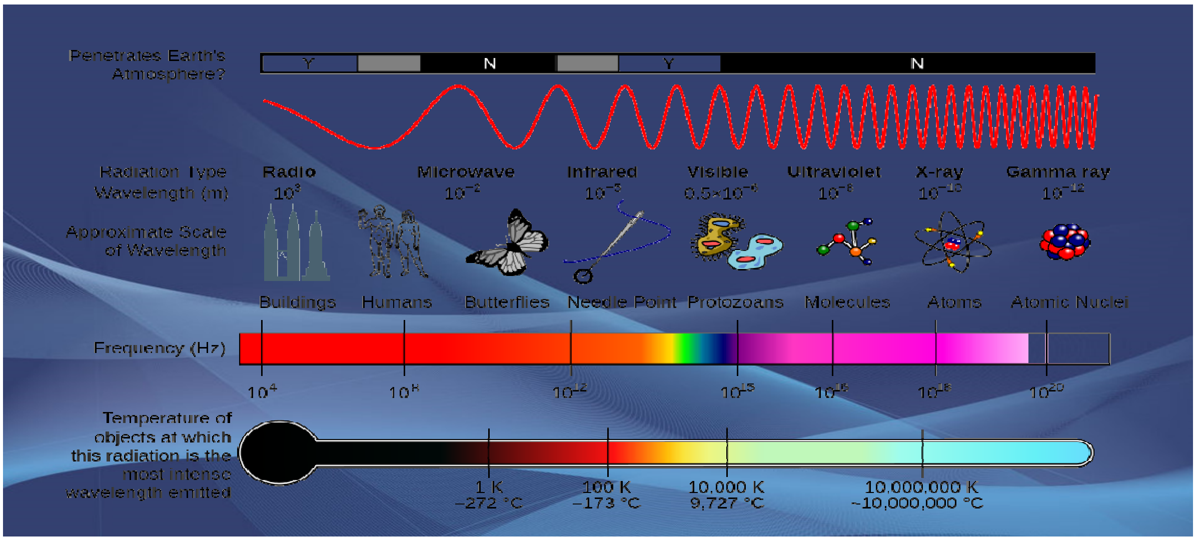

Plate 1. : Electromagnetic radiations (Zamanian *et al,* 2005).

The wide spread of high voltage transformers everywhere, near homes, markets, buildings and schools is the motivating factor for conducting this study.

The aim of this study is to investigate the effects of electromagnetic radiation from high voltage transformers on students' health while the objectives are: a) measuring the power density of the electromagnetic radiation near schools and calculating the electric field and the magnetic field strengths. b) Measuring the blood pressure, heart pulse rate and blood oxygen saturation of selected students in each studied school. c) 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.

1.1 LITERATURE REVIEW

A study on effects of radiation from cell towers and high tension power lines on inhabitants of buildings shows that people who live close to radiation sources are more susceptible to the risk (Adekunle et al, 2015). According to Carl Blackman, weak electromagnetic fields release calcium ions from cell membranes (Blackman *et al*, 1982). It was discovered that electric service 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). A recent 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). The percentage of radiation that penetrates the skull of an adult in a study is 35%, ten years old is 60%, and five years old is 85%. The younger the child the deeper the penetration due to the fact their skulls are thinner and still developing (Om Gandhi *et al*, 1996). 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 activate 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 200m from the base station, of headache, sleep disturbance, discomfort within 200m, and of irritability, dejection, wooziness, loss of memory within 100m. Women were found to protest significantly more often than men of nausea, headache, and loss of appetite, sleep disturbance, despair, discomfort and visual perturbations (Santini *et al,* 2002). 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 *et al*, 2010). For several decades high voltage power lines, once suspected of being a cause of childhood leukemia and other illnesses have driven down property values and scared homeowners into fearing for their health(EPA, 1990). 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).

1.2 REFERENCE LEVELS

Table 1.0: Reference levels for power flux density exposure (exposure levels in $\mu W/m^2$) (Building Biology Institute, 2008).

