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Effects of Electromagnetic Radiation from Microwave Ovens on Workers' Health at Cafeterias in some Higher Educational Institutions in Palestine

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Electric and Magnetic Field Radiation Leakage from Microwave Ovens at Homes in Palestine

By

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Dedication

This Thesis is dedicated with gratitude to:

My dear parents for the million things they gave me, for the unlimited support, care, and love they always give me. My gratitude goes to my fiancé Fayez for his encouragement and support. I also extend my gratitude to my sisters and brothers with love and respect.

Acknowledgments

First of all I heartily thank Allah for giving me the will and patience to undertake this study as a completion to my master's degree. I am also indebted and deeply grateful to my supervisors Prof. Issam Rashid Abdelraziq, and Dr. Mohammed Abu-Jafar for their support, encouragement, and most importantly thier helpful comments on earlier drafts. I am also grateful to the examining committee members. Special thanks are due to my grandmother as well as my aunt Nahedah who was the first to encourage me to pursue my higher studies. I also extend my gratitude to my uncle Dr. Mamdouh Abu Shehab. Special thanks are due to my sister safa' for helping me in measurements. Many thanks also go to my friends for their support.

After all, I would like to thank the cafeterias managers; specially the manager of the Arab American University cafeteria, Ibrahim Zaghloul. I would like to thank workers for their cooperation to make this research possible.

الاقرار

أنا الموقعة أدناه مقدمة الرسالة التي تحمل العنوان:

Effects of Electromagnetic Radiation from Microwave Ovens on Workers' Health at Cafeterias in some Higher Educational Institutions in Palestine

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 الطالبة:**
Signature:	**التوقيع :**
Date:	**التاريخ:**

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List of Abbreviations

Symbol	Abbreviation
ε_0	Electric permittivity in vacuum
μ_0	Magnetic permeability in vacuum
μ	Magnetic permeability
$\mu W/cm^2$	Micro watt per centimeter square
A/m	Ampere per meter
Am	Before midday
AU	The Arab American University Cafeterias
dB	Decibel(s)
DBP	Diastolic Blood Pressure
E	Electric field
EHRS	Environmental Health and Radioactive Safety
ELF	Extremely Low Frequency
EM	Electromagnetic Radiation
FDA	Food and Drug Administration
FM	Frequency Modulation
G_1	Group of workers with the age range of 20-34 years
G_2	Group of workers with the range age of 35-55 years
G_A	Group of workers with duration of employment from 5 months to 5 years
G_B	Group of workers with duration of employment from 6 to 10 years
H	Magnetic field strength
HC	Hisham Hijawi College Cafeterias
HPR	Heart Pulse Rate
ICNIRP	International Commission on Non Ionizing Radiation Protection
IR	Infrared
IRPA	International Radiation Protection Association
$J/m^2.s$	Joule Per meter square second
Lux	Unit of illumination
mos.	Months
NU	An- Najah National University Cafeterias
OSHA	Occupational Safety and Health Administration
P	Probability significant
Pm	After midday
PU	Palestine Technical University Cafeterias
R	Pearson correlation factor
RADAR	Radio Detection And Ranging

RF	Radio Frequency
RF-EMR	Radio Frequency Electromagnetic Radiation
RFR	Radio Frequency Radiation
RLS	Radio Location Station
RW	Radio Wave
SAR	Specific Absorption Rate
SAR_A	Specific Absorption Rate of Workers at the Arab American University Cafeterias
SAR_H	Specific Absorption Rate of Workers at Hisham Hijawi College Cafeteria
SAR_K	Specific Absorption Rate of Workers at Palestine Technical University Cafeteria
SAR_N	Specific Absorption Rate of Workers at An-Najah National University cafeterias
SBP	Systolic Blood Pressure
S_{eq}	Power flux density
$SPO_2\%$	Blood Oxygen Saturation
T	Tympanic Temperature
UV	Ultra Violet
VRT	Visual Reaction Time
W/Kg	Watt per Kilogram
Y	Years
dv	The Incremental volume
dm	The Incremental mass
dw	The incremental energy
α	Absorption coefficient of the substance (Alpha)
λ	Wavelength (Lambda)
ρ	Mass density (Rho)
σ	Electrical conductivity of the material (Sigma)

Abstract Effects of Electromagnetic Radiation from Microwave Ovens on Workers' Health at Cafeterias in some Higher Educational Institutions in Palestine

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Abstract

This study highlights the effects of electromagnetic radiation from microwave ovens on the health of the workers who are exposed to this radiation during their work at cafeterias in four higher educational institutions in Palestine. To achieve the aim of the study, the researcher focused on a sample that consists of 28 workers whose ages range between 20-55 years. Measurements of heart pulse rate, blood oxygen saturation, tympanic temperature, systolic and diastolic blood pressure were taken three times between (8:00-8:30) am and another three times at the same day after the end of their using of the microwave ovens at around 2:00 till 2:30 pm. The average of these measurements was taken. The study was carried out during December 2013 and January 2014. The researcher of this study focused on four higher education institutions in the northern part of Palestine. These higher educational institutions are An-Najah National University, the Arab American University, Hisham Hijawi College, and Palestine Technical University. The gathered data were subjected to statistical analysis. The results demonstrate that the average of the measured values of radiation leakage equals 46.126 mW/m^2. The average

values of radiation leakage are small compared with the standard value which equals 5×10^4 mW/m^2 recorded by American National Standard Institute. It has been concluded that there is a correlation between radiation leakage from microwave ovens with oven's age, distance from oven, and the duration of use. Using measurable health parameters to detect the effect on workers' health reveals that there is a change in the measurable parameters, but that change remains in the normal human range. That is, there is no dangerous health effects of microwave radiation from microwave ovens used in the cafeterias of the university under study, which indicates adopting high security factors in designing modern microwave ovens.

Chapter One

Introduction

1.1 Background

The worldwide technology development has been dramatically increasing. This generates a great interest by people to follow the evolution of technology.

Wide exposure to such evolution may lead to environmental pollution occurs in different forms including, air, water, soil, radioactive, noise, thermal, and light pollution. The various types of pollution do not simply negatively affect the natural world, but they can have measurable impact on human beings (Neelam, and Sanjeev, 2013).

Microwave radiations are used in many areas of science and technology such as television, radar, and microwave ovens (Gupta, 1988)**.** Moreover microwave radiation is used to treat muscle soreness, but the most commonly use is in microwave ovens (FDA, 2006).

Despite the benefits resulting from the use of microwave radiation application, there are many risks that threaten people's lives and affect human health. The intensive use of electromagnetic radiation technology makes the pollution of electromagnetic field of radio frequency generated by telecommunication system one of the biggest environmental problems of the twentieth century (Adiloze, *et al*, 2010).

Microwave oven is one of the important appliances that are mainly used in homes, restaurants, and cafeterias. The reason for the increasing demand on this device is to reheat food in an amazingly short time. Microwave ovens play a crucial role in people’s life. For example it can quickly reheat different kinds of food with no physical change of food. Another benefit of microwave ovens is related to the place available in the kitchen since it occupies a small place (Seong-Lee, 2004).

1.1.1 Instruction of Microwave Oven

The microwave oven consists of some parts. Each of these parts plays a vital role. It consists of a cavity magnetron, a high voltage power source, a high voltage capacitor, a waveguide, a stirrer, a turntable, a cooking cavity, a door and a choke. A cavity magnetron is a device which converts high-voltage electric energy to microwave radiation. A high voltage power source is a simple electronic power converter. A high voltage capacitor is connected to the magnetron. A waveguide is a tool to control the direction of the microwaves. Stirrer is commonly used to distribute microwaves from the wave guide and allow more uniform heating. Turntable rotates the food products through the fixed hot and cold spots inside the cooking cavity. Cooking cavity is a space inside which the food is heated when exposed to microwaves. Door and choke allows the access of food to the cooking cavity (Jaime, 2014).

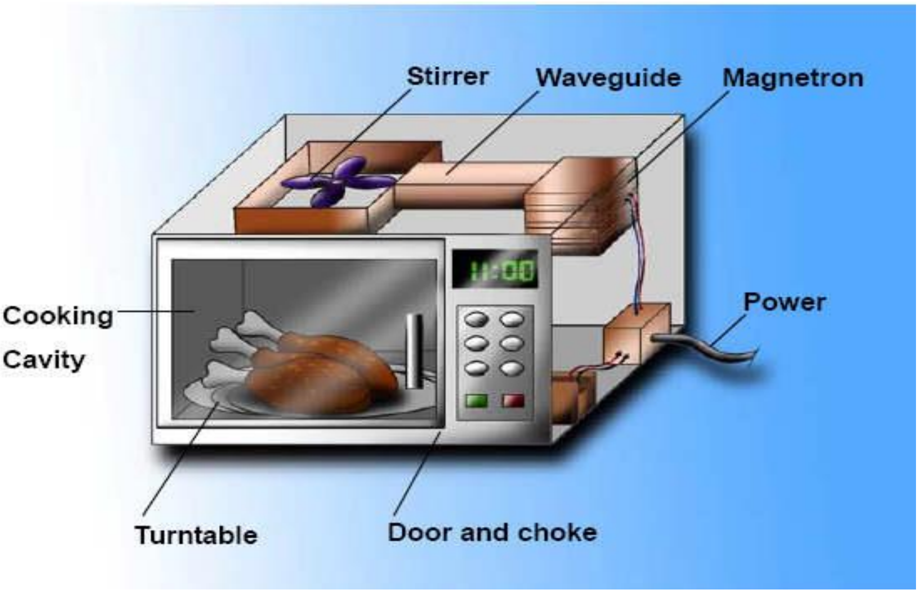

Fig. 1.1 Basic structure of a microwave oven
(http://www.tlbox.com/category/appliances/small-appliances/microwave-ovens/)

1.1.2 Operating Principle of Microwave Oven

The most important portion of microwave oven is a magnetron, which is "a tube in which electrons are subjected to both magnetic and electric fields". The electromagnetic field with a microwave frequency of about 2.45 GHz, wavelength λ = 12.6 cm will produce, according to this alternating electromagnetic field polar molecules such as water molecules inside food, will rotate due to absorption of microwave energy. The rotation of water molecules would generate heat. In addition to the dipole water molecules, there is another source of heat by ionic compounds in food. As they are accelerated by electromagnetic field, they collide with other molecules and produce heat (Priyanka, *et al*, 2013).

