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Faculty of Graduate Studies

Radiation Enviroment in Selected Healthcare Centers in Palestine

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Dedication

To the one who has taught me my first words…. To my mother

To the one who has made me so proud to be his daughter….. To my father’s soul

To the one who has shared with me my happiness and tears……To my husband

To my soul mates………To my sisters and brothers

To whom filling my life………. My children

To all those who contributed to the success of this work

Acknowledgment

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الإقرار

أنا الموقعة أدناه مقدمة الرسالة التي تحمل العنوان:

Radiation Enviroment in Selected Healthcare Centers in Palestine

أقر بأن ما اشتملت عليه هذه الرسالة إنما هو نتاج جهدي الخاص، باستثناء ما تمت الإشارة إليه حيثما ورد، وأن هذه الرسالة ككل من أو جزء منها لم يقدم من قبل لنيل أية درجة أو بحث علمي أو بحثي لدى أية 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 and Symbols

CR	Control Room
CT	Computed Tomography Scanner
DNA	Deoxyribonucleic Acid
dB	Decibel
DBP	Diastolic Blood Pressure
EPA	Environmental Protection Agency
EMF	Electromagnetic Field
EMI	Electromagnetic Intensity
EMR	Electromagnetic Radiation
FCC	Federal Communications Commission
H1	Arab Specialist Hospital
H2	Patient Friends Society
H3	Salfeet Hospital
H4	Rafediya Hospital
HF	High Frequency
HPR	Heart Pulse Rate
ICNIRP	International Commission on non-Ionizing Radiation Protection
IRPA	International Radiation Protection Agency
J/kg	Joule per Kilogram
MRI	Magnetic Resonance Imaging
mSv/y	Millisevert per Year
mSv/wk	Millisevert per Week
OSHA	Occupational Safety and Health Administration
P-value	Probability
R	Pearson Correlation Coefficient
RF	Radio Frequency
RPII	Radiation Protection Institute of Ireland
SAR	Specific Absorption Rate
SBP	Systolic Blood Pressure
S.D	Standard Deviation
$SPO_2\%$	Blood Oxygen Saturation
UV	Ultraviolet
V/m	Volte per Meter
W/m	Watt per Meter
WHO	World Health Organization
WR	Waiting Room
ρ	Mass Density
σ	Electrical Conductivity

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Abstract

The dose rate for X, Gamma ray and beta radiation flux density inside the control room and waiting room in the X-ray rooms have been measured by using Radiation moinitor, the measurements has been taking in the staff places, and at a height of 1 meter from the surface of the earth. The measured values of X-ray radiation dose were less than the maximum permissible dose for worker adopted by the Palestinian Ministry of Health in all tested rooms.

The values of power flux density for frequency ranged from 200MHz up to 8 GHz, in some healthcare centers in Palestine have been measured by using Acoustimeter. The average values of measured power flux density were 2000μW/m^2, 402μW/m^2, 1262μW/m^2 and 28μW/m^2 in Arab Specialist hospital, Patient friends society, Salfeet hospital and Rafediya hospital respectively.

The magnitude of electric field, magnetic field and the specific absorption rate (SAR) were calculated from the measured power flux density, which were less than the standard levels limitation of exposure to electromagnetic radiation EMR.

The effect of EMR in operators health has been studied. Blood oxygen saturation (SPO_2%), heart pulse rate (HPR), systolic blood pressure (SBP)

and diastolic blood pressure (DBP) of the selected operators were measured before and after their shift, a significant impact does not appear in measured health parameter after exposure to EMR in radiology departments. Moreover, the measured values were within the standard values.

Chapter One

Introduction

1.1 Background

Radiation is the propagation or emission of energy in the form of particles or waves travelling through space or in a medium. Electromagnetic radiation is a type of radiation in which there are continuous propagation waves, and further classified on the electromagnetic spectrum based on the wavelength, frequency, or energy of these waves (Andrew and Juhani, 2012).

The electromagnetic wave is produced when the charges are accelerated, or if the current varies with time. Electromagnetic wave consists of an electric field perpendicular to the magnetic field and both are perpendicular to the direction of propagation, and moving at the speed of light (Kenneth, 2012) Fig1.1

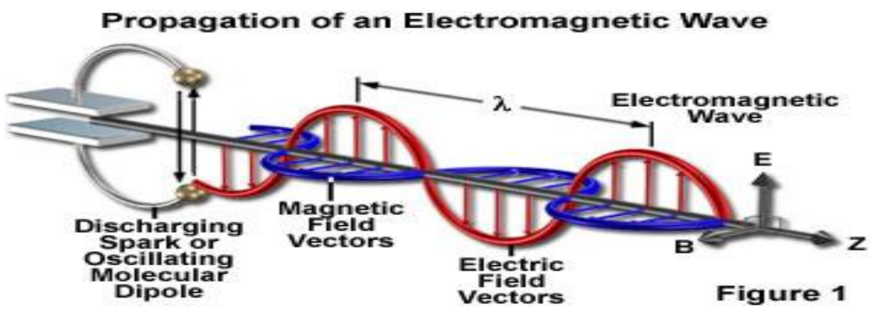

Fig. (1. 1): The electromagnetic wave (Kenneth, 2012)

There are two types of radiations:

1- Ionizing radiations: radiation with sufficient energy to cause ionization in the medium through which it passes, and carries enough energy to break chemical bonds. Radiation consisting of particles, X-rays, gamma rays and high frequency ultraviolet (UV), are ionizing due to their composition of high-energy and high frequency, and their ability to remove electrons from atoms or molecules (Hoon *et al*, 2011) (Radiation Safety Committee, 1995).

Ionizing radiation has the ability to modify cells and their genetic material, thereby leading to potentially deleterious effects. The radiation deleterious effects are typically classified into two types; stochastic effects which are due to radiation induced mutations, and deterministic effects, otherwise known as tissue reactions, which are due to radiation-induced cell death. In X-ray imaging, the primary stochastic effect of concern is cancer, while the primary deterministic effect of concern is skin and hair changes (David *et al*, 2003).

2- Non ionizing radiations: consist of lower frequency UV, visible light, infrared, microwaves and radio waves. The electromagnetic spectrum are shown in Fig (1.2).

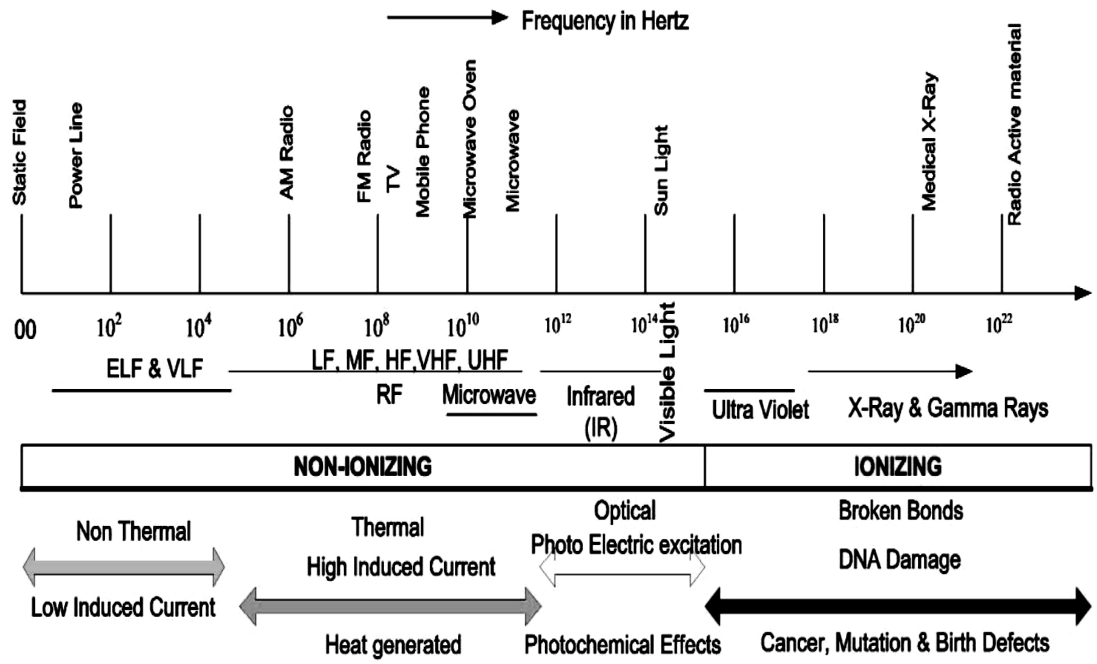

Fig. (1.2): the electromagnetic spectrum (Zamanian *et al*, 2005)

The energy of non-ionizing radiation is too weak to break chemical bonds, and to form ions.