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

2.0 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:

$B = \mu H$ --- (2.1)

Where μ is the constant of proportionality (the magnetic permeability) in vacuum or air, as well as in nonmagnetic (including biological) materials. For ohmic materials, the internal electric field *E* and current density *J* are related by Ohm's Law:

$\vec{J} = \sigma \vec{E}$ --- (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:

$P = E^2/\eta$ -- (2.3)

OR

$P = EH$ -- (2.4)

OR

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

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

2.1 HEALTH VARIABLES CONSIDERED

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

a) Heart pulse rate (HPR): is the amount of heartbeats per unit time.
b) Blood pressure (Systolic and Diastolic): is the pressure applied by circulating blood upon the walls of blood vessels, during each heartbeat; blood pressure varies between a maximum (systolic) and a minimum (diastolic) pressure. The normal (systolic and diastolic) blood pressure is at or below 120/80 mmHg. The high blood pressure is considered at or above140/90 mmHg (Nivedita *et al*, 2012).
c) Tympanic Temperature: This parameter helps to check body temperature in the ear.
d) Blood oxygen saturation SpO_2%: is the relative amount of ox- hemoglobin to the total absorption of the hemoglobin available in the blood. The normal values for blood oxygen saturation are from 95% to 100% (Michael, 2007).

3.0 METHODOLOGY

3.1 Study Sample

This study was conducted on students in five schools, distributed in several locations in Apata District: Queens Girls Secondary School, Apata Community Grammar School, Comprehensive College, Adifase high school, Command Secondary School. The sample of this study was 150 students including 78 male and 72 female. Number of students with age (15 - 17) years are 85 students, and students with age (8 - 10) years are 65 students. The students chosen at random have no history of any disease.

Table 3.2: The distance between the transformers and schools.

School	Distance between the schools and transformer	Transformers Power (KVA)
Queens Girls Secondary (S1)	25m and 5m	500 and 250
Apata Community Grammar (S2)	12m	500
Comprehensive College (S3)	8m	250
Adifase high school (S4)	45m	250
Command Secondary School (S5)	35m	500

In this study the Transformers height above the ground level are (10 - 12) meters.

3.2 STAGES OF STUDY

Several stages were performed:

1. Power Holding Company of Nigeria (Apata District) in Ibadan was visited and permission was taken to help find suitable schools for the study, the nearest from the transformers.
2. The nature of these transformers near these schools were discussed with electric engineers in the company, taking into considerations that the distance between the transformers and the schools is less than 200m.
3. Permission was taken from the authorities of the selected schools after informing them about the nature of the study.
4. The power flux density of the electromagnetic radiations from the transformers was then measured at different distances.
5. Regular visits to these schools at 9:00 a.m. and before the students leave the schools at 1:30 p.m. in order to measure the health parameters.
6. Measurements of these parameters were taken four times for each student during (9:00 – 9:30) a.m. and four times during (1:30 – 2:00) p.m. The average values of these measurements will be considered in the analysis part. In Nigeria, it is important to note that a 50 Hz is used for transformers and transmission lines.

3.3 MEASUREMENTS AND INSTRUMENTATION

3.3.1 Spectra of radio frequency (RF) 3040

Radio frequency 3040 is used to make accuracy measurements to establish human safety, particularly in residential and workplace environments. It measured the power flux density in the selected schools, and the field strengths (the strongest signal). It is has a high accuracy of ± 2dB. It was placed in different locations in the schools, in order to get the signal. The average of these readings was taken three times during (9:00 – 9:30) a.m. and three times during (1:30 – 2:00) p.m.

3.3.2 Pulse meter

Pulse meter is used to measure the blood oxygen saturation three times for each student during (9:00 – 9:30) a.m. and three times during (1:30 – 2:00) p.m. It has an accuracy of ± 0.5 %,

3.3.3 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 (9:00 – 9:30) a.m. and three times during (1:30 – 2:00) p.m. It has an accuracy of ± 0.5 mmHg and ± 0.5 % for reading heart pulse rate.

3.3.4 Ear thermometer GT-302

This device is used to measure the human body temperature through the ear drum (tympanic) temperature of the ear for each selected student three times during (9:00 – 9:30) a.m. and three times during (1:30 – 2:00) p.m. The display temperature range is 30°C to 40°C, with accuracy range ± 0.001°C.