1.2 Literature Survey

During recent years, many scholars have conducted a large number of studies on the effect of electromagnetic radiation emitted by many sources.

For example, Osepchuk, made a review of the safety of microwave ovens. He has showed that typical leakage values imply exposure values well below the most conservative exposure standards in the world. Microwave ovens are being more accepted and safer than they were in 1973 (Osepchuk, 1978).

While evaluating the health risks from exposure to electromagnetic radiation, Matthes investigated the measurements of radiation emitted from microwave ovens and he found that detrimental health effects are not expected to occur as a result of radiation exposure during microwave cooking (Matthes, 1992).

Kolodynski and Kolodynska from their experiments on school children living near the Radio Location Station (RLS), they conclude that these children had less developed memory and attention. Their reaction time was slower and their neuromuscular apparatus endurance was lowered (Kolodynski, and Kolodynska, 1996).

Sieber and his team proved that fears can be neglected concerning the formation of D-amino acids in microwaved milk. A biological experiment showed that no evidence for the hazards of microwave heat treatment of milk (Sieber, *et al*, 1996). Moreover Inaloz and his group in their study believe that it is not easy to say that microwave ovens have cataract genic effect on human eyes (Inaloz, *et al*, 1997).

Alhekail in his study argued that user exposure to RF radiation from microwave ovens is much less than the public exposure limit set by the international standard ICNIRP in 1998 at 2.45 GHz which is 10^4 mW/m^2, and that a detrimental effect on health is an unlikely result of exposure to radiation from microwave ovens (Alhekail, 2001).

On the other hand microwave ovens greatly affected food stuffs, Song and Milner studied the effect of microwave ovens on garlic. They demonstrated that heating garlic for 60 second in a microwave oven is enough to inactivate its allinase, garlic's principle active ingredient against cancer (Song, and Milner, 2001).

Radio frequency signals at an average specific absorption rate (SAR) of at least 5.0 W/kg under extended exposure conditions are capable of inducing chromosomal damage in human lymphocytes. This research has been studied by Tice and his group (Tice, *et al*, 2002).

Vallejo showed that microwave ovens have serious effects on nutrients in people's food such as broccoli "zapped" in the microwave with a little water lost up to 97 percent of its beneficial antioxidants. By comparison, steamed broccoli lost 11 percent or fewer of its antioxidants. There were also reductions in phenolic compounds and glucosinolates, but mineral levels remained intact (Vallejo, 2003).

In addition, Kesarik and his team summarized in their research that the regular and long term use of microwave devices (mobile phone, microwave ovens) at domestic level can have negative impact upon biological systems especially on brain (Kesarik, *et al*, 2003).

Alto and his group found that the electromagnetic field emitted by a commercial mobile phone affects regional cerebral blood flow in humans (Aalto, *et al*, 2006). Radiation from a cell phone penetrates deeper into the head of children. Children may be more susceptible to damage from cell phone radiation. Children absorb energy differently than adults because of differences in their anatomies and tissue composition. This has been summarized by Wiart and his team in 2008 (Wiart, *et al*, 2008).

A study done by Mailankot and his team to evaluate the effect of radio frequency electromagnetic radiation(RF-EMR) from mobile phones on free radical metabolism and sperm quality. They summarized that semen quality is negatively affected from RF-EMR emitted. Male fertility may impair by exposure to these radiations (Mailankot, *et al*, 2009).

Tacken and his group investigate the idea that after low temperature microwave heating, triglyceride and carotenoid concentration in human milk remained stable. Therefore, mature human milk can be safely heated in a microwave oven without loss of fat or carotenoid (Tacken, *et al*, 2009).

The study conducted by Cinquanta and his team on heating orange juice in microwave ovens showed that there is a slight decrease in vitamin C content after microwave heating (Cinquanta, *et al*, 2010). Han and his group in their study demonstrated that watching TV and using a mobile phone during the first term pregnancy may increase risk of embryo growth ceasing significantly (Han, *et al*, 2010). A study was done by Mousa to measure the electromagnetic radiation from some cellular base station around the city of Nablus. He summarized that the measured and calculated values of electric field, magnetic field, and the power density were small compared to the international standards (Mousa, 2011).

Robinson and his group in their study argued that children as young as 17 month could start microwave ovens, open the door, and remove the contents, but these actions may put them at a significant risk for scald burn injury (Robinson, *et al*, 2011).

People usually think that, there is a dangerous health problem due to radiation leakage from microwave ovens. Several experiments carried out in this field. According to Australian standard it is found that the maximum allowable leakage from a microwave oven is 5 mW/cm^2 at 5 cm distance from the surface of a microwave oven. The only danger from the exposure to the radiation emitted by an oven is a thermal effect (Mohammad, *et al*, 2011). The detrimental effects of microwave radiation emitted by mobile phones at students in university are studied in 2012. Mortazavi and his group summarized that the student visual reaction time (VRT) decreased after exposure to electromagnetic fields generated by specific absorption rate mobile phone (Mortazavi, *et al*, 2012).

Lahham and Sharabati in their study found that the amount of radiation leakage from microwave ovens at a distance 1 m vary from 0.4 to 16.4 $\mu W/cm^2$ with an average value that equals to 3.64 $\mu W/cm^2$. They concluded that there is a linear relation between the amount of leakage with both oven age and the operating power (Lahham and Sharabati, 2013).

Thambiraj and his group argued that microwave ovens are considered an important source of injury at home especially among young children in the United States (Thambiraj, *et al*, 2013).

The effect of electromagnetic field from mobile phones on fasting blood glucose in Wister Albino rats was determined by Meo and Rubeaan study. They concluded that there is an increment in fasting blood glucose and serum insulin in long-term exposure Albino rats (Meo, and Rubeaan, 2013).

1.3 Objectives of the Study

People are aware about the impact of radiation leaking from microwave ovens on their health. It has been found that generally, cafeterias' workers use microwave ovens for 6 hours a day. A study done to investigate the radio frequency radiation leakage from microwave ovens used in different cafeterias in a group of higher educational institutions in the northern part of Palestine.

The aims of this study are:

1. To measure the amount of radiation leakage as a function of distance from microwave ovens, operating power, and oven age.
2. To calculate the electric fields, magnetic fields, and SAR.
3. To detect the effects of the electromagnetic radiation leakage on the workers by measuring the health factors such as heart pulse rate, blood oxygen saturation, tympanic temperature, and blood pressure.

Chapter Two

Theoretical Background

This chapter consists of three sections. Section one highlights the electromagnetic spectrum. Section two discusses absorption of radiation. Finally, section three explains the specific absorption rate (SAR).

2.1 Electromagnetic Spectrum

Electromagnetic spectrum is defined as a series of energy waves composed of oscillating electric and magnetic fields transmitted through empty space at the speed of light. It can be described as the complete range of the wavelength of electromagnetic radiation beginning with the longest wavelength, the lowest frequency radio waves and extended through the visible light all the way to the extremely short wavelength and highest frequency gamma rays (OSHA, 2005).

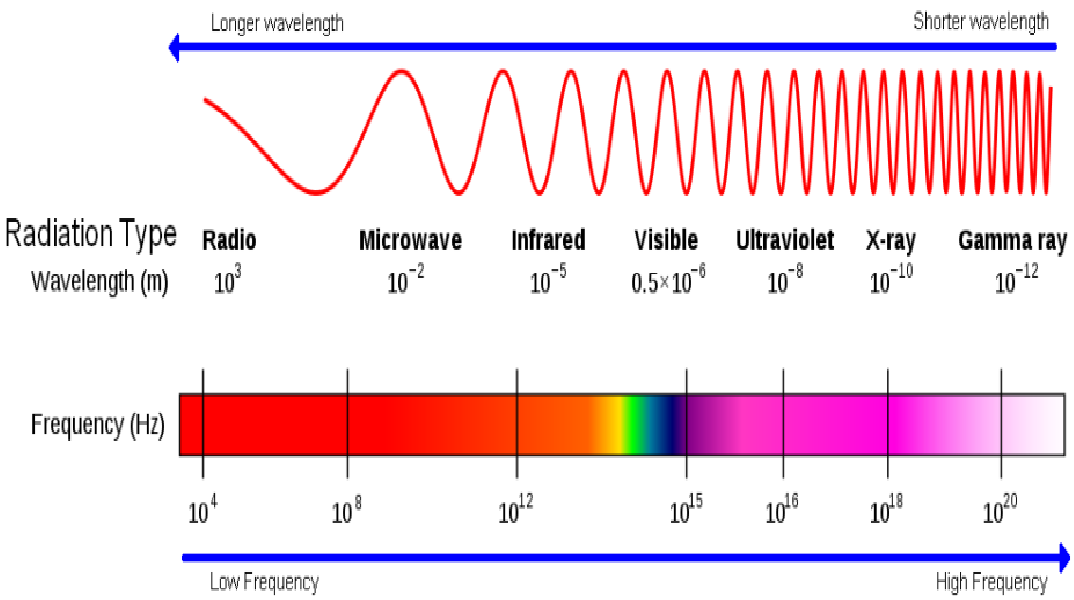

Fig. 2.1 Electromagnetic Spectrum

The electromagnetic spectrum consists of two major kinds of radiations:

1. Ionizing radiation: A radiation that has sufficient energy to ionize atoms by knocking electrons out of their orbital shells through breaking the chemical bonds within a molecule. Ionizing radiation has very high frequency and short wavelength including X-rays, and gamma rays which are at the upper end of EM spectrum.
2. Non-Ionizing radiation: An electromagnetic radiation that doesn't have enough energy to ionize matter. It includes, ultraviolet radiation (UV), visible light, infrared radiation (IR), microwaves (MW), radio waves (RW) and extremely low frequency (ELF) (EHRS, 2013).