Electricity and telecommunications are the technologies that have caused most of the current concerns regarding possible health risks and for which most research are available. A number of other applications also employ EMR in the range below 300 GHz. Television and radio transmitters use frequencies similar to mobile phones, as do microwave ovens. Surveillances system of the type found in stores, as well as by cashier machines, often use so-called intermediate frequencies, up to about 40 kHz (Anders and Maria, 2003).

The thermal effect of radio waves and microwave appears in raising the temperature of water molecules in the body, if the body cannot dispose high temperature, continual damage might occur (Shani *et al*, 1995).

1.2 Previous Studies

The effect of electromagnetic radiation leakage has been studied by many researchers:

Sezdi studied the radiological leakage in the Radiology Department of Istanbul Health Faculty in Istanbul University. The effects of X-Ray on both the operator and the patients who are located near the radiography room, were investigated. The measurements were performed in front of the user barrier (and in the back of the user barrier to observe the amount of the radiation dose of the user, from the measurement results, it was seen that the user barriers are appropriate to the standards except one room (Sezdi, 2010).

The amount of X-ray leakage from colored TV and video display terminals was being measured by Mazin and Qusay. They found that the amount of radiation leakage is less than the maximum level of the natural background radiation dose (2 mSv/y) (Mazin and Qusay, 2006).

Yan and his group detected DNA double-strand breaks in lymphocytes caused by γ-ray irradiation. A clear dose-response relationship with DNA double-strand breaks using the comet assay was found at different times after irradiation. A time-response relationship was also found within 72 h after irradiation (Yan, *et al*, 2013).

Jung-Hoon and his group characterized the functional modifications of adult Drosophila midgut intestinal stem cells after ionizing radiation treatment. They showed the effects of ionizing radiation on functional modifications of stem cells. The adult Drosophila midgut intestinal stem cells offer a potentially rich new system for the exploration of the biological effects of ionizing radiation (Jung-Hoon *et al*, 2014).

Exposures Extremely low frequency electromagnetic fields have shown to be in connection with Alzheimer disease, motor neuron disease and Parkinson disease (WHO 2007). Some studies show that exposure to low frequency EMR reduce melatonin levels in people. Melatonin protects the brain against damage leading to Alzheimer disease; hence, degenerative diseases such as Alzheimer and Parkinson disease as well as cancer have linked to suppressed melatonin production in the body (Wood, *et al*; 1998) (Wilson, *et al*; 1990).

Power flux density, electric fields, magnetic fields and the specific absorption rate (SAR) were investigated of 115 microwave ovens in domestic use in Palestine SAR values were much less than the recommended value (Muna, 2014).

Paola and his group showed the relation between high frequency electromagnetic field and the risk of childhood leukemia as a function of distance from radio station. The risk was higher than expected for the distance up to 6 km from the radio station, and there was a significant decline in risk with increasing distance both for male mortality (P = 0.03) and for childhood leukemia (P = 0.036), (where P is the probability) (Paola *et al*, 2002).

Tynes and Haldorsen tested the hypothesis that exposure to electromagnetic fields of the type generated by high-voltage power lines increases the incidence of cancer in children aged 0-14 years. They found that there is no association between exposure to time-weighted average exposure to magnetic fields and cancer at all sites, brain tumors, lymphoma, or leukemia. Cancer at other sites showed elevated odds ratios in the two highest exposure categories in some, but not all, measures of exposure (Tynes and Haldorsen, 1997).

The electromagnetic field emitted by a commercial mobile phone affects regional cerebral blood flow in humans. This has been concluded by Aalto and his group (Aalto *et al*, 2006).

Han and his group in their study investigated that watching TV and using mobile phones during the first term pregnancy may increase the risk of embryo growth ceasing significantly (Han *et al*, 2010)

Aitken and his group studied the effect of human exposures to radio frequency electromagnetic radiation, including a recent report indicating that regular mobile phone use can negatively impact upon human semen quality. In their study, mice were exposed to 900 MHz RFEMR at a specific absorption rate approximately 90 mW/kg inside a waveguide for 7 days at 12 h per day. They suggest that while RFEMR does not have a dramatic impact on male germ cell development, a significant genotoxic effect on epididymal spermatozoa is evident and deserves further investigation (Aitken *et al*, 2005).

Hutter and his group studied the relation between exposure from mobile telecommunication and other sources of HF-EMFs (high frequency electromagnetic fields) and the associations between exposure and symptoms, sleeping problems, and cognitive performance in subjects living near mobile phone base stations. They found that there was a significant relation of some symptoms to measured power density; this was highest for headaches. Perceptual speed increased, while accuracy decreased insignificantly with increasing exposure levels. There was no significant effect on sleep quality (Hutter *et al*, 2005).

Al Faqeeh studied the effect of exposing students to extremely low frequency electromagnetic radiation from high voltage transformers. Results show that the measured values of power flux density were within slight concern limit. The effect of EMR on the student's health resulted in increasing tympanic temperature, heart pulse rate, arterial blood pressure (systolic and diastolic). On the other hand, the blood oxygen saturation was decreased (Al Faqeeh, 2013).

Thaher studied the effects of Electromagnetic radiation from antennas on children's health in schools. She showed that there is a significant shift of the measured mean values of arterial blood pressure (systolic and diastolic), heart pulse rate, and blood oxygen saturation of the children due to exposure of electromagnetic radiation from antennas within the ranges 18-1862$\mu W/m^2$ (Thaher, 2014).

Abu Subha studied the effect of electromagnetic radiation (EMR) emitted by cell phone towers on human health. The statistical results showed that Pearson correlation coefficient (R) between power flux density and the dependent variables are varying from 0.294 to 0.657, and the probabilities (P) are < 0.05 for all health factors (Abu Subha, 2014).

1.3 Objectives

The aim of this study is to investigate the radiation at Radiology Departments in some healthcare centers in Palestine, then to compare it with the international and local standards.

The main goals of the study include the following:

- ❖ Measuring X-ray radiation dose rate leakage from X-ray room, background radiation dose rate of gamma ray, and β-particle flux density in the control room and in the reception room at Radiology Departments, and it will be compared with X-ray exposure limits.
- ❖ Measuring power flux density for microwaves and radiowaves in each Radiology Departments in studied healthcare centers. SAR,

electric and magnetic fields will be calculated. They will be compared with the electromagnetic field standard levels.

- The effects of the electromagnetic radiation leakage on the operators will be detecte by measuring the health factors which are blood pressure, heart pulse rate, blood oxygen saturation before and after exposure to EMR in Radiology Departments in each studied healthcare centers.

Chapter Two

Theory

2.1 Power Flux Density

Energy is transmited from one place to another with the electromagnetic waves propagation. The average of energy flows in an electromagnetic wave is described by the Poynting vector**,** which is defined by the expression

$$\vec{S} = \vec{E} \times \vec{H} \quad 2\text{-}1$$

Where E is the electric field and H is the magnetic field. The magnitude of Poynting vector represents the rate of energy flows through a unit surface area perpendicular to the direction of wave propagation. The magnitude of Poynting vector represents power per unit area and its direction is along the direction of wave propagation. The SI units of the magnitude of Poynting vector is $J/s.m^2 = W/m^2$ (Serway and Jewett, 2008).