4.0 RESULTS

4.01 Measurements of power flux density

Table 4.1: Average values of power flux density, electric field, magnetic field strength and magnetic flux density 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)
S1	548	143.73	3.81	4.79
S2	600	150.4	3.99	5.01
S3	490	135.92	3.61	4.53
S4	464	132.26	3.51	4.41
S5	346	114.21	3.03	3.81

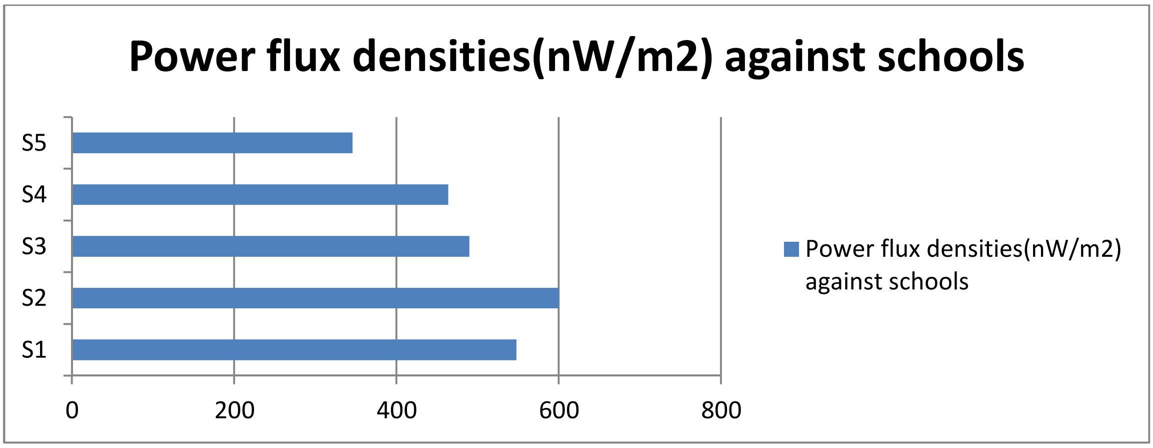

Fig. 4.1.: Average values of the measured power flux density levels for high voltage Transformers, in studied schools.

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, before (b) and after (a) exposure to EMR from high voltage transformer.

Variables	Temperature(°C)		SpO2%		HPR(beats/min)		DBP(mmHg)		SBP(mmHg)	
School	b	a	b	a	b	a	b	a	b	a
S1	34.9	35.4	97	95	77	81	71	78	122	123
S4	34.7	35.2	96	93	82	93	63	67	95	108
S5	34.8	35.1	97	96	87	94	60	66	106	107

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, before (b) and after (a) exposure to EMR from high voltage transformer.

Variables	Temperature(°C)		SpO2%		HPR(beats/min)		DBP(mmHg)		SBP(mmHg)	
School	b	a	b	a	b	a	b	a	b	a
S1	34.8	35.1	97	96	82	94	72	77	114	123
S2	34.6	35.0	97	96	84	90	70	80	117	120
S3	34.4	34.6	97	94	91	97	61	74	93	112
S4	35.2	35.5	97	95	89	105	63	71	92	107
S5	35.0	35.0	97	95	87	94	60	65	106	107

It can be observed from tables 4.2 and 4.3 that all students male and female are suffering from exposure to EMR from high voltage transformers.

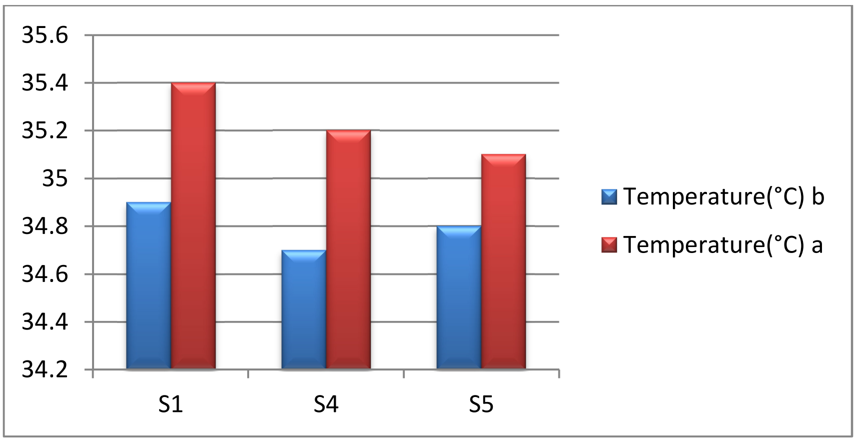

Fig. 4.1: Average values of tympanic temperature for male students in each studied school before (b) and after (a) exposure to EMR from high voltage transformers.