Microwaves are a part of electromagnetic spectrum with frequencies ranging from 300 MHz to 300 GHz corresponding to wave length range 1 mm to 1m. They fall under non ionizing radiation. In modern world, microwave radiation of specific frequency range is used for specific application. Those in (30-300) MHz range are used in FM radio and television, those with (300 MHz-3 GHz) are used in microwave ovens, and RADAR (Radio Detection And Ranging). Microwave frequency of (30 GHz-300 GHz) has been assigned for satellite-to-earth communications (Toshi, *et al*, 2013).

2.2 Absorption of Radiation Energy

Beer's law deals with the absorption of radiation through materials. It states that the intensity I of the transmitted beam of radiation at an absorber decreases exponentially depending on two factors; the absorption coefficient (α) of the absorber and the path length (x) of the radiation through the absorber (Ingle and Crouch, 1988). Mathematically, it is expressed as follows:

$$I = I_o \, e^{-\alpha x} \tag{2.1}$$

Where: I is the transmitted intensity (J/m^2.s), I_o is the incident intensity (J/m^2.s), α is the absorption coefficient (cm^{-1}), x is the path length (cm).

Energy transferred from an electromagnetic wave which travels through space into a receiver object has a rate that depends on the strength of electromagnetic field components. The rate of energy transferred per unit area is called power density. The power density S_{eq} in W/m^2 is defined as the product of the electric field strength (E) in V/m times the magnetic field strength (H) in A/m (OSHA, 1990).

$$S_{eq} = E \times H \tag{2.2}$$

For linear materials, the magnetic flux density (B) is related to the magnetic field strength (H) with the relation

$$B = \mu H \tag{2.3}$$

Where the constant $\mu = 4\pi \times 10^{-7}$ T.m/A is the magnetic permeability.

Under the simple conditions of wave travel through free space, the relationship of electromagnetic fields is reduced to:

$$E = \left(\frac{\mu o}{\epsilon o}\right)^{1/2} H \text{ (Under free space conditions)} \tag{2.4}$$

The electric field strength (E) is calculated as:

$$S_{eq} = \frac{E^2}{377} \tag{2.5}$$

The magnetic field strength (H) is calculated from the relation

$$S_{eq} = 377\ H^2 \qquad (2.6)$$

Where $(\frac{\mu o}{\varepsilon o})^{1/2} = 377\Omega$ is the characteristic impedance of free space (OSHA, 1990).

2.3 Specific Absorption Rate

Specific absorption rate (SAR) is used to describe the rate of radio frequency radiation (RFR) energy absorbed in a unit of tissue in the body. It is expressed in Watt per kilogram (W/Kg) of tissue. SAR is usually averaged over the whole body or over small volume tissue typically between 1 and 10 g of tissue. SAR has more authenticity to determine the biological effect of radio frequency radiations (RFR's) than power density, since SAR reflects what is really being absorbed by matter rather than the energy in space (Levitt, and Lai, 2010).

Mathematically, SAR is defined as the time derivative of the incremental energy (dW) absorbed by an incremental mass (dm) contained in a small element of volume (dv) of a given mass density (ρ).

$$SAR = \frac{d}{dt}(\frac{dw}{dm}) \qquad (2.7)$$

$$SAR = \frac{\sigma E^2}{\rho} \qquad (2.8)$$

Where σ is the electrical conductivity of the material, and E is the electric field inside the material (Vijay, *et al*, 2012).

Chapter Three

Methodology

This chapter focuses on five topics including, study sample (Sec. 3.1), stages of the study (Sec. 3.2), timetable of the study (Sec. 3.3), standard exposure radiation (Sec 3.4), and experimental apparatus (Sec. 3.5).

3.1 Study Sample

The sample population of this study consists of 28 workers distributed in some of cafeterias in four higher educational institutions in the northern part of Palestine. These workers are the only workers which use microwave ovens while working inside cafeterias. The study focuses on cafeterias in specific higher educational institutions which are An-Najah National University that is in Nablus city, the Arab American University which is located in Jenin city, Hisham Hijawi College is in Nablus city, and Palestine Technical University which is in Tulkarm city.

The workers' ages range between 20 to 55 years. The shift time of the workers is 6 hours per day. The chosen workers have good health records.

The sample population of this study also involves 15 microwave ovens with uniform size used in the cafeterias of the selected higher educational institutions. These cafeterias use microwave ovens for 6 hours a day.

Light intensity is measured in different sites in the region of microwave ovens in the cafeterias under study. Values are found to vary from (200-600) Lux. These values are in the normal range of the light intensity. The sound pressure level was (50-60) dB which is considered to be within permissible limits.

The number of examined workers, and microwave ovens in each cafeteria are given in table 3.1.

Table 3.1: Number of examined workers and microwave ovens in different cafeterias in Palestine

Cafeterias in Higher Educational Institutions	Number of examined Workers	Number of microwave ovens
An-Najah National University	18	10
The Arab American University	7	3
Hisham Hijawi College	1	1
Palestine Technical University	2	1

3.2 Stages of the Study

Stages that have been adopted in this study are as follows:

1. Visiting the higher educational institutions and taking the permission for carrying out examination on workers and microwave ovens.
2. Informing the workers about the nature of the study and taking their approval for doing the measurements on them.
3. Collecting the necessary information of the study concerning information about ovens such as dates of manufacturing, country of origin, operating power, age, number of users, duration of use, the location of the oven regarding the public and physical condition. Information about workers age, and employment duration.
4. Measuring the light intensity of the cafeterias during the period between 8:00 and 2:00.
5. Measuring the sound pressure levels in the cafeterias during the period between 8:00 and 2:00.

6. Measuring the power flux density of the electromagnetic radiation in the cafeterias.
7. Measuring several health parameters as:
   a. Heart pulse rate
   b. Blood oxygen saturation
   c. Tympanic temperature
   d. Arterial blood pressure (Systolic and Diastolic)

3.3 Timetable of the Study

This study was conducted during December, 2013 and January, 2014. The measurements of heart pulse rate, blood oxygen saturation, tympanic temperature, and blood pressure (Systolic and Diastolic) of the sample were carried out three times before the workers start at 8:00-8:30 am. The measurements were repeated three times after the workers finish using microwave ovens at 2:00-2:30 pm. The averages of the measured values were recorded.

3.4 Standard Exposure Radiation

Measurements of electromagnetic radiation from different ovens will be compared with the electromagnetic field levels from American National Standard Institute (ANSI), which recommends exposure limit of 5×10^4 mW/m^2 at 1500-100000 MHz frequency range.

The standard levels for workers exposure to power flux density provided by American National Standard Institute are given in table 3.2.

Table 3.2: Reference levels for power flux density exposure (exposure levels in mW/cm^2) (American National Standard Institute, 1982)

Frequency range (MHz)	Power flux density $(mW/m^2)\times10^4$
0.3-3	100
3-30	$900/f^2$
30-300	1.0
300-1500	f/300
1500-100000*	5.0

*: This is the frequency range of microwave oven which is 2.45 GHz corresponding to 12.6 cm microwaves.

The reference levels for general public exposure to time varying electric and magnetic fields with exposure time 6 min are given in table 3.3.

Table 3.3: Reference levels for general public exposure to time varying electric and magnetic fields for 6 min provided by ICNIRP (Vecchia, 2007)

Exposure category	Frequency range	E-field strength (V/m)	H-field strength (A/m)	power density S_{eq} $(mW/m^2) \times 10^3$
Occupational	100KHz-1 MHz	614	$1.63/f$	-
	1MHz-10MHz	$614/f$	$1.63/f$	$1000/f^2$
	10MHz-400MHz	61.4	0.163	10
	400MHz-2GHz	$3.07\times f^{0.5}$	$0.00814\times f^{0.5}$	$f/40$
	2GHz-300GHz	137	0.364	50
General public	100 KHz-15KHz	86.8	4.86	-
	150KHz-1MHz	86.8	$0.729/f$	-
	1MHz-10MHz	$86.8/f^{0.5}$	$0.729/f$	-
	10MHz-40MHz	27.4	0.0729	2
	400MHz-2GHz	$1.37\times f^{0.5}$	$0.00364\times f^{0.5}$	$f/200$
	2GHz-300GHz	61.4	0.163	*10*

Where f is the frequency in hertz, S_{eq} is the equivalent power flux densities.

The reference values for SAR are given in table 3.4.

Table 3.4: 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

3.5 Experimental Apparatus

To fulfill the purpose of this study, many tools and devices have been used. In the following subsections the instruments used will be briefly explained.

3.5.1 Sound Level Meter 2900

Measuring of noise level in the selected cafeterias was obtaining by using sound level meter. Quest Technologies USA, Model 2900 type 2. It has an accuracy of ± 0.5 dB at 25 °C. This device gives the reading with precision of 0.1 dB. Sound level meter was used to make sure that the sound level is in quite range < 60 dB. Fig. 3.1 shows the sound pressure level meter that is used (Instruction manual for sound pressure level meter, 1998).

Fig. 3.1: Sound Pressure Level Meter Model 2900 **(**Instruction Manual for Sound Pressure Level Meter, 1998**)**

3.5.2 Lux Hitester

Hioki 3423 lux Hitester Digital illumination meter is used to measure the light intensity. This instrument is suited for a wide range of application. It measures a broad range of luminosities; from the low light provided by induction lighting up to a maximum intensity of 199,900 lux. This instrument was used in this study to measure the intensity of light in different regions in the selected cafeterias. Fig. 3.2 shows Hioki 3423 lux Hitester Digital illumination meter.

Fig. 3.2 Hioki 3423 Lux Hitester Digital Illumination Meter (Instruction Manual for Lux Hitester, Japan, 2006)

3.5.3 Acoustimeter RF Meter

Acoustimeter AM-10 RF Meter is a dedicated radio frequency (RF) radiation meter. Frequency response is 200 MHz-8 GHz. This meter is used to measure radiation from different sources. It measures RF radiation from 200 MHz up to 8 GHz with accuracy ±3 dB, and can measure average exposure levels from 1 to 100,000 microwatts per square meter ($\mu W/m^2$). The peak exposure levels from 0.02 to 6.00 volts per meter (V/m). Power flux density in this study was measured by using this device. Acoustimeter RF meter is shown in Fig. 3.3.