The relationship of electromagnetic fields for electromagnetic waves travel through free space can be expressed by:

$$E = \left(\frac{\mu o}{\epsilon o}\right)^{1/2} H \quad 2\text{-}2$$

The electric field strength (E) is calculated as: $|\vec{S}| = P = \frac{E^2}{377}$, and the magnetic field strength (H) is calculated from the relation $P = 377\ H^2$, where $\left(\frac{\mu o}{\varepsilon o}\right)^{1/2} = 377\Omega$ is the characteristic impedance of free spac, and P is the power flux density (Serway and Jewett, 2008).

2.2 Interaction Between Non-Ionizing Electromagnetic Field and Human Body

Time-varying electric fields interact with the human body, the results of this interaction is the flow of electric charges, formation of electric dipoles, and the reorientation of electric dipoles already present in the tissue. The relative magnitudes of these different effects depend on the electrical properties of the body (ICNIRP, 2009).

The result of interaction between time-varying magnetic fields and the human body is the generation of induced electric fields and circulating electric currents. The exact path and magnitude of the resulting current induced in any part of the body will depend on the electrical conductivity of the tissue (ICNIRP, 2009).

The result of exposure to a uniform electromagnetic field result is a highly non-uniform distribution of energy within the body. The parameters that mostly used to specify the basic characteristics of exposure to an electromagnetic field (EMF) are current density, SAR, and power density (Lisheng *et al,* 2009).

The ratio of total energy absorbed in tissues to its mass is characterized by Specific Absorption Rate (SAR), whereas the local SAR is the mean value of SARs within a locate unit volume or mass. SAR is also defined as the time derivative of the incremental energy (*dW*) dissipated in an incremental mass (*dm*) contained in a volume element (*dV*) of a given density (*ρ*) (Davoodi *et al*, 2009), (Lisheng *et al*, 2009).

$$SAR = \frac{d}{dt}\left(\frac{dw}{dm}\right) = \frac{d}{dt}\left(\frac{dw}{\rho dv}\right) \qquad 2\text{-}3$$

The accuracy of a given SAR value depends on three parameters, tissue density, conductivity and electric field, the most significant of these is induced electric field (Nookala *et al*, 2011).

$$SAR = \frac{\sigma E^2}{\rho} \qquad 2\text{-}4$$

Where σ is the electrical conductivity of the tissues, ρ is mass density, and E is the electric field inside the tissues. The electrical conductivity and mass density vary with the type of body tissue and also depend on the frequency of the applied field (ICNIRP, 2010) (Vijay *et al*, 2012).

The Federal Communications Commission (FCC) in the United States of America (USA) set that 1.6 W/Kg is the maximum level of SAR permissible. While the European Union Council and the International Commission on Non-Ionizing Radiation Protection (ICNIRP) in Europe set that the permissible SAR value is from 0.0 to 2.0 W/Kg (ICNIRP, 2010).

2.3 X-rays

2.3.1 X-Ray Machines

Valuable information can be provided by X-ray examinations about patient health, and play an important role in helping doctors make an accurate diagnosis. The most type of X-ray equipments is:

1- Radiographic equipment: Radiography equipment provides a single two-dimensional snapshot image, which is a partially penetrated projected shadow. These rooms generally include a fixed screen to protect the operator area. The rooms should be sufficiently large to reduce the radiation intensity at the operator's screen (RPII, 2009)

2-Computed tomography scanners:

Computed tomography scanners (CT or CAT scanners) use X-rays and computers to produce images of the body in sections called slices. A typical time of X-ray exposure during a CT procedure is 1-30 seconds (Radiation safety committee, 1995) The same examination lasts for a period ranging between 15 to 30 minutes. Fig. (2.1) shows a CT scanner.

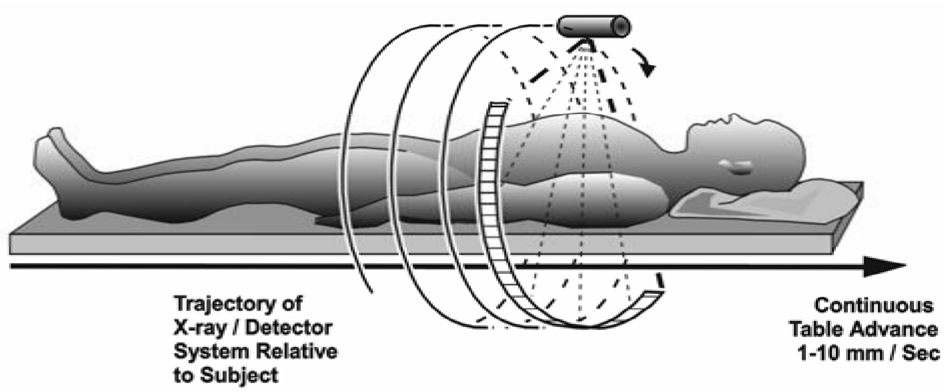

Fig. (2.1): Schematic of helical CT scanning (Erik L, 2006).

3- Mobile X-ray machines:

Mobile X-ray machines are transported to the patients who cannot be moved. Mobile machines are typically used to examine patients in the operating or recovery room during or after surgery, trauma victims in the emergency room, patients located in intensive care units, neonatal units, and other bed confined patients (Radiation safety committee, 1995). Fig. 2.2 shows a mobile X-ray unit.

Fig. (2.2): Mobile X-ray unit (http://www.diytrade.com)

4- Fluoroscopy: Fluoroscopy allows for continuous real-time imaging and tends to be used in complex investigations and treatments requiring some staff to be in close contact with the patient during all or part of the procedure. The procedures may be long and can involve high doses in the vicinity of the patient (RPII, 2009).

2.3.2 Dose Rate Calculation

There are a variety of approaches used to measure the amount of ionizing radiation received by patients undergoing medical imaging procedures. It is typical to estimate some quantity reflecting the amount of radiation energy absorped in tissue (Andrew *et al*, 2012).

The scientific unit for radiation effective dose quantity, is the millisievert (mSv). Other radiation dose measurement units include Rad, Rem, Roentgen, Sievert, and Gray. D is the fundamental dose quantity given by

$$D = \frac{dE}{dm} \qquad 2\text{-}5$$

Where dE is the mean energy transmit to matter of mass dm by ionizing radiation. The SI unit for absorbed dose is joule per kilogram (J /kg) and its special name is gray (Gy) (ICRP, 2007).

2.3.3 Production of X-Ray:

Firstly electrons are emitted by a filament heated with an electric current; the process is called thermionic emission. Then the electrons are accelerated through an electric potential of several kV to several MV,so the electrons achieved a kinetic energy of several eV. When the electrons strike a target they are slowed down, and some of their kinetic energy can be converted to high energy photons this radiation is more commonly known as X-rays (Environmental Health and Safety, 2012) (Kenneth, 2012).

The wavelength of the X-rays is controlled by the applied voltage. (Fuller *et al*, 1978). When electrons incident on a thick target, the fraction F of energy converted to X-rays is approximately:

$$F = 7 \times 10^{-4} Z V_k \qquad 2\text{-}6$$

Where Z is the atomic number of the target, and V_k is the accelerating voltage in mV (Environmental Health and Safety, 2012).

2.3.4 Interaction between X- Ray and Matter

X-rays hold substantial energy that may be imparted to the matter they interact with. That interaction takes place as either absorption or scattering The X-ray interact with atoms (Daniel *et al*,2013).

The interaction between X-rays and matter occurs in the following ways:

1- Coherent (Rayleigh) scattering: Coherent Scattering may occur when low energy photon passes near an outer electron of an atom has low binding energy. The incident photon interacts with the electron in the outer shell by causing it to vibrate momentarily at the same frequency as the incoming photon. The vibration causes the electron to emit energy in the form of another X-ray photon with the same frequency and energy as in the incident photon. In effect, the direction of the incident x-ray photon is convert (Carl and Gudrun, 1996).