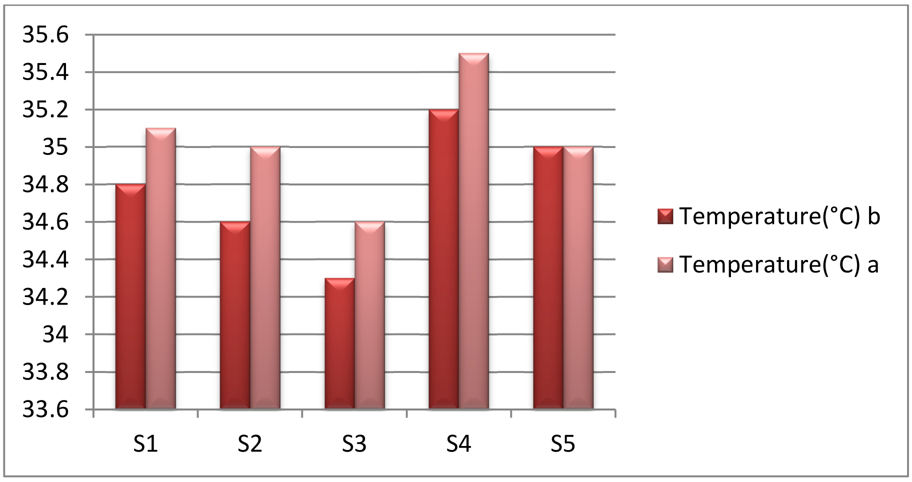

Fig. 4.2: Average values of tympanic temperature for female students in each studied school before (b) and after (a) exposure to EMR from high voltage transformers.

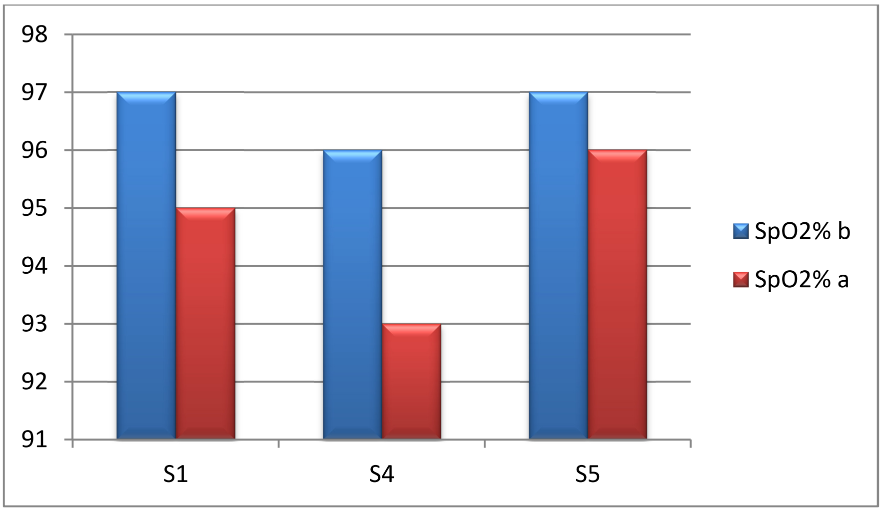

Fig. 4.3: Average values of blood oxygen saturation SpO2 % for male students in each studied school before (b) and after (a) exposure to EMR from transformers.