Fig. 3.3 Acoustimeter RF Meter (Instruction Manual for Spectran RF 6080, Aronia AG Germany, 2007)

3.5.4 Micro Life Blood Pressure Meter

Automatic Blood Pressure Monitor (micro life AG, Modno. BP 2BHO). Its measuring range is 30-280 mm-Hg, with accuracy ± 0.02 mm-Hg, and ± 2% for reading heart pulse rate with operating temperature range of +10 °C to +40 °C. Arterial blood pressure systolic, diastolic and heart pulse rate values in this study were determined by using micro life blood pressure meter**.** Micro life blood pressure meter is shown in Fig. 3.4 below (Instructions manual for Automatic Digital Electronic Wrist Blood Pressure, 1998a).

Fig. 3.4 Micro Life Blood Pressure Meter (Instructions Manual for Automatic Digital Electronic Wrist Blood Pressure, 1998a)

3.5.5 Pulse Oximeter

Pulse Oximeter LM-800.Finger Oximeter with accuracy ± 1% is used to measure the blood oxygen saturation of each worker in the cafeterias. Pulse oximeter is shown in figure 3.5 (Instructions Manual for Pulse Oximeter, 2012).

Fig. 3.5 Pulse Oximeter (Instructions manual for pulse oximeter, 2012)

3.5.6 TempScan Thermometer

The GT-302/GT-302-1 ear thermometer instrument is used to measure human body temperature through the tympanic temperature of the ear. The display temperature range is 32.0 to 42.9 °C with an accuracy range of ±0.01°C.The temperature values of this study were detected by using Temperature Scan thermometer which is shown in Fig. 3.6.

Fig. 3.6: TempScan Thermometer (Instructions Manual for Digital Ear Thermometer, China, 2011)

3.5.7 Scan Probe

Scan Probe is a tool used to detect the presence of an electromagnetic field. It provides audio and visual indication of relative field strength. It is a one axis sensor. It is powered by 2 AAA batteries. Scan Probe offers a green, red, and yellow 5-LED light and audible tone which changes pitch with field strength. Scan Probe is shown in Fig. 3.7.

Fig. 3.7 Scan Probe (Instruction Manual for Scan Probe, China, 2006)

3.6 Statistical Analysis

Microsoft Excel and Statistical Package for Social Science (SPSS) programs were used to analyze the gathered data, to find the relationship between the dependent and independent variables. Measurements were analyzed statistically as the following: The probability (P) and Pearson correlation factor (R) were used to measure the strength correlation between radiation leakage from microwave ovens and the dependent variables, before and after exposure to this radiation. The P values ranged from zero to one. Values with $P < 0.05$ were considered statistically significant.

Pearson correlation coefficient (R) reflects the degree of linear relationship between two variables. It ranges from -1 to +1. There is an increasing linear relationship when R value is +1 which is called a perfect positive. While a decreasing linear relationship occurs when R value is -1. When R value is equal to zero, this indicates that there is no correlation exists between the studied variables. The (R) values ranged from zero to one as follows:

a. $0.00 \leq |R| \leq 0.35$, weak correlation
b. $0.36 \leq |R| \leq 0.67$, moderate correlation
c. $0.68 \leq |R| \leq 0.90$, strong correlation
d. $0.90 \leq |R| \leq 1.0$, very strong correlation (Richard, 1990)

Chapter Four

Results

Experimental measurements which were conducted to achieve the purpose of this study will be discussed in this chapter. Measurements of light intensity and sound pressure levels will be explained in Sec 4.1. Measuring of Radiation leakage from microwave ovens with distance, operating power, and duration of use will be explained in Sec 4.2. Electric fields, magnetic fields, and SAR are calculated and presented in Sec 4.3. Measurements of health effects of microwave radiation will be discussed in Sec 4.4.

4.1 Light Intensity and Sound Pressure Levels Results

The light intensity level and sound pressure level were recorded many times between 8:00 am to 2:00 pm. Light intensity measurements were carried out by using Lux Hitester. Sound pressure meter was used to measure the sound level in the cafeterias. It has been found that the light intensity level was between 200-600 Lux. While the sound pressure level was ranging from 50-60 dB which is considered to be within permissible limits. Average values of light intensity and sound pressure levels in the universities' cafeterias are given in table 4.1. It has been found that there are effects from sound level, light intensity and other electromagnetic waves (Abdelraziq, *et al*, 2000), (Qamhieh, *et al*, 2000), (Abdelraziq, *et al*, 2003), (Abdelraziq, *et al*, 2003), (Sadeq Rowaida, 2010), (Sadeq, *et al*, 2012), (Abo-Ras Hadeel, 2012), (Al- Faqeeh Iman, 2013), (Al-Sheikh Ibrahim Dana, 2012), (Al-Sheikh Mohammad Noorhan, 2013), (Dana, *et* *al*, 2013), (Noorhan, *et al*, 2013), (Abu-Sabha Omar, 2014), (Suliman Mohammed, 2014), (Thaher Reham, 2014), (Darawshe Muna, 2014).

Table 4.1: Average values of light intensity level and sound pressure level in the cafeterias of the selected higher educational institutions

Higher Educational Institutions Cafeterias	Light intensity level (Lux)	Sound pressure level (dB)
An Najah National University Cafeterias	424.93	54.03
The Arab American University Cafeterias	417.05	54.19
Hisham Hijawi Cafeterias	552.47	52.01
Palestine Technical University Cafeterias	200.51	52.73

4.2 Radiation Leakage from Microwave Ovens

Radiation leakage from microwave ovens was measured by using Acoustimeter RF Meter and Scan Probe. The scan Probe is used to cover all possible radiation points of the oven. RF meter is then used to measure radiation leakage from the ovens. Measurement of ovens leakage was performed by inserting a glass of water inside the oven and operating the oven for 10 min. The average value of radiation leakage at a distance of 5 cm from microwave oven was measured to be (46.126 mW/m^2) which is small compared to the standard value. The standard value set in table 3.2 for occupational use of microwave ovens is 5×10^4 mW/m^2.

Average values of the radiation leakage from the microwave ovens that have been measured in the different cafeterias of this study are shown in Fig. 4.1.

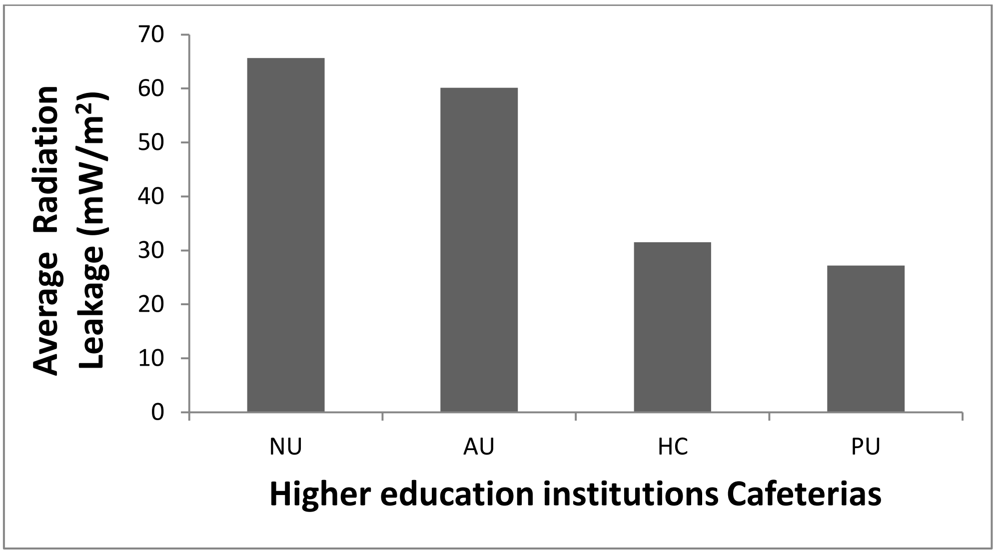

Fig. 4.1 Average values of the measured radiation leakage level at 5 cm distance from microwave ovens in the cafeterias under study.

4.2.1 Radiation Leakage with Distance

Radiation leakage from the microwave ovens is measured at different distances ranging between 0-3 m. A decrease in radiation leakage was clearly observed as moving away from the ovens. The radiation leakage as a function of distance is shown in Fig. 4.2.

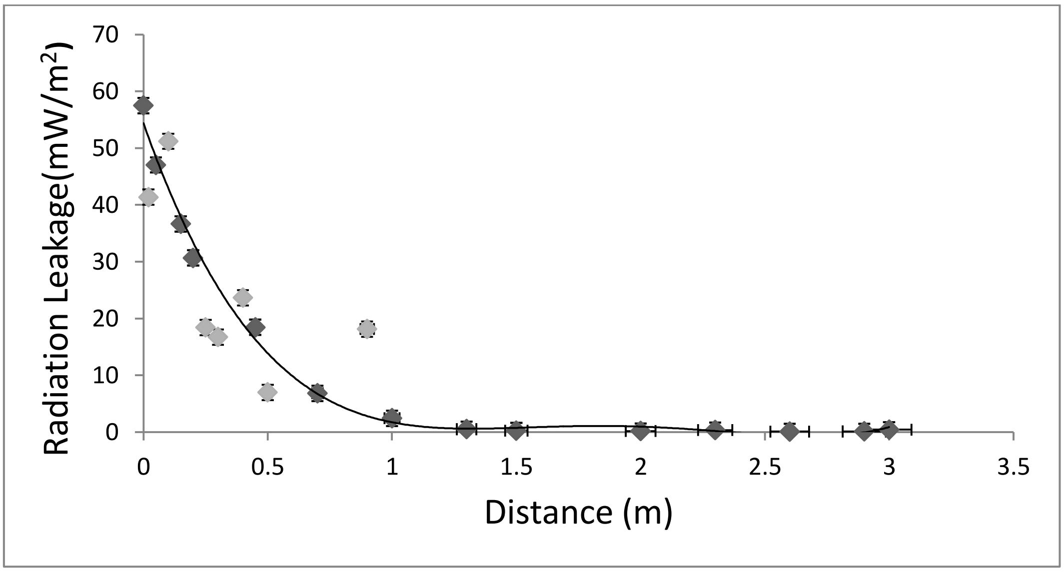

Fig. 4.2 Radiation leakage from microwave ovens as a function of distance

It has been observed from Fig. 4.2 that there is an exponential decrease of radiation leakage with distance from the ovens.