2- The Compton effect: occurs when the incident X-ray photon has energy between 100 keV - 10 MeV ejects an electron from an atom and an X-ray photon of lower energy is scattered from the atom. Relativistic energy and momentum are conserved in this process(Daniel *et al*,2013).

3- The Photoelectric Effect: In this process, the photon is absorbed and an electron is emitted from the atomic shell with kinetic energy, K

$$K = h\nu - Be \qquad 2\text{-}7$$

Where Be is the binding energy of electrons in atomic shell (Carl and Gudrun, 1996).

4- Pair Production: Pair Production (PP) can occur when the x-ray photon energy is greater than 1.02 MeV, when an electron and positron are created with the annihilation of the X-ray photon. Positrons are very short lived and disappear (positron annihilation) with the formation of two photons of 0.51MeV energy. Pair production process only occurs at high X-ray photon energies with high atomic weight targets. Pair production Only occurs when the incident X-rays energy exceed 1.02 MeV and does not become important until its energy exceeds about 2 MeV (Daniel *et al*,2013).

2.4 Beta Particles

Beta particles (β) are fast-moving electrons with a negative or positive electrical charge that are emitted from the unstable atoms nucleus during radioactive decay. In beta decays a neutron in the nucleus changes into a proton, or a proton into a neutron plus a β-particle (EPA, 2012) (Kenneth, 2012).

During β^- decay process the nucleus changes state, according to the following formula:

$$ {}^{A}_{Z}X \rightarrow {}_{Z+1}^{A}Y + \beta^- + \bar{\nu}_e \qquad \text{2-8} $$

During β^+ decay the nucleus changes state, according to the following formula:

$$ {}^{A}_{Z}X \rightarrow {}^{A}_{Z-1}Y + \beta^{+} + \nu_e \qquad 2\text{-}9 $$

2.5 Gamma Rays

After alpha or beta decay, the final nucleus may be left in excited state. The nucleus will emit one or more photons "known as gamma rays" to reach its ground state, gamma rays have energy in the range of 100keV to Mev and so much penetrating power (Kenneth, 2012).

All gamma-ray detectors give some response even in the absence of a measurement sample. This response is due to the ambient background in the location of the detector. The ambient background consists of radiation from nuclear material in nearby storage areas, cosmic-ray interactions, and natural radioactivity in the local environment (EPA, 2012).

2.6 Radiation Protection

The three basic methods used to reduce the external radiation hazard are time, distance, and shielding.

1- **Time**

The amount of radiation an individual accumulates will depend on how long the individual stays in the radiation field, where (Rssc Radiation Protection, 2011):

Dose (mSv) = Dose Rate (mSv/hr) x Time (hr) 2-9

2- **Distance**

The amount of radiation an individual receives will also depend on how close the person is to the source. The intensity of radiation (I) is inversely proportional to r^2 (Rssc Radiation Protection, 2011):

$$I\alpha\frac{1}{r^2} \qquad 2\text{-}10$$

3- Shielding

The shield is a broad piece of metal or other suitable material, used as a protection against electromagnetic radiation, the amount of protective shielding required depend on the amount of energy each type of radiation has. A thin sheet of light material like paper is sufficient to provide against alpha radiation. Beta radiation can be shielded with an additional covering like heavy clothing while X and gamma radiation will require thick and dense shielding materials like lead (Hoon *et al*, 2011).

The design of radiology rooms should be to a standard that will keep the doses to workers and members of the public as low as reasonably achievable taking social and economic factors into consideration. This means that the facility should be designed to ensure that the radiation exposure of workers and general public are much lower than those of the standard dose limits (RPII, 2009).

Chapter Three

Methodology

3.1 Study Sample

The sample population of this study involves four healthcare center in the northern part of Palestine including:

1- Arab Specialist hospital in Nablus city (H1)

2- Patient Friends Society in Nablus city (H2)

3- Salfeet hospital in Salfeet city (H3)

4- Rafediya hospital in Nablus city (H4)

This study includes operators (males and females) in the four healthcare centers. The chosen operators had no history of cardiovascular heart disease.

The population of the total operators in each healthcare center is given in Table (3.1)

Table (3.1) The total number of operators in each studied health care center

Healthcare center	Symbol	Number of radiologists
Arab Specialist Hospital	(H1)	3
Patient Friends Society	(H2)	5
Salfeet Hospital	(H3)	2
Rafediya Hospital	(H4)	7

This study was conducted between November 2014 and January 2015. The measurements were done twice a day: one before the operators start and the second after they finish their shift.

The health parameters were measured three times for each operator on three different days, and then the average of readings was taken for each operators. The power flux density of microwaves and radiowawes were measured in the Radiology Departments at different locations, and at a height of 1 meter from the surface of the earth and averaged to get the value of EMR intensity during the workers shift.

The X-ray radiation dose rate leakage in control rooms and waiting rooms in the Radiology Departments, were measured in the staff places, and at a height of 1 meter from the surface of the earth. The gamma background radiation were measured when the X-ray devices were closed.

Light intensity and sound pressure level were taken tens time during measurements to normalize the light and noise effect, to make sure that the only parameter that plays the important role in the operators health factor activity is electromagnetic radiation (EMR) intensity.

3.2 Experimental Apparatus

3.2.1 Ionizing Radiation Equipment

3.2.1.1 Radiation Monitor

AT6130 Radiation Monitor is a compact device measures gamma and X-radiation indication ambient equivalent dose rate from 0.01µSv to 100mSv, as well as for measurement of beta particle flux density emitted from contaminated surfaces from 10 to 10^4particles/(min. cm^2). Radiation Monitor is shown in Fig. (3.1) (Radiation Monitors User Manual, 2011).

Fig. (3.1): AT6130 Radiation Monitor

3.2.2 Non-Ionizing Radiation Equipment

3.2.2.1 Acoustimeter

Acoustimeter RF meter AM-10 has been designed to judgment the level of microwave and RF signals in environment. This meter is used to measures the radiation from different sources in the range from 200 MHz right up to 8 GHz. It measures RF radiation, and measures average exposure levels from 1 to 100,000 microwatts per square meter [$\mu W/m^2$], peak exposure levels from 0.02 to 6.00 Volts per meter [V/m]. Acoustimeter is shown in Fig. (3.2) (Acoustimeter User Manual, 2013).

Fig. (3.2): Acoustimeter AM-10 RF meter

3.2.2.2 Lux Hitester

The Lux Hitester model 3423 is a digital device used to measure the intensity of light brightness. It measures a broad range of luminosities, from the low light up to a maximum intensity of 199,900 lx. This device is suited for a wide range of applications involving illumination equipment, lighting work, and facility management. Lux Hitester is shown in Fig. (3.3) (Instruction Manual for the Lux Hitester 3423, 2013).

Fig. (3.3): Hioki 3423 lux hitester digital illumination

3.2.3 Sound Level Meter

The sound level meter model 2900 is measuring the noise level in decibels (dB), Fig. (3.4). The accuracy of its measurement is ± 0.5 dB. The readings of sound level meter ranging from 0 to 140 dB (Instruction manual of Sound Level Meter, 1998).

Fig. 3.4 Sound level meter model 2900

3.2.4 Automatic Blood Pressure Monitor

Automatic Blood Pressure Monitor model BP 2BHO, Fig. (3.5) is used for measuring systolic and diastolic arterial blood pressure and pulse rate. The measuring range is from 30 to 280 mmHg, with accuracy ± 2% mm-Hg, and ± 2% for reading heart pulse rate. (Instruction for the Automatic Blood pressure Monitor, 2011).

Fig. 3.5: Automatic Blood Pressure Monitor micro life AG, BP 2BHO

3.2.5 Pulse Oximeter

The Pulse Oximeter model CMS50DL, Fig. (3.6) measures the blood oxygen saturation, and heart pulse rate. The accuracy of its measurement is ± 1% (Instruction Manual of Pulse Oximeter CMS50DL, 2011).