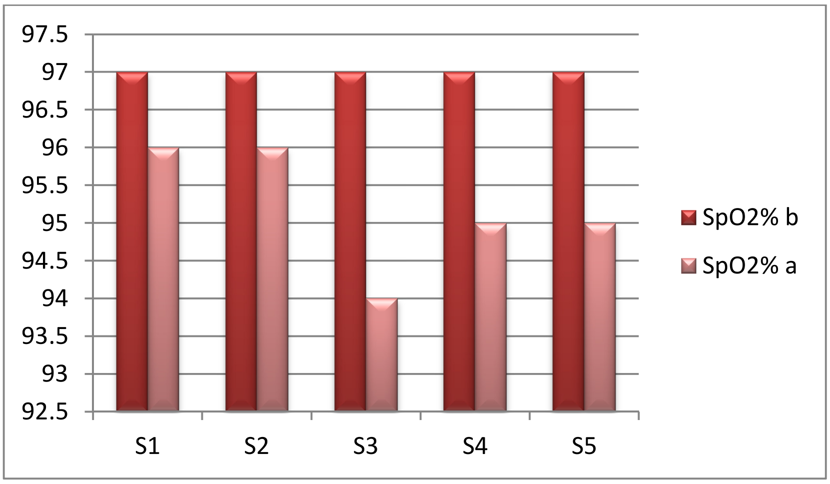

Fig. 4.4: Average values of blood oxygen saturation SpO2 % for female students in each studied school before (b) and after (a) exposure to EMR from high voltage transformer.

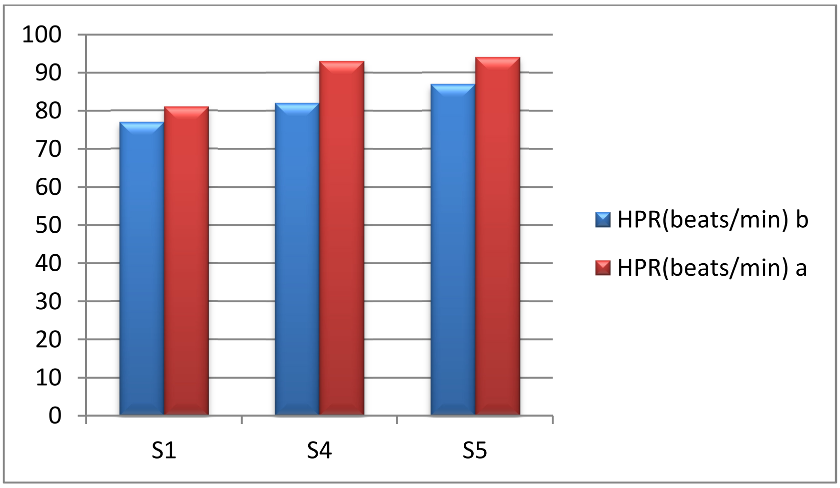

Fig. 4.5: Average values of heart pulse rate for male students in each studied school before (b) and after (a) exposure to EMR from high voltage transformers

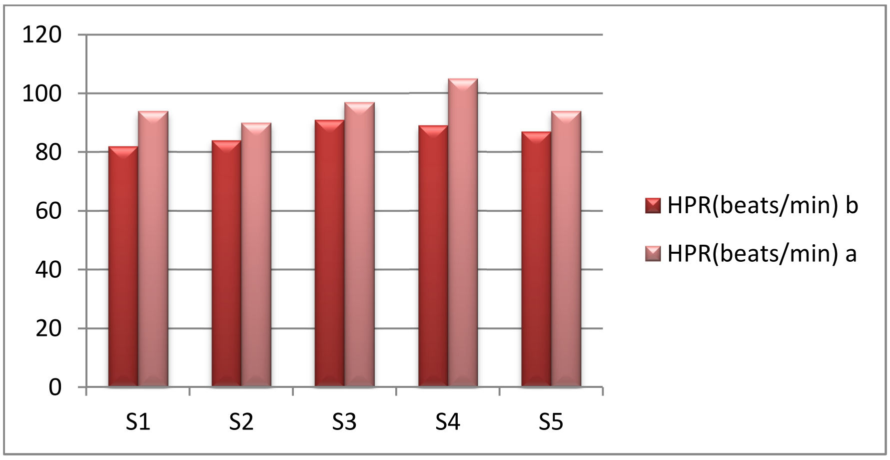

Fig. 4.6: Average values of heart pulse rate for female students in each studied school before (b) and after (a) exposure to EMR from high voltage transformers.