4.2.2 Radiation Leakage with Operating Power

The tested ovens were of different types with operating power between 700W to 1600W. A sample of 15 ovens was divided into two groups according to the oven's operating power. The first group includes ovens with operating power from 750 to 900 W. The second group includes ovens with operating power from 1000 to 1600 W.

Radiation leakage from ovens versus operating power is shown in Fig. 4.3.

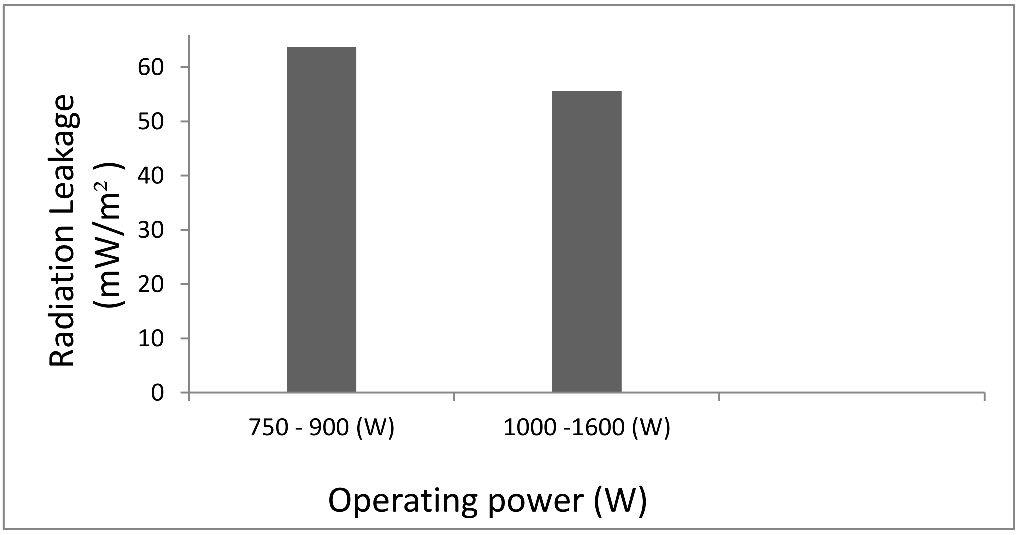

Fig. 4.3 Average values of radiation leakage against ovens operating power

It has been noticed that ovens with operating power from 1000 to 1600 W have less radiation leakage than ovens with operating power from 750 to 900 W. This relation may be explained that the manufactures take into their consideration the safety factor of higher operating power ovens more than lower operating power ones.

4.2.3 Radiation Leakage with Duration of Use

The tested ovens are with different duration of use ranging from 5 months to 10 years. Ovens were classified according to duration of use. It has been found that 6 ovens have 5 months to 5 years of use range and 9 ovens have 6 to 10 years of duration of use. Radiation leakage from ovens as a function of duration of use is shown in Fig. 4.4.

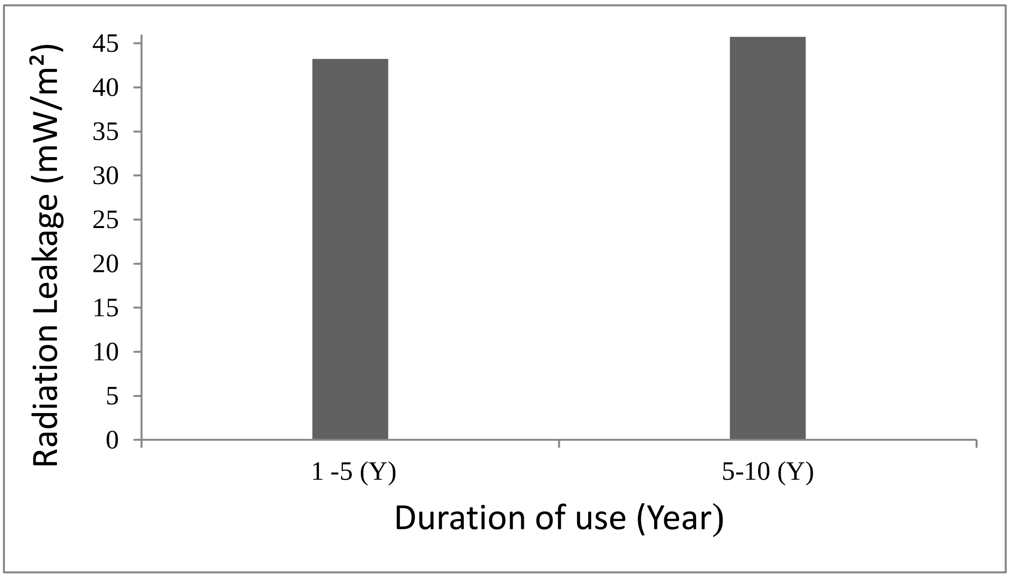

Fig. 4.4 Average radiation leakage from microwave ovens as a function of duration of use

It has been noticed from Fig. 4.4 that the radiation leakage from microwave ovens increases as their duration of use increases.

4.3 Calculation of Specific Absorption Rate (SAR)

The electric fields (E), magnetic fields (H), and magnetic flux density (B) have been calculated respectively as shown in table 4.2.

Table 4.2: Average values of power flux density, electric field, magnetic field strength, magnetic flux density in the selected cafeterias.

Cafeterias of higher education institutions	$S(mW/m^2)$ (Measured)	E(V/m) (Calculated)	H(A/m) ×10-3 (Calculated)	B(G) $\times 10^{-8}$ (Calculated)
NU	65.67	5	13.20	1.66
AU	60.14	4.76	12.63	1.59
HC	31.50	3.45	9.14	1.15
PU	27.20	3.20	8.49	1.07

The calculated values of electric field and magnetic field strength are small compared with the standard values set in table 3.3 which equals 137 V/m for electric field and 0.364 A/m for magnetic field strength.

The calculated values in table 4.2 will be used to calculate specific absorption rate (SAR) for specific tissues such as the skin, brain, muscle, and the eye sclera of the workers. SAR values were calculated according to mass density (ρ) and the tissue conductivity (σ) values which are given in table 4.3 (Angelone, *et al*, 2004). The SAR calculation was done using the equation

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

Table 4.3: Calculated SAR values for some tissues of workers in the cafeterias used in this study (Angelone, *et al*, 2004).

Tissue	$\sigma(\Omega^{-1}m^{-1})$	$\rho(Kg/m^3)$	SAR_N (W/Kg) $\times 10^{-3}$	SAR_A (W/Kg) $\times 10^{-3}$	SAR_H (W/Kg) $\times 10^{-3}$	SAR_K (W/Kg) $\times 10^{-3}$
Skin	0.872	1100	19.63	18	9.41	8.13
Brain	0.77	1030	18.51	16.95	8.88	7.67
Muscle	0.948	1040	22.57	20.67	10.83	9.35
Eye sclera	1.173	1100	26.40	24.18	12.66	10.94

4.4 Measurements of Health Parameters

The study sample includes 28 workers distributed in the tested cafeterias. The worker's ages were between 20 to 55 years. All the workers are males. The sample was divided according to the age into two groups. The first group (G_1) included 23 workers whose ages are between 20 to 34 years. The second group (G_2) contains 5 workers whose ages are between 35 to 55 years. The health parameters are heart pulse rate, blood oxygen saturation, tympanic temperature, arterial blood pressure systolic and diastolic. The workers' health parameters were measured three times before and three times after exposure to microwave radiation by using several instruments. The average values of the workers' health parameters are given in table 4.4.

Table 4.4: Average values of heart pulse rate, oxygen saturation, tympanic temperature, and arterial blood pressure systolic and diastolic, before (b) and after (a) exposure to microwave radiation for the tested workers.

Health parameter	Average values (b)	Average values (a)	Normal Range
HPR(beats/min)	78	81	60-100[a]
SPO_2%	98	98	95%-100%[b]
T(℃)	33.0	33.6	33.6-37.6[c]
SBP(mmHg)	134	132	120[d]
DBP(mmHg)	78	81	80[d]

a: (NIH, 2011).

b: (WHO, 2011).

c: (Elizabeth and Karen, 2009).

d: (NIH, 2003).

Average values of heart pulse rate (HPR), blood oxygen saturation (SPO_2%), tympanic temperature, and arterial blood pressure systolic (SBP) and diastolic (DBP), before and after exposures to microwave radiation are presented in table 4.5 for the two age groups G_1 and G_2.

Table 4.5: Average values of heart pulse rate, blood oxygen saturation, tympanic temperature, and arterial blood pressure systolic and diastolic, before (b) and after (a) exposure to microwave radiation for groups G_1 and G_2.

Variables		G_1 (20-34)y	G_2 (35-55)y
HPR(beats/min)	(b)	78	77
HPR(beats/min)	(a)	83	76
SPO_2%	(b)	98	98
SPO_2%	(a)	98	98
T(°C)	(b)	34.0	32.9
T(°C)	(a)	33.6	33.5
SBP (mmHg)	(b)	134	130
SBP (mmHg)	(a)	131	139
DBP (mmHg)	(b)	79	85
DBP (mmHg)	(a)	80	85

The Percentage change of the average values of heart pulse rate, blood oxygen saturation, tympanic temperature, and arterial blood pressure (systolic and diastolic) for the workers age groups before and after exposure to microwave radiation have been calculated and listed in table 4.6.

Table 4.6: Percentage change of the average values of heart pulse rate, blood oxygen saturation, tympanic temperature, and arterial blood pressure systolic and diastolic for workers age groups G_1 and G_2.