Fig.(3.6): Pulse Oximeter CMS50DL

3.3 Stages of Study

Some stages are performed in this study as follows:

1. Approval was brought from the Ministry of Health to conduct a study in government hospitals.
2. Selecting operators who work in the Radiology Department, and they do not having health problems.
3. Measuring the sound pressure level at different places and radiology departments.
4. Measuring the light intensity at different places and radiology departments.
5. Measuring the power density in different places in the Radiology Department.
6. Measuring equivelant dose rate for X, Gamma ray and beta radiation flux density inside control room and outside the radiology room in the staff places, and at a height of 1 meter from the surface of the earth.
7. Measuring the health parameters which are:

    1. Blood oxygen saturation SPO_2%
    2. Blood pressure (Systolic and diastolic)
    3. Heart pulse rate

The average values of power density, electric field, magnetic field and SAR in each healthcare center were compared with the recommended exposure limits given in Table (3.2) Table (3.3) and Table (3.4).

The maximum permissible exposure limits adopted by FCC for both occupational and general public exposure expressed in terms of electric field strength (V/m) and magnetic field strength (A/m) and power density (W/m^2) for the frequency range which is measured by the acoustimeter are given in Table (3.2).

Table (3.2) FCC maximum exposure limits for power density, Electric field strength and magnetic field strength (FCC, 1996)

Frequency range (MHz)	Power density (W/m^2)		Electric field strength (V/m)		Magnetic field strength (A/m)	
	Worker	General public	Worker	General public	Worker	General public
200-300	1	0.2	61.4	27.5	0.163	0.073
300-1500	f/300	f/1500	--	--	--	--
1500-8000	50	10	--	--	--	--

*f = frequency in MHz

The ICNIRP limits for frequencies range from 200MHz to 8GHz for both worker and general public exposure expressed in terms of electric field strength (V/m) and magnetic field strength (A/m) and power density (W/m^2) for a wide frequency range are given in Table (3.3).

Table (3.3) ICNIRP maximum exposure limits for power density, Electric Field strength and magnetic field strength (1998)

Frequency range	Power density (W/m^2)		Electric field strength (V/m)		Magnetic field strength (A/m)	
	Worker	General public	Worker	General public	Worker	General public
200-400MHz	10	2	61	28	0.16	0.073
400-2000MHz	f/40	f/200	$3f^{1/2}$	$1.375f^{1/2}$	$0.008f^{1/2}$	$0.0037f^{1/2}$
2-8GHz	50	10	137	61	0.36	0.16

SAR limits set by the FCC and ICNIRP are shown in Table (3.4) for the operating frequency range from 100KHz-10GHz.

Table (3.4) FCC and ICNIRP limits for SAR

		ICNIRP (W/Kg)	FCC (W/Kg)
Occupational	Whole- body	0.4	0.4
	Head and trunk	10	8
General public	Whole- body	0.08	0.08
	Head and trunk	2	1.6

Chapter Four

Results and Disscussion

4.1 Measurements of Ionizing Radiation

4.1.1 Measurements of Radiation Dose Rate of X and Gamma rays

The radiation monitor was used to measure the radiation dose rate of X and gamma rays, The measuring was taking in the staff places, and at a height of 1 meter from the surface of the earth. the background radiation (the reading of radiation monitor when the X-ray machines were OFF) were ranging from 0.04μSv/h to 0.06μSv/h in all studied healthcare centers.

The equivelan dose rate of X- ray were measured for radiographic rooms in all studied centers, and for the CT room in H1 and H4. The measurements were taken in the control room and waiting room, when the X-ray machine operating at maximum power during patients imaging in a day shift.

The maximum results of measurements of X - ray dose rate in control rooms and waiting rooms when X-ray machines were ON are given in Table (4.1)

Table (4.1) Maximum measured values of X -ray radiation dose rate, in control room (CR) and waiting room (WR) for radiographic rooms in each studied healthcare center

Healthcare center	Radiation dose rate (μSv/h)	
	CR	WR
Arab Specialist Hospital H1	0.24	0.00
Patients Friends Society H2	0.03	0.00
Salfeet Hospital H3	0.06	0.02
Rafediya Hospital H4	0.03	0.02

The values of measured X-ray leakage from radiographic room in all studied rooms in all healthcare centers were less than and recommended values of ICRP which adopted by Palestinian Ministry of Health, the values of X-ray radiation dose rate in WR in all studied healthcare centers is equal to the background radiation. Table 4.2 shows a comparison between the masured values and the adopted values in Palestine (Palestinian Ministry of Health website, 2015).

The measured values of X-ray radiation dose rate in Table (4.1) were used to calculate the X-ray radiation dose rate per week by using equation (2.9).

The radiologists expose to this X-ray dose rate for 7 hours every day then:

X-ray Radiation dose rate per hour (μSv/h)*49(h/Wk) = X-ray Radiation dose rate per week (μSv/Wk).

Table (4.2) The maximum permissible dose and measured values for X-ray radiation dose rate for radiographic room in each studied healthcare center

The maximum permissible dose for worker	The maximum permissible dose for public	Dose µSv/Wk*	H1	H2	H3	H4
400µSv/Wk	20µSv/Wk	CR	13.72	3.43	4.9	3.43
		WR	1.96	1.96	2.94	2.94

*Wk: Week

The maximum value of X-ray radiation dose rate at CR was measured at the Arab Specialist Hospital as 13.72µSv/Wk which is 3.43% of the ICRP limit for worker (ICRP, 2014). The minimum value of X-ray radiation dose rate at CR was measured at Patients Friends Society and Rafediya Hospital as 3.43µSv/Wk which is 0.85% of the ICRP limit for worker.

The maximum result of measurement of X ray equivelant dose rate at control room and waiting room when CT machine is ON are given in Table (4.3)

Table (4.3) Maximum measured values of X ray radiation dose rate in control room (CR) and waiting room (WR) for CT room in H1 and H4

Healthcare Center	Radiation dose rate (µSv/h)	
	CR	WR
Arab Specialist Hospital H1	0.39	2.90
Rafediya Hospital H4	0.76	1.76

The measured values of X-ray radiation dose rate in Table (4.3) were used to calculate the X-ray radiation dose rate per week by using equation (2.9).

Table (4.4) The maximum permissible dose and measured values for X-ray radiation dose rate for CT room in H1 and H4

The maximum permissible dose for worker	The maximum permissible dose for public	Dose µSv/Wk*	H1	H4
400µSv/Wk	20µSv/Wk	CR	21.07	39.20
		WR	147.98	88.20

*Wk: Week

The measured value of X-ray radiation dose rate at CR at Arab Specialist Hospital and Rafediya Hospital is less than the ICRP limit for worker (ICRP, 2014).

The measured value of X-ray radiation dose rate at WR at Arab Specialist Hospital and Rafediya Hospital is less than the ICRP limit for worker (ICRP, 2014).

Any member of the public does not usually stay only a few minutes in the waiting room (generally do not stay a week), so do not expect to receive any member of the public doses of X-ray more than the the permissible doses.

The leakage of X-ray at control room is less than the leakage at waiting room for CT room in Arab Specialist Hospital and Rafediya Hospital, and this can be due to the shielding, scince shielding in CR prevent the background radiation and because the X-ray beam in CT rooms is very narrow. The leakage in the Arab Specialist Hospital is greater than the other studied healthcare centers, and this can be due to the distance between the X-ray machine and the doors of control room and waiting room, since the X-ray rooms space in Arab Specialist hospital is less than the other studied healthcare centers.

4.1.2 Measurements of Flux Density of β-Particles

Radiation monitor was used to measure the values of β-particles flux density. The background β-particles flux density (the reading of radiation monitor when the X-ray machine was OFF) were zero in all studied healthcare centers.

The flux density of β-particles were measured in the CR and WR of Radiographic room in all studied healthcare centers. The flux density of β-particle also measured in the CR and WR of CT room in Arab Specialist Hospital and Rafediya Hospital.