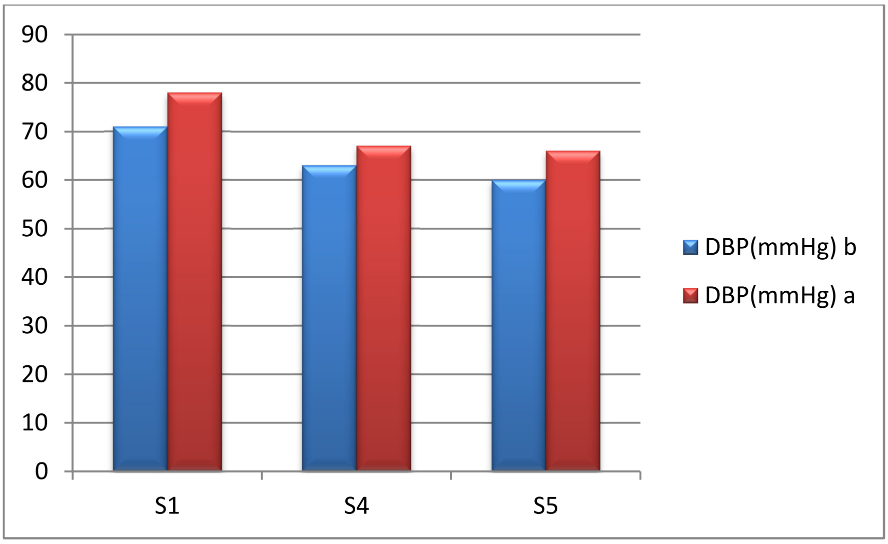

Fig. 4.7: Average values of diastolic blood pressure for male students in each studied school before (b) and after (a) exposure to EMR from high voltage transformers.

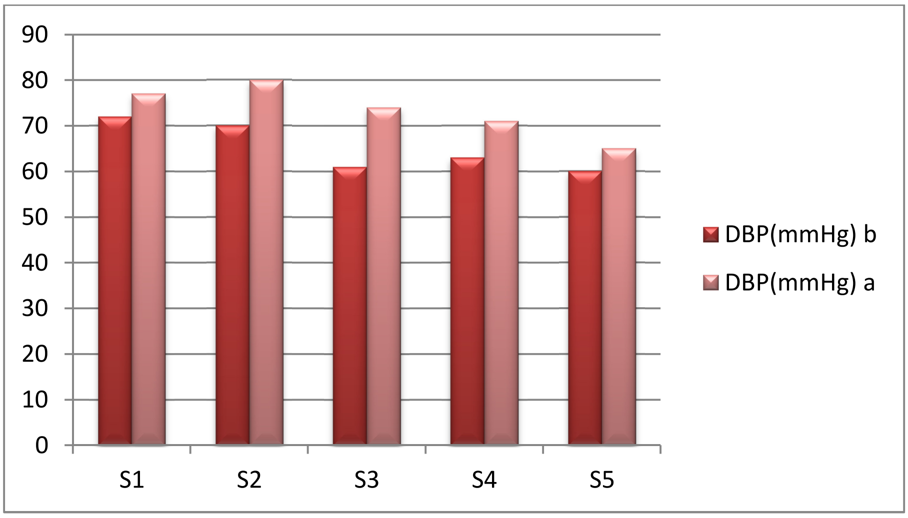

Fig. 4.8: Average values of diastolic blood pressure for female students in each studied school before (b) and after (a) exposure to EMR from high voltage transformers.

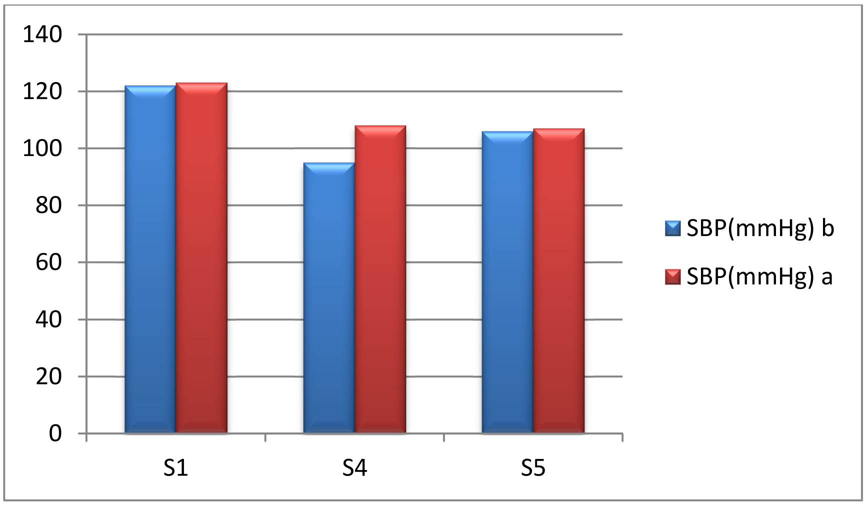

Fig. 4.9: Average values of systolic blood pressure for male students in each studied school before (b) and after (a) exposure to EMR from high voltage transformers.