Variables	G_1 (20-34)y (%)	G_2 (35-55)y (%)
HPR(beats/min)	5.58	1.04
SPO2%	0.35	0.00
T(°C)	2.0	1.7
SBP(mmHg)	2.46	6.29
DBP(mmHg)	1.77	0.23

Minimum, maximum, mean, and standard deviation values, before and after exposure to microwave radiation for both age groups, are presented in tables 4.7 and 4.8.

Table 4.7: Minimum (Min.), maximum (Max.), mean, and standard deviation values, before (b) and after (a) exposure to microwave radiation for group G_1 (20-34) years old.

Variables	Min.	Max.	Mean	S.D.
HPR(beats/min) (b)	61	97	78	10.0
HPR(beats/min) (a)	70	106	83	9.3
SPO_2% (b)	97	99	98	0.9
SPO_2% (a)	96	99	98	0.9
T(°C) (b)	32.1	34.8	33.0	0.7
T(°C) (a)	32.7	34.6	33.6	0.5
SBP (mmHg) (b)	108	171	134	15.0
SBP (mmHg) (a)	103	163	131	14.8
DBP (mmHg) (b)	54	94	79	10.7
DBP (mmHg) (a)	39	98	80	14.3

Table 4.8: Minimum (Min.), maximum (Max.), mean, and standard deviation values, before (b) and after (a) exposure to microwave radiation for group G_2 (35-55) years old.

Variables	Min.	Max.	Mean	S.D.
HPR(Beats/min) (b)	66	89	77	9.7
HPR(Beats/min) (a)	67	90	76	9.0
SPO_2% (b)	97	99	98	0.8
SPO_2% (a)	97	99	98	0.8
T(°C) (b)	32.4	33.9	32.9	0.6
T(°C) (a)	33.1	33.8	33.5	0.3
SBP (mmHg) (b)	117	142	130	10.8
SBP (mmHg) (a)	122	154	139	14.0
DBP (mmHg) (b)	75	98	85	10.0
DBP (mmHg) (a)	71	102	85	12.0

The sample of 28 workers was also classified according to the duration of employment. Group (G_A) involved 21 workers with 5 months to 5 years of work. Group (G_B) contain 7 workers with 6 to 10 years of work. Average values of heart pulse rate (HPR), blood oxygen saturation (SPO_2%), tympanic temperature, and arterial blood pressure (systolic and diastolic) before and after exposure to microwave radiation for duration of employment groups are presented in table 4.9.

Table 4.9: Average values of heart pulse rate, blood oxygen saturation, tympanic temperature, and arterial blood pressure systolic and diastolic before (b) and after (a) exposure to microwave radiation for both groups G_A and G_B.

Variables		G_A (5mos.-5y)	G_B (6-10)y
HPR(beats/min)	(b)	79	75
HPR(beats/min)	(a)	82	79
SPO2%	(b)	98	98
SPO2%	(a)	98	98
T(°C)	(b)	32.8	33.3
T(°C)	(a)	33.5	33.7
SBP (mmHg)	(b)	131	138
SBP (mmHg)	(a)	130	139
DBP (mmHg)	(b)	77	83
DBP (mmHg)	(a)	80	83

Table 4.10: Percentage change of the average values of heart pulse rate, blood oxygen saturation, tympanic temperature, and arterial blood pressure systolic and diastolic for the workers duration of employment for both groups G_A and G_B.

Variables	G_A(5mos.-5y) (%)	G_B (6-10)y (%)
HPR(beats/min)	4.3	5.71
SPO2%	0.34	0.15
T(°C)	2.2	1.2
SBP(mmHg)	0.44	0.21
DBP(mmHg)	3.44	0.00

Minimum, maximum, mean and standard deviation values, before and after exposure to microwave radiation for duration of employment groups, are presented in tables 4.11 and 4.12.

Table4.11: Minimum (Min.), maximum (Max.), mean, and standard deviation values before (b) and after (a) exposure to microwave radiation for group G_A (5mos.-5y).

Variables		Min.	Max.	Mean	S.D.
HPR(beats/min)	(b)	61	97	79	10.4
HPR(beats/min)	(a)	67	106	82	9.9
SPO_2%	(b)	97	99	98	0.9
SPO_2%	(a)	96	99	98	0.9
T(°C)	(b)	32.1	34.8	32.8	0.6
T(°C)	(a)	32.7	34.6	33.5	0.5
SBP (mmHg)	(b)	108	157	131	12.4
SBP (mmHg)	(a)	103	163	130	15.3
DBP (mmHg)	(b)	54	94	77	10.4
DBP (mmHg)	(a)	39	102	80	14.6

Table4.12: Minimum (Min.), maximum (Max.), mean, and standard deviation values before (b) and after (a) exposure to microwave radiation for group G_B (6-10) y.

Variables		Min.	Max.	Mean	S.D.
HPR(beats/min)	(b)	63	84	75	7.5
HPR(beats/min)	(a)	70	95	79	8.4
SPO_2%	(b)	97	99	98	1.0
SPO_2%	(a)	97	99	98	0.7
T(°C)	(b)	32.3	34	33.3	0.6
T(°C)	(a)	33.2	34.3	33.7	0.4
SBP (mmHg)	(b)	117	171	138	19.7
SBP (mmHg)	(a)	122	154	139	13.2
DBP (mmHg)	(b)	73	93	83	8.9
DBP (mmHg)	(a)	61	92	83	11.0

4.4.1 Heart Pulse Rate Result

The automatic blood pressure meter was used to measure heart pulse rate of the workers. Average values of heart pulse rate before and after exposure to microwave radiation have been calculated and plotted in Fig. 4.5 for both age groups G_1 and G_2.

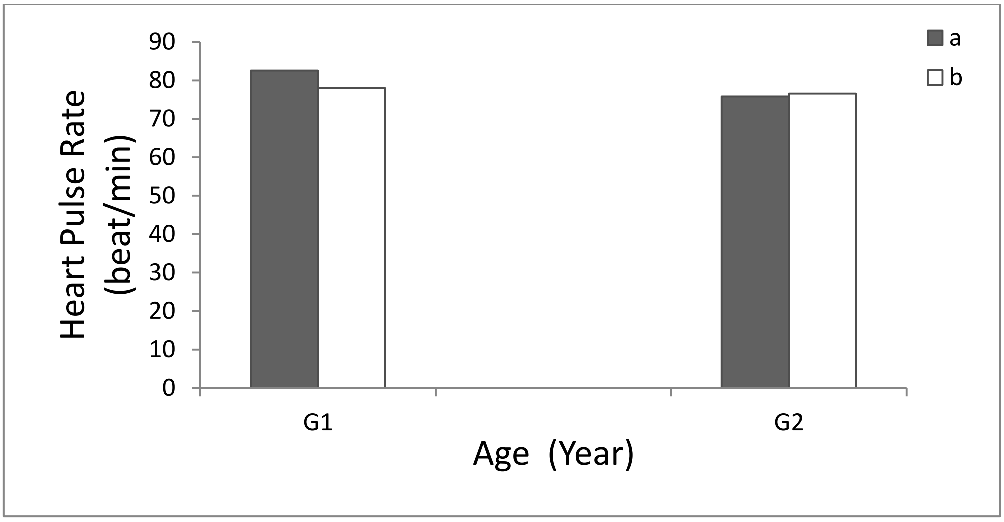

Fig. 4.5 Average values of heart pulse rate of workers before and after exposure to microwave radiation from microwave ovens of G_1 and G_2 of groups.

It has been observed that the heart pulse rate for the workers between 20-34 years age increases after exposure to microwave radiation, while the average values of heart pulse rate for workers whose age range between 35-55 years decreases after exposure to microwave radiation.

The average values of heart pulse rate of workers before and after exposure to microwave radiation from microwave ovens of G_A and G_B groups are shown in Fig. 4.6.

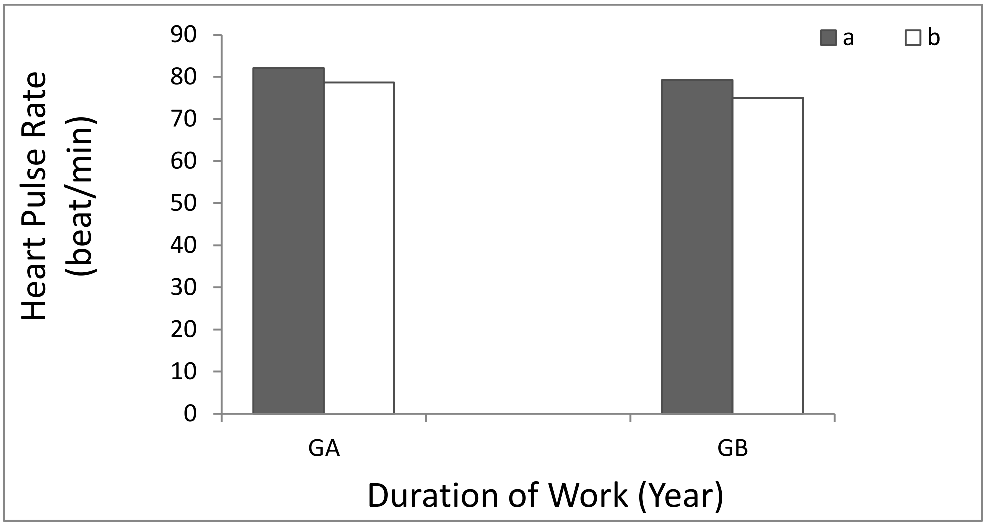

Fig. 4.6 Average values of heart pulse rate of workers before and after exposure to microwave radiation of G_A and G_B groups.

The average values of heart pulse rate for both groups G_A and G_B increase after exposure to microwave radiation from microwave ovens.

4.4.2 Blood Oxygen Saturation Result

Pulse Oximeter has been used to measure SPO_2% for workers. SPO_2% values have been recorded three times at 8:00 am and three times after 6 hours of work, which is around 2:00 pm. Average values of blood oxygen saturation of workers before and after exposure to microwave radiation from microwave ovens are shown in Figs. 4.7 and 4.8.