The measurements were taken when the X-ray machine operating at different power during patients imaging in a day shift. The average values of β-particles flux density in all studied healthcare centers when X-ray machines were ON are given in Table (4.5)

Table (4.5) Average measured values of β- particles flux density, in CR and WR at radiographic room in each studied healthcare center (ON case)

Healthcare center	β-particles flux density ($1/min.cm^2$)	
	CR	WR
Arab Specialist Hospital H1	34.50	72.00
Patients Friends Society H2	4.30	5.80
Salfeet Hospital H3	8.96	10.20
Rafediya Hospital H4	14.80	4.90

The average values of β-particles flux density in Arab Specialist Hospital and Rafediya Hospital when X-ray machines were ON given in Table (4.6)

Table (4.6) Average measured values of β- particles flux density, in CR and WR at CT room in H1and H4 (ON case)

Healthcare center	β-particles flux density ($1/min.cm^2$)	
	CR	WR
Arab Specialist Hospital H1	104.00	520.00
Rafediya Hospital H4	26.10	18.90

4.2 Measurments of non-Ionizing Radiation

4.2.1 Measurements of Power Flux Density

The Acoustimeter AM-10 RF meter was used to measure the values of power flux density for microwaves and radiowaves (200MHz-8GHz), in different places in radiology departments, then the average values were taken. The measured values of power flux density were used to calculate the electric fields and magnetic fields by using equations (2.2). The measured values of power flux density and the calculated values of the electric fields and magnetic fields are given in Table (4.7).

Table (4.7) Average values of power flux density, electric field and magnetic field strength in each studied healthcare center and ICNIRP exposure limits

Healthcare center		Power density $P\times10^{-6}$ (W/m^2) (measured)	ICNIRP $P\times10^{-6}$ (W/m^2)	Electric field E (V/m) (calculated)	Magnetic field $H\times10^{-3}$ (A/m) (calculated)
Arab Specialist Hospital	H1	2000	10×10^{6} for Worker	0.870	2.30
Patients Friends Society	H2	402		0.390	1.03
Salfeet Hospital	H3	1262		0.690	1.83
Rafediya Hospital	H4	28	2×10^{6} for general puplic	0.126	0.27

The measured values of power flux density in all Healthcare centers are less than the ICNIRP exposure limits and FCC limits in table (3.2) and table (3.3).

The calculated values of electric field and magnetic field is less than the FCC exposure limits in table (3.2), and less than the ICNIRP exposure limits in table (3.3)

The average values of the measured power flux density levels in studied healthcare centers are shown in Fig. 4.1.

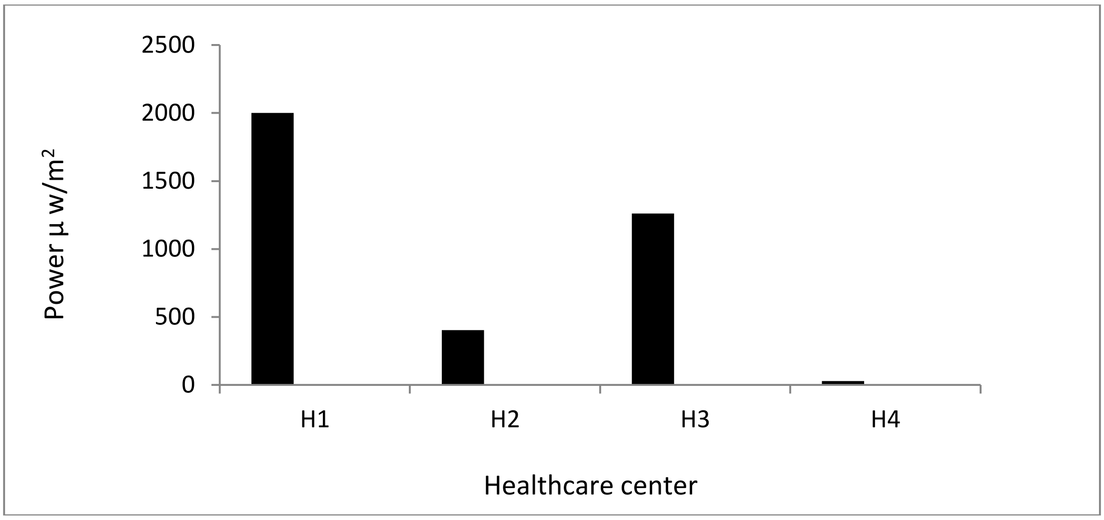

Fig. (4.1): The measured power flux density levels in each studied healthcare center

The maximum value of power flux density was measured at the Arab Specialist Hospital as 2000µW/m^2. The minimum value of power flux density was measured at Rafediya Hospital as 28µW/m^2.

The specific absorption rate (SAR) values are calculated in table (4.8) by using equation (2-4), according to conductivity (σ) and mass density (ρ) values for human head tissues (Adheed, 2012).

Table (4.8) SAR values for human head tissues in each studied healthcare center and FCC exposure limit

Tissue	Conductivity σ* (S/m)	Density ρ* (kg/m^3)	SAR_{H1} x10^{-4} W/Kg	SAR_{H2} x10^{-4} W/Kg	SAR_{H3} x10^{-4} W/Kg	SAR_{H4} x10^{-4} W/Kg	SAR FCC exposure limit ×10^{-4} W/Kg
Skin	1.25	1010	9.37	1.88	5.89	0.200	1600
Fat	0.26	920	2.10	0.43	1.35	0.045	
Bone	0.45	1810	1.88	0.38	1.18	0.039	
Brain	1.29	1040	9.39	1.89	5.91	1.970	

* (Adheed, 2012)

SAR values in Table (4.8) are much less than the maximum level of SAR permissible set by the FCC (1.6W/Kg) and ICNIRP (2W/Kg) in Table (3.4).

The results of this study show that all values of the power flux density, electric fields, magnetic fields and SAR were much below than the international standards.

4.3 Measurements of Sound Pressure Level

The Sound level meter was used to measure sound pressure levels. Sound pressure levels were measured several times in each radiological department in each healthcare center. The average results of measurements of sound pressure level are given in Table (4.9).

Table (4.9) The average values of sound pressure level in each studied healthcare center

Healthcare center	sound pressure level (dB)
Arab Specialist Hospital H1	42.3
Patients Friends Society H2	46.0
Salfeet Hospital H3	45.0
Rafediya Hospital H4	45.9

Sound pressure levels were measured in radiology departments during the work period in order to be sure it will not effect on the studied health parameters.

Sound pressure levels almost equal in all studied healthcare centers and less than 60 dB. Previous studies showed that sound pressure levels over 60 dB has effects on health parameters (Abdel-Ali *et al*, 2003; Abdel-Raziq *et al*, 2003; Sadiq *et al*, 2012)

4.4 Measurements of Light Intensity

Lux Hitester was used to measure the intensity of light. The light intensity was measured ten times in each radiology department corridors in each health care center. The average results of measurements of light intensity are given in Table (4.10)

Table (4.10) Average values of intensity of light intensity

Healthcare center	Light intensity (lx)
Arab Specialist Hospital H1	200
Patients Friends Society H2	215
Salfeet Hospital H3	325
Rafediya Hospital H4	240

Light intensity in all studied healthcare centers in radiology departments ranged from 200 Lux to 325 Lux, and these values are close to recommended value. (The recommended light intensity in hospital corridors is around 300 lx) (Zumtobel, 2015)

4.5 Measurements of Health Effects Resulting from Exposure to EMR

The health parameters (blood oxygen saturation, heart pulse rate, and systolic and diastolic blood pressure levels) were measured three times for each operators on three different days, twice a day: one before the operator's starts and the other after he finishes his shift.

The average measured values of the blood oxygen saturation, heart pulse rate, and blood pressure levels (systolic and diastolic), for operators in each studied healthcare center before (b) and after (a) exposure to EMR are given in Table 4.11.