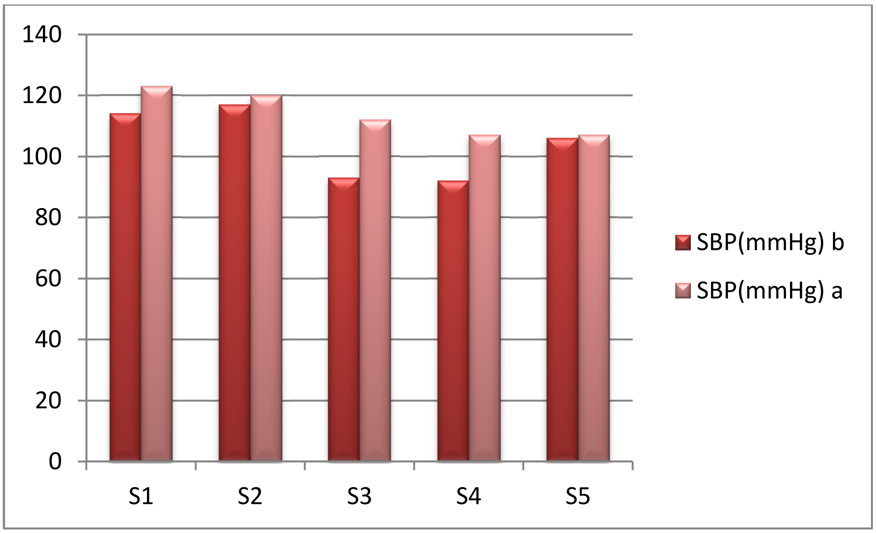

Fig. 4.10: Average values of systolic blood pressure for female students in each studied school before (b) and after (a) exposure to EMR from high voltage transformers.

5.0 DISCUSSION

Average values of tympanic temperature of selected students 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 there is a general increase in these temperatures. 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).

Average values of blood oxygen saturation SpO2 % were decreased after the students were exposed to EMR from high voltage transformers as shown in Figs 4.2 and 4.3. The most affected students were from Adifase High school, then from Command Secondary school. 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, 2008).

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 were from Adifase high school and Command secondary school. A study done on volunteers exposed to electric field (20 kV/m), and magnetic fields (50 G), under controlled laboratory condition showed increase in heart rate (Dermot Byrne, 2007).

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. Adifase high school is the most affected school. 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, 2008, National Radiological Protection, 2004). In this study, the diastolic blood pressure increased by (4 – 13) mm Hg. There is conspicuous increase in systolic blood pressure average values as shown in Figs (4.9 – 4.10). Comprehensive secondary school and Command secondary school are the most affected schools. There are studies that showed exposure to microwave radiation will increase the systolic blood pressure by about five mmHg (Havas, 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. Students in Adifase high school are the most affected from the high voltage transformers electromagnetic radiation. The second school is Command secondary School. 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 according to the guidelines of Building Biology Institute. A research done in Iran found that the average power flux density in buildings within 5m to 150m 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).

6.0 CONCLUSION AND RECOMMENDATIONS

It is clear from this study that electromagnetic emissions from high voltage transformers have great effects on people living within 200m from them. It is equally important to note that the closer you are to such transformers the greater their effects. This study established the fact that sophisticated equipments like RF3040 could detect EMR emissions. The results show from analysis that the measured values of power flux density were within slight concern limit when compared with the standard as obtained by Building Biology Institute in 2008.

The following are some recommendations, which can be put in place to reduce the effect of EMR from high voltage transformers in our immediate environment.

1. Locations of schools must be far away from high voltage transformers at least 200m.
2. It is imperative to note that the public should be sensitized on the dangers of high voltage emissions to the citizens and the society at large.
3. Intending building owners should adhere strictly to standards before embarking on building construction.
4. The regulatory authorities should enforce strict adherence to safety standards of operation.
5. Town planners and other relevant agencies should take cognizance of this knowledge.
6. Further research should be carried out on other sources of radiation within communities and on how to reduce their effects.
7. Further research should be done considering other health parameters different from the ones used in this study.

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