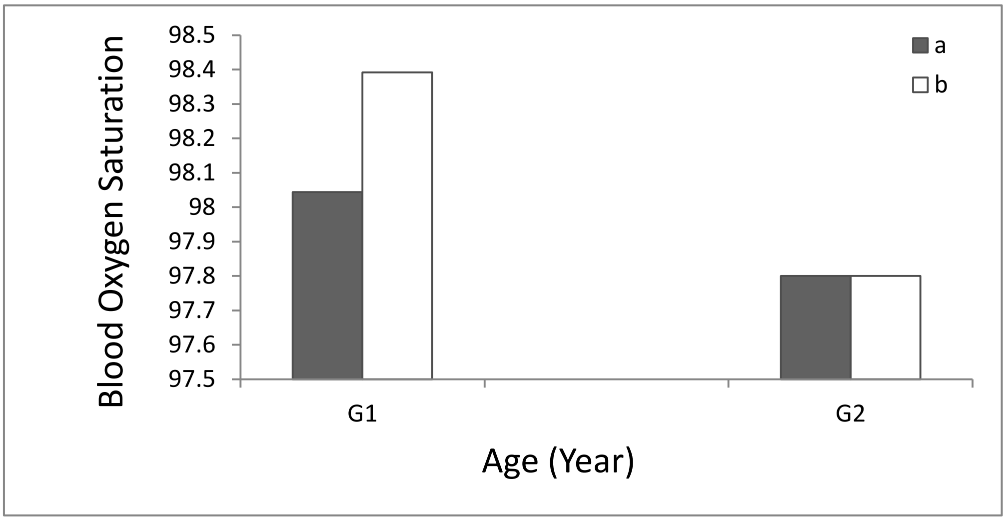

Fig. 4.7 Average values of blood oxygen saturation of workers before and after exposure to microwave radiation of G_1 and G_2 groups.

Blood oxygen saturation values decrease after exposure to microwave radiation for the first age group G_1, while there is no change in SPO_2% values for group G_2 of workers after exposure to microwave radiation.

Fig. 4.8 Average values of blood oxygen saturation of workers before and after exposure to microwave radiation of G_A and G_B of groups.

There is no change in the average values of SPO_2% after exposure to microwave radiation for G_A and G_B groups of workers.

4.4.3 Tympanic Temperature Results

Temperatures of the workers were measured through their ears by using TempScan Thermometer. The temperatures of workers were measured three times before and three times after exposure to microwave radiation from the microwave ovens. Average values of temperature before and after exposure to microwave radiation are shown in Figs. 4.9 and 4.10.

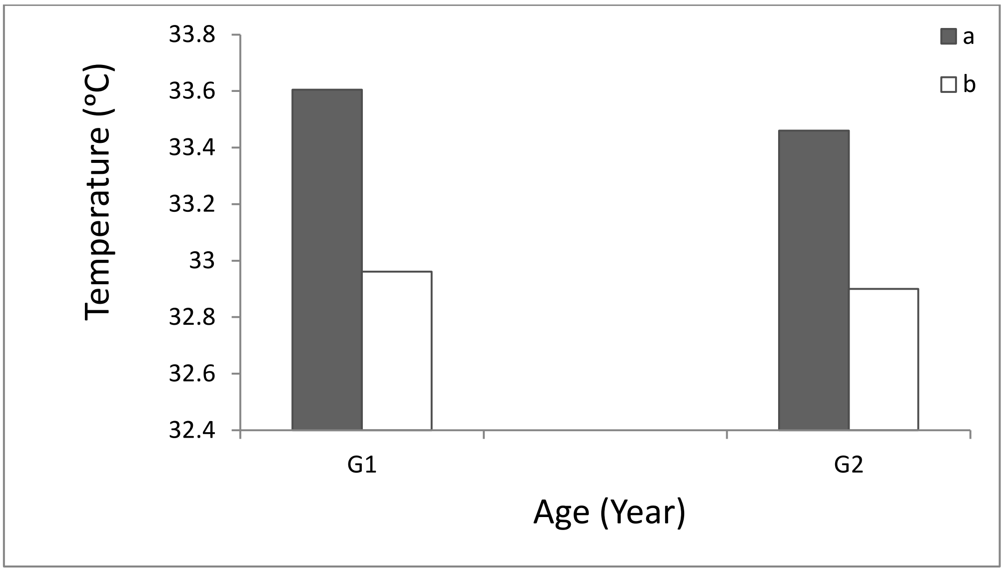

Fig. 4.9 Average values of temperature of workers before and after exposure to microwave radiation of G_1 and G_2 of groups**.**

There is a noticeable increment in temperature values for G_1 and G_2 of workers after exposure to microwave radiation

Fig. 4.10 Average values of temperature of workers before and after exposure to microwave radiation of G_A and G_B groups**.**

There is no change in temperature values for both groups G_A and G_B groups of workers after exposure to microwave radiation.

4.4.4 Blood Pressure Results

Arterial blood pressures systolic and diastolic were measured by using micro life blood pressure meter for each worker. The average values recorded three times at 8:00 am and three times at 2:00 pm after the workers' exposure to microwave radiation from the microwave ovens.

Average values of systolic and diastolic blood pressure for workers before and after exposure to microwave radiation of G_1 and G_2 groups are shown in Fig. 4.11 and Fig. 4.12.

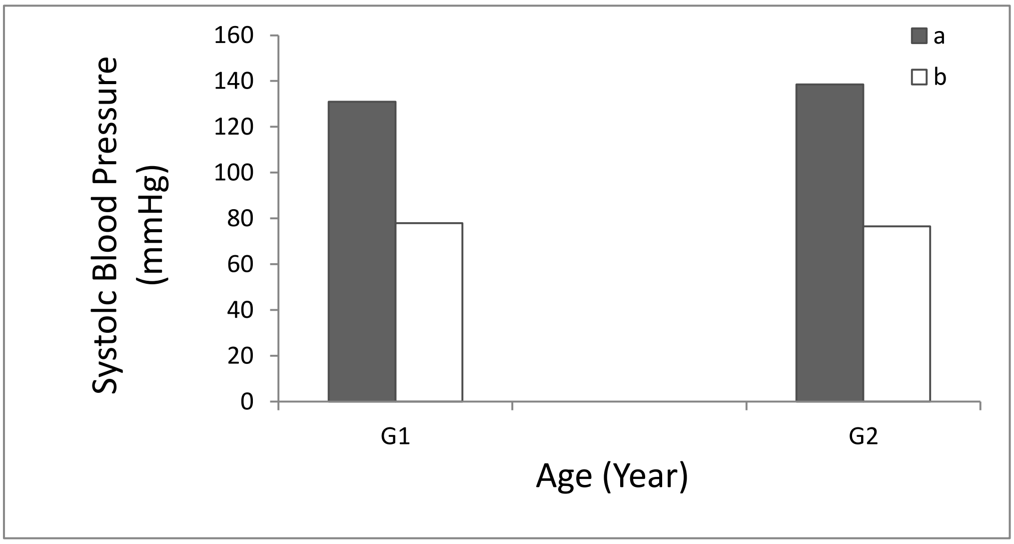

Fig. 4.11 Average values of systolic blood pressure of workers before and after exposure to microwave radiation of G_1 and G_2 groups**.**

Fig. 4.11 shows an increment in systolic blood pressure values after exposure to microwave radiation for both age groups G_1 and G_2.

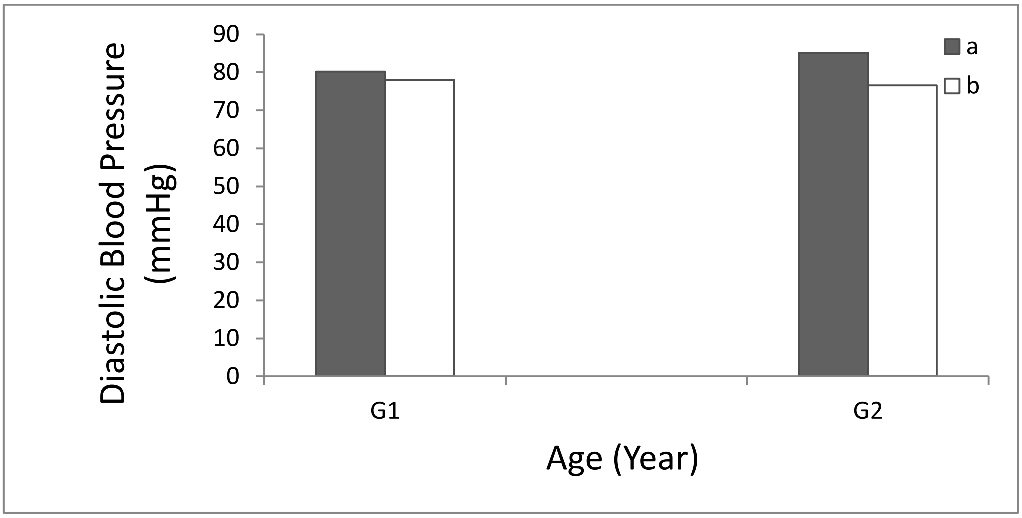

Fig. 4.12 Average values of diastolic blood pressure of workers before and after exposure to microwave radiation of G_1 and G_2 groups**.**

It has been observed that there is no change in the average values of diastolic blood pressure after exposure to microwave radiation for G_1 and G_2 groups.

Average values of systolic and diastolic blood pressure of workers before and after exposure to microwave radiation of G_A and G_B groups are shown in Fig. 4.13 and Fig. 4.14.