Table (4.11) Average values of the blood oxygen saturation, heart pulse rate, systolic and diastolic blood pressure levels for operators in each studied healthcare center

Healthcare Center	SPO_2%		HPR beats/min		DBP mmHg		SBP mmHg	
	b	a	b	a	b	a	b	a
Arab Specialist Hospital H1	98.3	97.0	78	90	85	87	135	138
Patients Friends Society H2	98.5	98.0	92	91	73	74	110	116
Salfeet Hospital H3	98.0	97.0	98	99	82	91	118	128
Rafediya Hospital H4	98.7	97.0	78	83	73	76	115	127

From Table 4.11, it can be observed a small change in the average values of all studied parameters (blood oxygen saturation, heart pulse rate, systolic and diastolic blood pressure). The measured parameter remain in the normal range of human beings after exposure to EMR in all studied healthcare centers. This does not negate the possibility that this EMR affect other health factors were not measured in this study.

4.4.1 Blood Oxygen Saturation (SPO_2 %) Results

Pulse oximeter LM-800 was used to measure the blood oxygen saturation of selected operaters. The average measured values of blood oxygen saturation for operaters, before (b) and after (a) exposure to EMR in each studied health care center, are shown in Fig. 4.2.

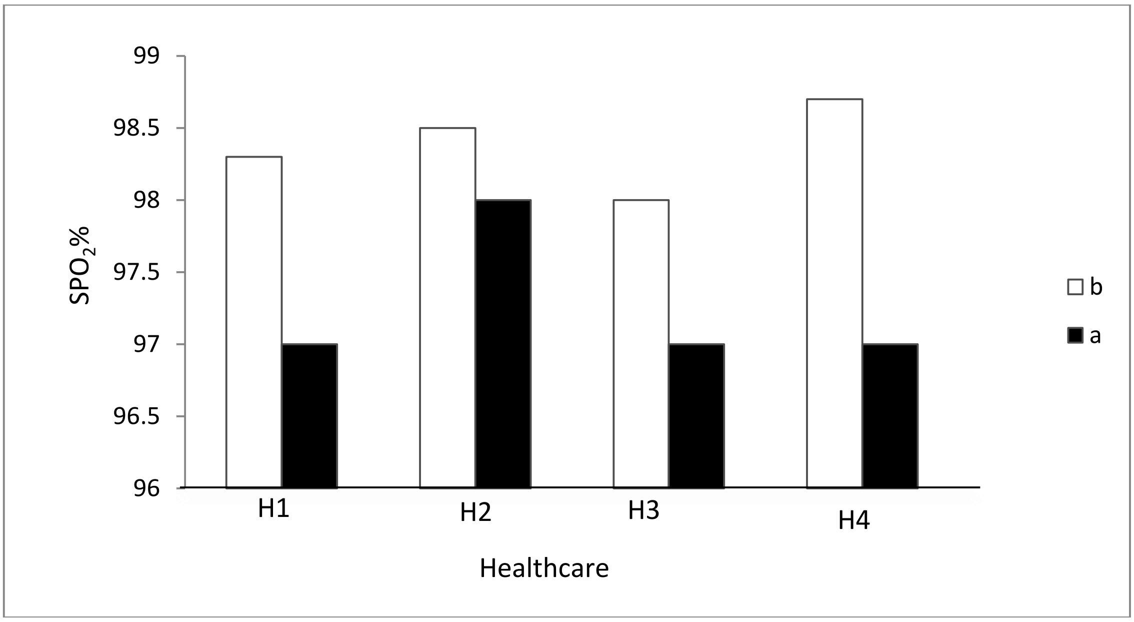

Fig. (4.2): Average values of blood oxygen saturation SpO_2 % for operators in each studied healthcare center before (b) and after (a) exposure to EMR

Fig. 4.2 shows that the average values of blood oxygen saturation of selected operators are decreased in all studied healthcare center after exposure to EMR but remain in normal range (95%-100%).

The net changes of blood oxygen saturation of selected operators before and after they exposed to EMR are small and less than measurement error of Pulse Oximeter (0.01) and it can be neglected.

4.4.2 Heart Pulse Rate Result

The Automatic Blood Pressure Monitor was used to measure the heart pulse rate of selected operators. The average measured values of heart pulse rate for operators, before (b) and after (a) exposure to EMR in each studied healthcare center, are shown in Fig. 4.3.

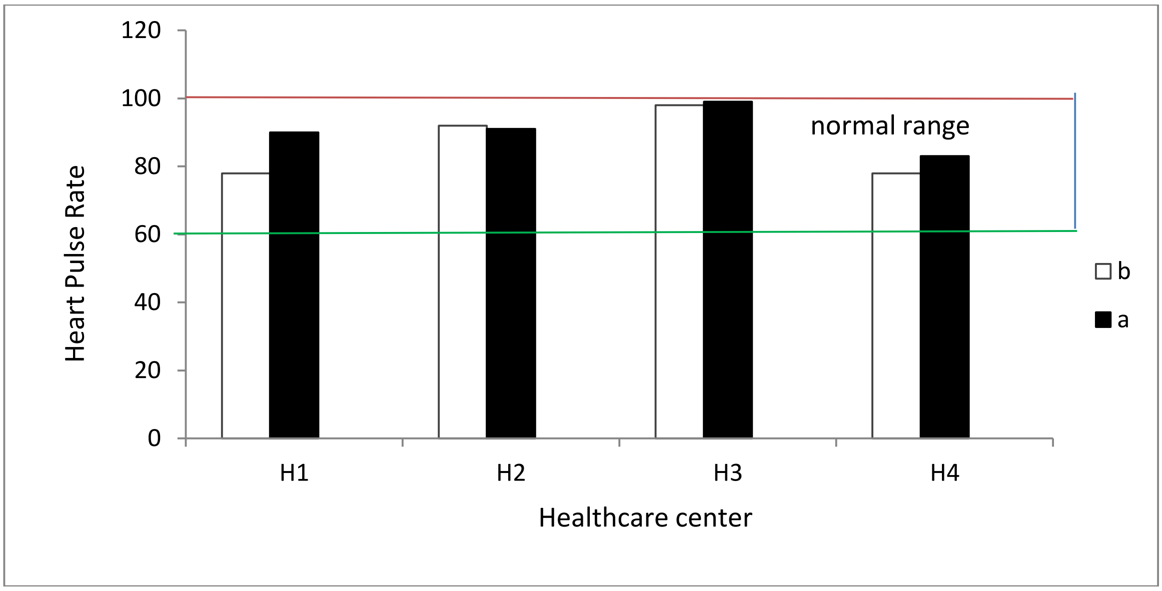

Fig. (4.3): Average values of heart pulse rate for operators in each studied healthcare center before (b) and after (a) exposure to EMR

The net changes of average values of heart pulse rate of selected operators before and after they exposed to EMR in all studied healthcare center are small and close to the measurement error of Automatic Blood Pressure Monitor and it can be neglected (0.02 beats/min).

4.4.3 Systolic and Diastolic Blood Pressure Results

The Automatic Blood Pressure Monitor was used to measure the systolic and diastolic blood pressure of selected operators. The average measured values of systolic blood pressure, for operators in each studied healthcare center, before (b) and after (a) exposure to EMR are represented in Fig. 4.4.