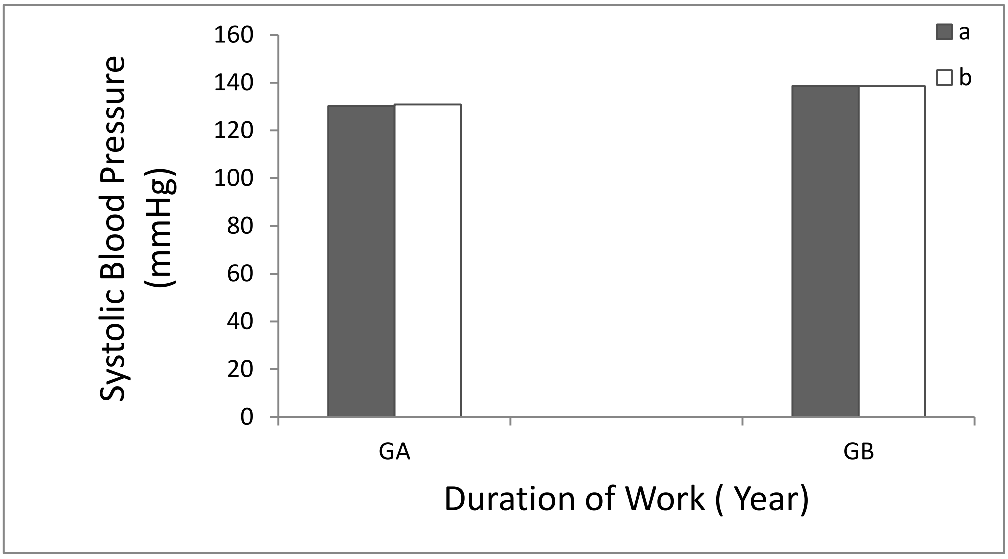

Fig. 4.13 Average values of systolic blood pressure of workers before and after exposure to microwave radiation of G_A and G_B groups**.**

No change occurred in the average values of systolic blood pressure after exposure to microwave radiation for both groups G_A and G_B.

Fig. 4.14 Average values of diastolic blood pressure of workers before and after exposure to microwave radiation of6 G_A and G_B groups**.**

No change has been noticed in the average values of diastolic blood pressure for G_A and G_B groups of workers.

4.5 Data Analysis of Dependent Variables and Radiation Leakage from Microwave Ovens

The Statistical Package for Social Science (SPSS) program was used to analyze the collected data. Paired sample tests of dependent variables which are (heart pulse rate, blood oxygen saturation, tympanic temperature, systolic and diastolic blood pressure) and radiation leakage as independent variables were carried out. Comparing between values before and after exposure to microwave radiation for the tested workers the correlation coefficient (R) is introduced in table 4.13.

Table 4.13: Pearson correlation coefficient between radiation leakage from microwave ovens and heart pulse rate, blood oxygen saturation, tympanic temperature, systolic and diastolic blood pressure for all workers in the cafeterias.

Paired samples	Pearson correlation(R)
HPR(beats/min)	0.781
SPO_2%	-0.849
T(℃)	0.800
SBP(mmHg)	0.567
DBP(mmHg)	0.694

Chapter Five

Discussion and Conclusion

5.1 Radiation Leakage with Distance and Operating Power

The average value of radiation leakage at a distance 5 cm from microwave ovens was 46.126 mW/m^2. This value is small compared with the standard value which is set in table 3.2 by American National Standard Institute which is 5×10^4 mW/m^2. It has been concluded that radiation leakage decreases exponentially with distance as shown in Fig. 4.2. The possibilities of radiation leakage from microwave ovens increased with duration of use. Ovens with 6 to 10 years of use have more radiation leakage than ovens with 5 months to 5 years of use. Such conclusions have been supported by other previous studies conducted by Lahham and Sharabati (Lahham and Sharabati, 2013).

5.2 The Effect of Microwave Radiation on Heart Pulse Rate

This study reveals that the average values of heart pulse rate for the workers in the tested cafeterias are increase after exposure to microwave radiation from microwave ovens. For example, the average value before exposure was 78 beat/min and after exposure, it increased to 81 beat/min. The strength of the result is good as it can be understood from the Pearson correlation factor ($R = 0.781$) between radiation leakage and heart pulse rate. The difference between average values of heart pulse rate before and after exposure to MWR is 3 beat/min. Despite the increase in HPR after exposure to microwave radiation, it remains within the normal range of human body which is from 60-100 beat/min (NIH, 2011).

5.3 The Effect of Microwave Radiation on Blood Oxygen Saturation

The results of blood oxygen saturation showed no change occurred in SPO_2% values after exposure to microwave radiation. The average value of SPO_2% before exposure was 98 and after exposure the value does not change. The Pearson correlation factor is 0.849 which shows a strong correlation between radiation leakage and blood oxygen saturation. The average values of SPO_2% is within the normal range which is 95%-100% as set by the world health organization in 2011 (WHO, 2011).

5.4 The Effect of Microwave Radiation on Tympanic Temperature

The average values of tympanic temperature for the workers in the tested cafeterias increase after exposure to microwave radiation. The average value of workers temperature was 33℃ and it increased to 33.6℃ after exposure to microwave radiation. The statistical results showed that the Pearson correlation coefficient between the radiation leakage and tympanic temperature equals 0.830. This indicates that there is a strong correlation between the dependent variable (Tympanic temperature) and the independent variable (Radiation Leakage). The standard value of tympanic temperature for humans is (33.6-37.6)℃ which was concluded in 2009 by Elizabeth and Karen (Elizabeth and Karen, 2009).

5.5 The Effect of Microwave Radiation on Systolic and Diastolic Blood Pressure

The results of systolic blood pressure are decreased after exposure to microwave radiation. The average value before exposure was 134 mmHg and after exposure it is decreased to 132 mmHg, while the average value of diastolic blood pressure increases after exposure to microwave radiation from microwave ovens. The average value of DBP was 78 mmHg and it increase to 81 mmHg. The statistical analysis for SBP and DBP as dependent variables and radiation leakage from microwave ovens as an independent variable showed that the Pearson coefficient for SBP and DBP respectively is (R = 0.567, R = 0.694). The standard value of arterial blood pressure as given in table 5.1 set by National Institute of Health is 120 mmHg for SBP and 80 mmHg for DBP (NIH, 2003).

The normal range of heart pulse rate, blood oxygen saturation, tympanic temperature, systolic and diastolic blood pressure is given in table 5.1.

Table 5.1: The normal range recommended standards of heart pulse rate, blood oxygen saturation, tympanic temperature, systolic and diastolic blood pressure.

Variables	Normal range
HPR(beat/min)	60-100[a]
SPO_2%	95%-100%[b]
T(°C)	33.6-37.6[c]
SBP(mmHg)	120[d]
DBP(mmHg)	80[d]

a: (NIH, 2011).

b: (WHO, 2011).

c: (Elizabeth and Karen, 2009).

d: (NIH, 2003).

In this study a small change in the average values of the studied parameters has been observed. The normal range of the measured health parameter was set in table 5.1. The changes in the studied variables remain in the normal range of human beings. The average value of radiation leakage was small compared with the standard values set by the American National Standard Institute. In Conclusion, there are no serious health effects of microwave radiation from microwave ovens on the workers of the cafeterias of the higher education institutions examined in this research. This conclusion enhances the results of the previous studies. For instance, Matthes' study in 1992 showed that exposure to microwave radiation during microwave cooking has no risk health effects (Matthes, 1992). Alhekail in his study observed that the health effects due to exposure to microwave radiation from microwave ovens are not expected to occur (Alhekail, 2001). Mohammads' study in 2011 summarized that -thermal health effects form the only result for the exposure to microwave radiation from microwave ovens because the measured radiation leakage is small compared with the level that may harm people (Mohammad, *et al*, 2011).

Chapter Six

Recommendations

In view of the outcome of this study as well as the conclusions of previous ones, the following recommendations can be made to avoid any dangerous effects that may occur from exposure to radiation from microwave ovens.

1. Informing workers about the importance of following the instructions manuals that come with microwave ovens.
2. Keeping a distance of more than 30 cm when using microwave ovens due to our results shown in Fig. 4.2.
3. Performing periodic test on the workers to determine any health effects that may occur.
4. Further studies should be done to determine the impact of radiation leakage on people who use microwave ovens for very long periods such as in main restaurants.

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قدمت هذه الأطروحة إستكمالا لمتطلبات الحصول على درجة الماجستير في الفيزياء بكلية الدراسات العليا في جامعة النجاح الوطنية في نابلس–فلسطين
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الملخص

ألقت هذه الدراسة الضوء على تأثير الإشعاع الكهرومغناطيسي من أفران المايكروويف على العمال الذين يتعرضون لهذه الأشعة خلال عملهم في المطاعم في بعض مؤسسات التعليم العالي في فلسطين. شملت عينة الدراسة 28 عاملا و تتراوح اعمارهم بين (20–55) سنة . أخذت قياسات معدل نبض القلب، ونسبة الاكسجين في الدم، ودرجة حرارة الجسم عن طريق الاذن، وضغط الدم الإنبساطي والإنقباضي ثلاث مرات من الساعة 8:00–8:30 صباحا وثلاث مرات في نفس اليوم بعد إنتهاء إستخدام أفران المايكرويف من الساعة 2:00–2:30 مساءً. ثم تم أخذ معدل هذه القياسات. أجريت هذه الدراسة خلال شهري كانون الأول 2013 وكانون الثاني 2014. ركزت الدراسة على أربعة من مؤسسات التعليم العالي في الجزء الشمالي من فلسطين وشملت جامعة النجاح الوطنية، والجامعة العربية الأمريكية، و كلية هشام حجاوي، وجامعة فلسطين التقنية. تم تحليل البيانات إحصائيا حيث أظهرت النتائج أن معدل القيم المقاسة لتسرب الأشعة يساوي 46.126 ملي واط /م^2 واعتبرت هذه القيمة ضمن القيم المعيارية. ولقد أُستنتج من هذه الدراسة وجود ارتباط ما بين تسرب الأشعة من أفران المايكروويف مع البعد عن الفرن، وفترة الإستخدام. ومن خلال إستخدام قياس العوامل الصحية لكشف التأثير الصحي على العمال، تبين أن هناك تغيراً ملحوظاً في المتغيرات المقاسة إلا أنها بقيت ضمن الحد الطبيعي المسموح به للإنسان. توصلت الدراسة إلى أنه ليس هناك مخاطر صحية للأشعة المتسربة من أفران المايكروويف المستخدمة في مطاعم بعض مؤسسات التعليم العالي التي شملتها هذه الدراسة وهذا يشير إلى إعتماد عوامل أمان إضافية في تصميم أفران المايكروويف الحديثة وإستخدامها.