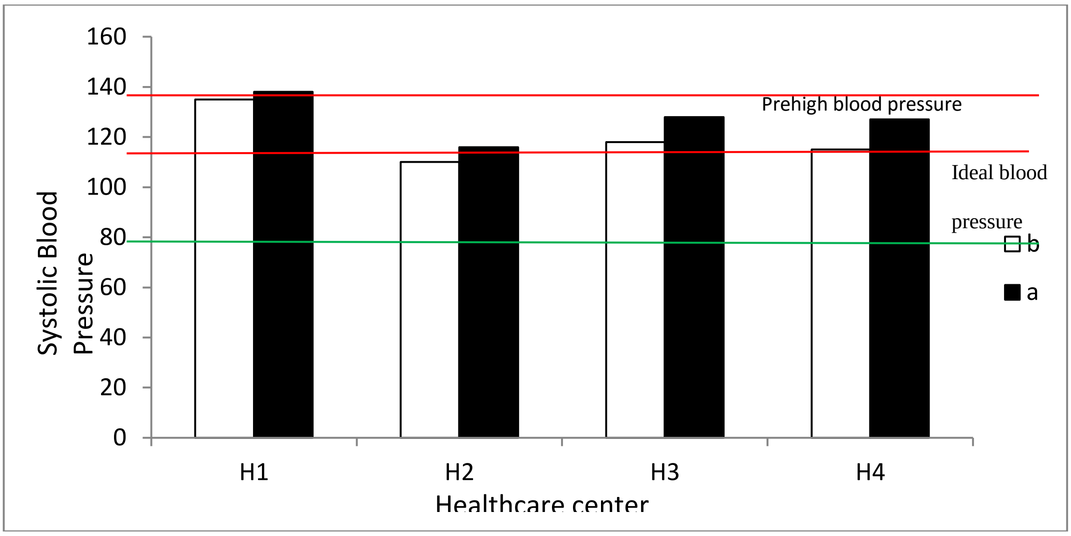

Fig. (4.4): Average values of systolic blood pressure for operators in each studied health care center before (b) and after (a) exposure to EMR

The net changes in Systolic blood pressure of selected operators before and after they exposed to EMR in all studied healthcare centers are larger than the error of Automatic Blood Pressure Monitor (0.02 mmHg).

The average measured values of diastolic blood pressure, for operators in each studied healthcare center, before (b) and after (a) exposure to EMR are represented in Fig. 4.5.

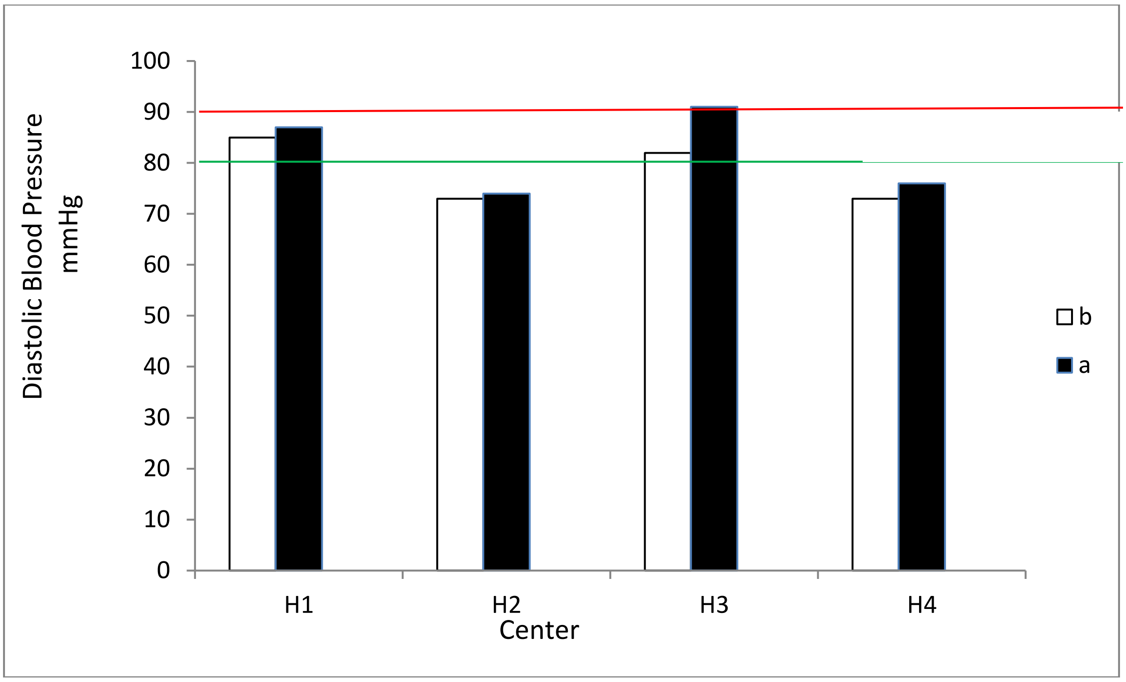

Fig. (4.5): Average values of diastolic blood Pressure for operators in each studied healthcare center before (b) and after (a) exposure to EMR

The net changes of diastolic blood pressure of selected opreators before and after they exposed to EMR in all studied healthcare centers are more than the error of Automatic Blood Pressure Monitor (0.02 mmHg).

Chapter Five

Conclusion

Workers in the radiology field worry about the possibility of exposure to excessive X-ray dose rate. This work was done to measure the X-ray radiation dose rate in four healthcare centers in Palestine and compare its value with the maximum permissible X-ray dose rate for workers and for general public.

The values of X-ray leakage were measured in the control room and waiting room for X-ray rooms at the four studied healthcare centers. The measured leakage in all studied rooms in studied healthcare centers is less than 400 μSv/Wk which is the ICRP recommended value for worker.

The results of this research do not expect any operators to receive exes X-ray doses more than the recommended value adopted by the Palestinian Ministryof health.

This research also includes measures of power flux density of microwaves and radiowaves, and β- particle Flux density. The power flux density was measured in all studied healthcare centers, the maximum value of power flux density was measured at Arab Specialist Hospital which is 2 mW/m^2, and the minimum value of power flux density was measured at Rafediya Hospital which is 0.028 mW/m^2. The values of power flux density in all healthcare centers are much less than the recommended exposure value which is $10W/m^2$ for worker and $2W/m^2$ for general public (ICNIRP).

The specific absorption rate SAR values were calculated for human head tissues, SAR values range from 0.20×10^{-4} to 9.39×10^{-4} W/Kg, and these values are much less than 1.6 W/Kg which is the standard limit set by the FCC.

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جامعة النجاح الوطنية

كلية الدراسات العليا

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اعداد

أسماء عبد الكريم شحادة

اشراف

أ.د.عصام عبد الرازق

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قدمت هذه الأطروحة استكمالا لمتطلبات الحصول على درجة الماجستير في الفيزياء بكلية الدراسات العليا في جامعة النجاح الوطنية في نابلس- فلسطين

2016

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الملخص

ركزت هذه الدراسة على البيئة الاشعاعية في بعض المراكز الصحية في فلسطين، حيث تم قياس مقدار الجرعة الناتجة من الاشعة السينية داخل غرفة التحكم وفي ممرات الانتظارعندما كانت الاجهزة تعمل وقورنت القيمة بالمعدلات المسوح بها من وزارة الصحة الفلسطينية حيث كانت جميع القراءات اقل من تلك القيمة. كما تم ايضا قياس كثافة جزيئات بيتا ومقدار الجرعة لاشعة جاما الناتجة من المصادر الطبيعية.

كما تم قياس قيمة كثافة تدفق الطاقة في هذه المراكز, وقد كان معدل التدفق 2000 ميكروواط/م2، 402 ميكروواط /م2، 1262 ميكروواط/م2 و28 ميكروواط/م2 في كل من المستشفى العربي التخصصي وجمعية اصدقاء المريض ومستشفى سلفيت ومستشفى رفيديا على الترتيب

كما تم حساب قيمة كل من المجال الكهربائي والمجال المغناطيسي ومقدار كمية امتصاص انسجة الدماغ للطاقة بالاعتماد على قيمة معدل التدفق.

تم دراسة تاثير الاشعة الكهرومغناطيسية في المراكز الصحية المدروسة على بعض المؤشرات الصحية للعاملين في مجال الاشعة, حيث تم قياس تشبع الدم بالاكسجين, ومعدل ضربات القلب, وضغط الدم الشرياني الانقباضي والانبساطي قبل بدء الموظف بالعمل وعند لانتهاء في الفترة الصباحية على مدى ثلاثة ايام مختلفة حيث اخذت معدل القراءات لكل موظف, لوحظ ان المؤشرات الصحية السابقة بقيت ضمن الحدود الطبيعية بعد التعرض للاشعاع في قسم الاشعة.